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GUIDELINES FOR THE LUBRICATION OF MEDIUM SPEED DIESEL ENGINES

2nd UPDATED VERSION 2008

This guideline replaces Recommendation No. 13, 1994

The International Council on Combustion Engines

Conseil International des Machines à Combustion

CONSEIL INTERNATIONAL
DES MACHINES A COMBUSTION

INTERNATIONAL COUNCIL
ON COMBUSTION ENGINES

CIMAC was founded in Paris in 1951 where the first Congress took place. Originally CIMAC was organized as an industry event to discuss new ideas and developments within the engine and components industry together with institutes and universities.

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' in November 2008.
It supersedes CIMAC Recommendation No. 13 previously published on that topic.

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FOREWORD BY THE PRESIDENT

The lubrication of Diesel engines presents some of the most difficult problems encountered by oil technologists. This CIMAC Guideline describes and gives insights into the lubrication of medium speed engines and current operating practices. Informations on the engine and its lubrication system, the lubricating oil, performance criteria, used oil analysis or quality limits of the oil in use have been compiled to contribute to the efficient and reliable operation of such machinery.

This Guideline has been developed by the CIMAC Working Group Marine Lubricants, comprising renowned experts from engine manufacturers, suppliers, oil companies, classification societies and ship operators/users. It follows the ultimate target of this Working Group, to recommend suitable lubricants for use in today's and in future engines, considering the increasing variety of existing and future fuels.

I congratulate the Working Group for elaborating this remarkable document, which I trust will be useful for the combustion engine community all over the world.

K. Wojik, CIMAC President
November 2008

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PREFACE

This document describes and gives insights into the lubrication of medium speed engines and current operating practices. Its objective is to contribute to the efficient and reliable operation of such machinery.

INTRODUCTION

Because fuels and lubricants are often associated with problems in medium speed diesel engines, CIMAC has identified both items as needing better understanding.

Following the efficient work of the Working Group on “Heavy Fuel Oils” [1] , a Working Group on Lubricants was formed by CIMAC in 1987 with the aim to develop a generally accepted user language on the lubrication of non automotive diesel engines, giving priority to medium speed, low speed and high speed diesel engines respectively. The current composition of the Working Group “Lubricants” is given in **Appendix No. 1.**

In 1994 CIMAC Working Lubricants published a document which provided guidelines on the lubrication of medium speed engines, as CIMAC Recommendation No. 13. [2]. This publication compiled insights into the lubrication of medium speed diesel engines as generated by the Groups’ members who represent users, engine and equipment manufacturers, institutions as well as additive and lubricant suppliers**.** In the mean time the Working Group felt that recent developments in the years since 1994 concerning the lubrication of medium speed diesel engines should also be incorporated. Work on this has been an ongoing task since then and it has resulted in these updated Guidelines, which will form the platform for a better understanding of its scope

The sections of this publication deal with:

- The engine and its lubrication system
- The lubricating oil
- The lubricating oil performance criteria
- The engine lubrication system
- The lubricating oil treatment system
- Used oil analysis and its significance
- Quality limits of the oil in use
- A trouble shooting list

By compiling the Working Group’s conclusions on these topics the work is not over. The ultimate target, directed by the Terms of Reference, remains broadly unchanged:

“To recommend suitable lubricants for use in today’s’ and future engines, given the variety of existing and future fuels”

1. THE ENGINE AND ITS LUBRICATION SYSTEM

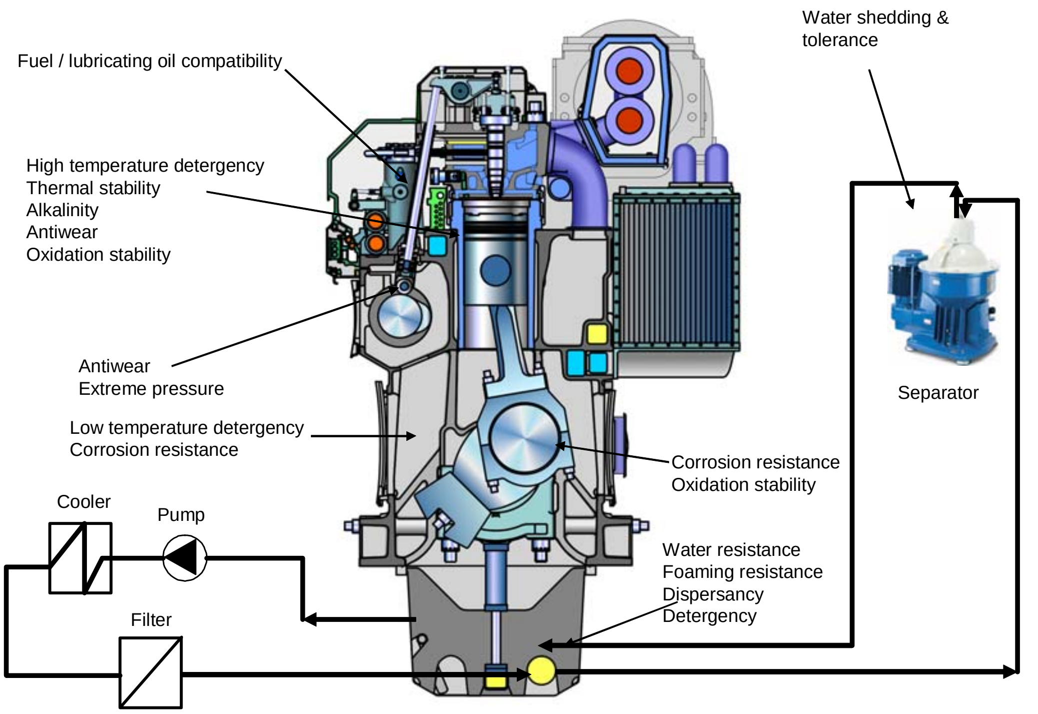
1.1 The Engine

The most common medium speed engine manufactured during recent decades is of the trunk piston type, and is burning heavy fuel oil (HFO) under the following main conditions:

- High firing pressure and under certain conditions, high pressure rise ratios,
- High mean piston speed,
- High combustion temperature.

These result in substantial stresses not only on the mechanical components, but also on the lubricating oil. To cope with these, the lubricating oil must be particularly tailored to the tasks as illustrated in **Figure No. 1:**

Figure No. 1: Properties of the lubricant required on its way through the engine



Courtesy of Wärtsilä

1.2 The Lubrication of Vital Engine Components

1.2.1 Bearing Lubrication

The lubricating oil enters the engine in a "clean" condition, and passes the main lubricating oil header to reach the main bearings. At this point, the lubricating oil is to perform its first duty, **which is Lubrication**. There must be an oil film of a defined thickness between the crankshaft journals and the bearing,. To achieve this, an adequate viscosity grade should be selected by the engine designer taking into account the engine characteristics and temperature requirements. The lubricating oil is then circulated through a passage in the crankshaft to reach the big end bearing of the connecting rod. Here again, the lubricating oil has to provide an oil film which is strong enough to resist the impact resulting from the combustion pressure on the piston head. The oil then passes through the drill-hole of the connecting rod towards the small end bearing of the gudgeon pin where a reliable oil film is also required for lubrication. Besides lubricating the bearings, the oil also acts a coolant for these engine parts.

1.2.2 Piston Cooling

After passing the gudgeon pin, the lubricating oil enters the piston interior where it is used as a coolant medium. The oil is used to cool the piston head, generally by a shaker effect or by jet cooling. For this purpose, the oil must show good resistance against deterioration at high temperatures in the presence of air (oxygen). This property generally is known as **Oxidation Stability.** Furthermore, for efficient cooling, the oil must be compatible with fuel contaminants and effectively disperse species like asphaltenes (from residual fuel). This prevents the formation of an insulating deposit layer on the piston undercrown. After passing through the piston head the oil then returns to the crankcase.

1.2.3 Cylinder Lubrication

There are different methods of cylinder lubrication:

- Splash lubrication (widely used)
- Forced lubrication, with oil entering the piston either via oil holes or via the shaker chamber.
- Forced lubrication from outside the cylinder (either with fresh oil or with the oil in use), utilizing an additional lubricant dosing pump and quills positioned in the cylinder wall.

All three methods need similar oil characteristics to be effective in the region between piston, ring pack and cylinder liner.

1.2.4 Other Aspects of Lubrication

Besides lubricating the internal regions of the engine, the oil is additionally supplied to:

- The camshaft and gear train. In this area, the oil is stressed by extreme pressures, either in gears or between rollers and cams. Here, **Anti-Wear** and **Extreme Pressure** properties are needed.
- The fuel injection system to serve as a fuel/lubricant barrier. The key property required here is the **Fuel / Lubricating Oil Compatibility.**
- The rocker arm-assembly and valve guides in the valve train.

2. THE LUBRICATING OIL

2.1 A User Language

The performance and reliability of the engine and its components are of primary importance to the end-user. The lubricant must be seen as an integral part of the engine and its systems. Both engine and lubricant provide an essential and defined contribution to the total system's performance and reliability.

Undisputable performance criteria, therefore, must be agreed between all parties concerned to specify properly the lubricant's key functions:

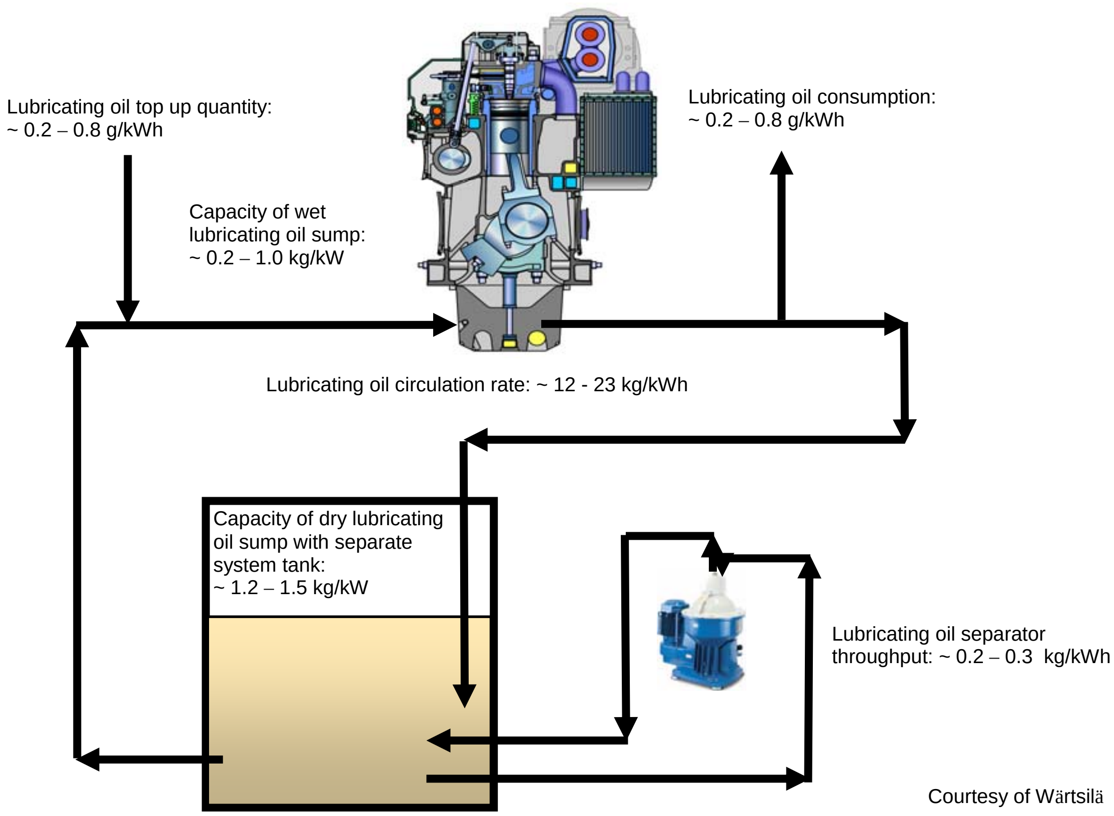
- To “protect” the engines’ components and mechanisms which, without an appropriate lubricating oil, would fail.
- To ensure that the components of the lubricated engine remain in an acceptable condition for an acceptable period. To comply with this the lubricating oil itself must be of acceptable performance. It must also be kept in an acceptable condition for an acceptable period. Considering the latter, oil change intervals and engine overhaul intervals should be ideally matched.
- The lubricating oil must be designed, produced, applied and maintained to remain in a condition that allows for satisfactory operation including a safety margin, as agreed between the engine user and the oil supplier
- “Acceptable”, in consequence, is to be understood as a clear differentiation from “unacceptable”, and no scale is applied to define “how acceptable” a condition is.
- With the aim of avoiding misunderstandings and resulting irritations there must be a common “user language” which must be simple, clear, unequivocal, generally accepted and used by all.
- It is emphasized that this “user language” has the purpose of specifying performance and not composition [3].

2.2 The Oil in Use

The engine hardly ever, apart from the first start up, enjoys unused, fresh oil. The lubricating oil circulating in the system is normally used oil, often referred to as “oil in use” [4]. Furthermore, it should be noted that for full effect the additive system of a fresh oil needs activation by thermal and other conditions prevalent in the engine.

For example, with an oil consumption of 1.0 [g/kWh] and a system’s content of approximately 1.0 [kg/kW] the theoretical replacement time of the entire oil volume in the system is approximately 1,000 [h]. **Figure No. 2** hereafter gives a view about lubricating oil circulation and replenishment speed. [5]

Figure No. 2: Lubricating oil circulation and replenishment speed



Courtesy of Wärtsilä

Even in regions of the engine in which the fresh (i.e. unused) lubricant is added,, preferably in the piston / ring pack / cylinder liner region,, the ratio of unused to used lubricant appears to be not more than 1: 100 [5].

So, with a given engine severity, the engine requirements are met by a combination of oil performance reserve and the efficiency of the oil maintenance system. In practice the oil may never be changed but simply refreshed by topping up. However, oil changes may be desirable occasionally for a variety of reasons. [6, 7, 8]

If the engine lubrication requirements are not met, undesirable consequences can occur. These include an increase in lubricating oil consumption, more frequent / unplanned oil changes, an increase in fouling, wear and tear on engine components, more frequent engine maintenance or even situations leading to major engine damage.

Maintaining lubricating oil conditions within acceptable limits or tolerances for medium speed engines is a function of the lubricating oil's additive package reserve, the degree of contamination from products of engine combustion or other extraneous sources, excessive lubricating oil consumption due to leakage or poor engine maintenance, and the frequency and amount of the system fresh oil replenishment or top ups.

Where lubricating oil separators are installed these should be regularly checked for optimum operational efficiency and correctly maintained. System filters similarly need to be regularly checked and cleaned or replaced.

Extended lubricating oil life or running hours can be obtained by optimising all these influences to ensure used oil conditions are maintained within acceptable limits as set by the engine manufacturers and oil suppliers.

The aforementioned balance indicates how important, apart from the lubricant's performance, the appropriate design, capacity and operation of the lubricant maintenance system is. This is detailed in **Section 5.** [9, 25]

Knowledge on key data of both the fresh oil and the oil in use is vital:

- Details listed on the **Technical Data Sheet** for a fresh oil should inform the user what has been ordered, and that the product meets the engine manufacturer's specification. It allows conformance control but cannot give much information on the performance to be expected in an individual engine under individual conditions.
- The **Used Oil Analytical Report** should indicate whether or not the oil in use is in good condition. In comparison with the above technical data sheet such a report should give clear evidence whether the lubricating oil, its additive reserve and the engine's impacts together with the treatment by the maintenance system are well in balance. The data on selected metallic elements might also give additional information on the engine's wear behaviour.

2.3 Properties of Lubricating Oils

2.3.1 Alkalinity

This property permits the oil to react against corrosive wear by neutralizing acidic combustion products from the fuel sulphur and from the oxidation of the oil. The alkalinity is defined by the **Base Number (BN),** which was previously referred to as **Total Base Number (TBN).**

2.3.2 Anti Foaming

The oil circulates through the engine at very high speed (up to around 40 times per hour). During this circulation, air and oil are mixed intensively with a significant foam risk. The foam can adversely affect the bearing lubrication. Air release properties need to be considered as part of the overall foaming control.

2.3.3 Anti-Wear (AW) and Extreme Pressure (EP)

Wherever the oil film is insufficient or temporarily interrupted between metallic surfaces, the tribological characteristics of these have to be supported by particular **Anti-Wear (AW)** and **Extreme Pressure (EP)** additives in order to help reduce abrasive and adhesive wear where possible.

2.3.4 Corrosion Protection

This property is required to protect surfaces of bearings and other sensitive engine components from corrosion.

2.3.5 Detergency

The oil has to clean and to keep clean cylinder liner, piston, ring pack and ring grooves from combustion products of fuels and lubricants. This property of the lubricating oil is called **High Temperature Detergency**.

After lubricating pistons and liners, the oil returns to the sump through the crankcase. Here it is acting as a cleaning agent to remove deposits from crankcase walls and from engine components in motion such as connecting rods, crankshafts and counterweights. This cleaning effect is executed by a property called **Low Temperature Detergency**. [10]

2.3.6 Dispersancy

The **Dispersancy** defines the ability of the oil to maintain in suspension all particles and unburnt components picked up by the oil in the piston and liner region, and elsewhere in the engine. All these impurities must be transported by the oil to the lubricating oil treatment system for removal. The dispersancy, furthermore, is the key property of the lubricant needed after its return to the oil tank. There it will prevent the settling of impurities which would otherwise lead to thick sludge at the bottom of the tank.

2.3.7 Volatility

Evaporation can contribute to lubricating oil consumption because the oil, as mentioned already, is often exposed to very high temperatures during its passage through the engine, in particular in the piston and liner region. The contribution of evaporation to oil consumption can be significant if excessively volatile components are used to blend the lubricant.

2.3.8 Lubricity

With the aim of ensuring hydrodynamic lubrication, the lubricating oil must be capable of “covering” surfaces which need protection. Therefore, good **Spreadability** characteristics are required, as well as a reliable cohesion to the metallic surfaces.

2.3.9 Oxidation Stability

Oxidation Stability is required to prevent the oxidation of a lubricant due to high temperatures and oxygen surplus in blow-by gases and air trapped in the engine interior. Otherwise this may result in oil viscosity increase and a lack of deposit control in the engine.

2.3.10 Thermal Stability

The oil is exposed to long periods of high temperature during its passage through the engine. An adequate **Thermal Stability**, therefore, is vital.

2.3.11 Viscosity and Viscosity Index (VI)

To avoid metal to metal contact it is essential to have a stable and sufficiently thick oil film between piston ring and liner, and in the bearings.

The **Viscosity Index (VI),** expresses how the oil viscosity changes with temperature. As the oil around the moving parts of the engine is of higher temperature and, hence, lower viscosity than when entering the engine, the **VI** is a relevant factor

2.3.12 Water Resistance

The lubricant must be water tolerant and still able to lubricate the engine components when contaminated with some water. Additives must be as water resistant as possible to avoid additive losses and the formation of hard crystals during the removal of water in the treatment system. They should not emulsify with the water seal of the purifier. Furthermore, filterability must be ensured, whatsoever the water content is. It must be noted, however, that certain filter designs do not work at all if the oil contains water.

2.4 Problem Complexes with Lubricating Oils

2.4.1 Catalyst (cat) Fines

Abrasive particles (such as alumina and silica) found in catalytically cracked fuel components may find their way into the lubricating oil where they could contribute to excessive wear. Efficient purification is particularly important under these conditions.

2.4.2 Ceramic Components and Coatings

Attempts are being made to improve thermal efficiency by designing a (partially) uncooled engine. Experiments were started with cylinder liners. A three-part piston, with carbon powder cooling, is described in [11]. A temperature of above 600 °C appears feasible at the piston top. With efficient heat transfer from the piston crown (carbon powder) provided, measurements at the lower surface of the ring carrier show temperatures of only 180 °C. This is seen as unproblematic for a high quality engine lubricant, even for prolonged periods.

More work is ongoing with ceramic coatings of piston rings and ring grooves.

2.4.3. Compatibility of Heavy Fuel Oil

The stability of Heavy Fuel Oil (HFO, sometimes called Residual Fuel Oil) is technically complex. Maintaining adequate stability of a HFO blend with another blend, with diluents or with lubricants is called **compatibility.** Compatibility is the ability of two or more components of a blend to co-exist for a sufficient long time without this blend breaking down.

Heavy fuel oil is obtained by blending residual fuel oil with suitable diluents, called cutter stocks, to obtain the required HFO viscosity grades. HFO is a complex mixture of many different hydrocarbons. It has a chemical structure totally different from that of marine lubricants, and this is the key reason for the occurrence of incompatibility.

The components mainly responsible for this lack of compatibility are called **asphaltenes**, which in a stable HFO are in an equilibrium with the rest of the HFO. If this equilibrium is disturbed and the asphaltenes cannot be held in solution, they coagulate into larger particles and precipitate as a heavy sediment.

In medium speed diesel engines HFO can contaminate the lubricant, often from the fuel pump. Here lubricating oil / fuel compatibility is crucial for a clean engine interior. Water adds to the problem because it further exacerbates deposit formation. The result can be Black Paint/Sludge with soft deposit layers forming in the crankcase interior, camshaft compartment and rocker arm mechanism. Additionally layers of harder carbonaceous deposits can form within the piston cooling gallery, the piston ring groove area and on the fuel injection pump plunger/barrel.

Currently it is not possible to predict these chemical interactions. Therefore the stability of the fuel is important.

The sediments can block fuel centrifuges and filters and cause deposits in storage tanks. Every effort should be undertaken to prevent the sludge from entering the lubricating oil system [12, 13, 14, 15,16].

2.4.4 The Contribution of Lubricating Oils to Emissions

Lubricating Oil can affect Exhaust Gas Emissions in two ways:

- Firstly, during combustion, the lubricant contributes to the total particulate emissions. .But in comparison to the fuel, this contribution is relatively small.
- Secondly, the particulate emissions from the lubricant as well as other ash constituents from the fuel may affect exhaust gas treatment catalysts, their operation and their efficiency.

The additives of lubricating oils contain metal compounds soluble in mineral oils which, during combustion, form metal sulphates and / or carbonates. Cylinder and crankcase oils may also contain small amounts of other solid elements, for example wear particles that are found in the exhaust gases. These may contribute to particulates in the exhaust emissions.

The specific lubricating oil consumption as well as the sulphated ash level of the lubricant shows a nearly linear effect on the particulate emission. Unburnt and partially burnt base oil fractions may contribute to particulate emissions as well. Finally, it should be emphasized, that a significant share of the particulates is recovered in the lubricant's maintenance system by centrifuging or filtration.

Reactive surfaces of the catalysts in a Selective Catalytic Reduction (SCR) system can be poisoned by a variety of particulates in combination with sulphur. To retain adequate efficiency of the SCRs, engines equipped with such systems must be run on distillates or low sulphur heavy fuel oil if possible. [17,18]

2.4.5 Cylinder Liner lacquering

Sometimes, medium speed engines can show problems with the formation of lacquer and sticky deposits in the honing grooves of cylinder liners. This will result in a smooth, glazed liner surface which can lead to hard carbonaceous deposits. These can score or polish cylinder liners. The final result of this process is a dramatic increase in oil consumption.

One of the major factors influencing lacquer formation is the chemical composition of the fuel used in the engine. Those having a high final boiling point (above 450 °C) and less than 0.7 % m/m sulphur are critical. With residual fuel, the chemical composition can contribute to the phenomenon as well. Lacquering can also occur when the engine is running at high load and low speed. [19]

2.4.6 Microbial Contamination

Avoiding microbial contamination is a function of good house keeping. Micro organisms are found in marine fuels and lubricants containing water. Bacteria, yeasts and moulds flourish in the oil-water interface drawing their nutrients from the fuel whilst surviving in the water. It appears that wherever there is water, there is a potential for microbial contamination. Warm engine rooms with temperatures of about 15 to 35 °C provide ideal breeding grounds. Heavily infected fuels will, within just a few hours, result in filter plugging, fuel starvation, injector fouling and purifier malfunction.

The microbial contamination of lubricants is characteristic for crankcase oils in wet engines, particularly those with water cooled pistons.

3. ADAPTION OF THE LUBRICATING OIL TO THE ENGINE AND THE FUEL

3.1 Sump Systems and Oil Quantities

Most large medium speed main engines in marine application have a “dry sump” system. Here, the oil is not kept in the engine’s crankcase, but is circulated to a separate oil tank.

This situation is in contrast to the “wet sump” system used typically in marine auxiliary and power plant engines, where the oil is held within the crankcase...

It is common practice to allow for an oil quantity of 0.5 – 1.5 [kg/kW] for the “dry sump” system and 0.1 – 1.0 [kg/kW] for the “wet sump” system [4]. Further, also various tailor-made versions of an engine with many modifications and adaptations according to customers’ requests, different fuels and service conditions are produced and delivered.

3.2 Lubricating Oil Parameters to be specified

Depending on the engine design and the fuels intended for use, the following lubricating oil performance parameters need to be specified:

- Viscosity
- Detergency and Dispersancy
- BN (Base Number)
- Anti-Wear / Extreme Pressure
- Compatibility with specified fuels

These requirements are to be specified by the engine designer.

The lubricating oil selection must take into consideration engine requirements and the relevant fuel which may impair the oil quality. It is crucial, therefore, to ensure that the oil in service re-entering the engine is of a controlled quality. This oil must be as free as practically possible from undesirable impurities such as metallic particles, rust, soot, water and all combustion by-products as well as raw fuel. To achieve this, the oil must be cleaned by using dedicated methods, matching the fuel quality burnt and the service pattern of the engine applied. Generally, the cleaning task is performed by centrifugal purification. Filters for protection have to be fitted after the cleaning system and before the engine. Engine designers are responsible for defining the level of cleanliness required for their engine.

This oil is fed into the engine at a flow rate, temperature and pressure specified by individual engine designers.

3.3 Use of LSFO and the Commensurate Lubricating Oil

The threshold between Low Sulphur Fuel Oil (LSFO) and High Sulphur Fuel Oil (HFSO) is normally taken to be 1.5 % m/m. For engines running on HFSO, middle alkaline engine lubricating oils of BN 30 – 55 are available. In addition, lubricating oils with BN 60 - 65 for special applications have recently been introduced. A general trend to lower oil consumption has reduced the problem of too much alkalinity with the consequence that installations running on 0.5 % m/m sulphur can be lubricated without problems with BN 30 for extended periods. However, lubricating oils with higher BN levels than this, when used in installations with high oil consumption, may give problems when running on LSFO for extended periods. It is recommended that before changing to extended periods of service with LSFO on middle alkaline engine oils, the OEM should be consulted.

3.4 The Lubrication of Medium Speed Gas Engines

CIMAC has dedicated a separate publication to the lubrication of gas engines. This was published in the year 2000 under the title “Recommendations for the Lubrication of Gas Engines” [20].

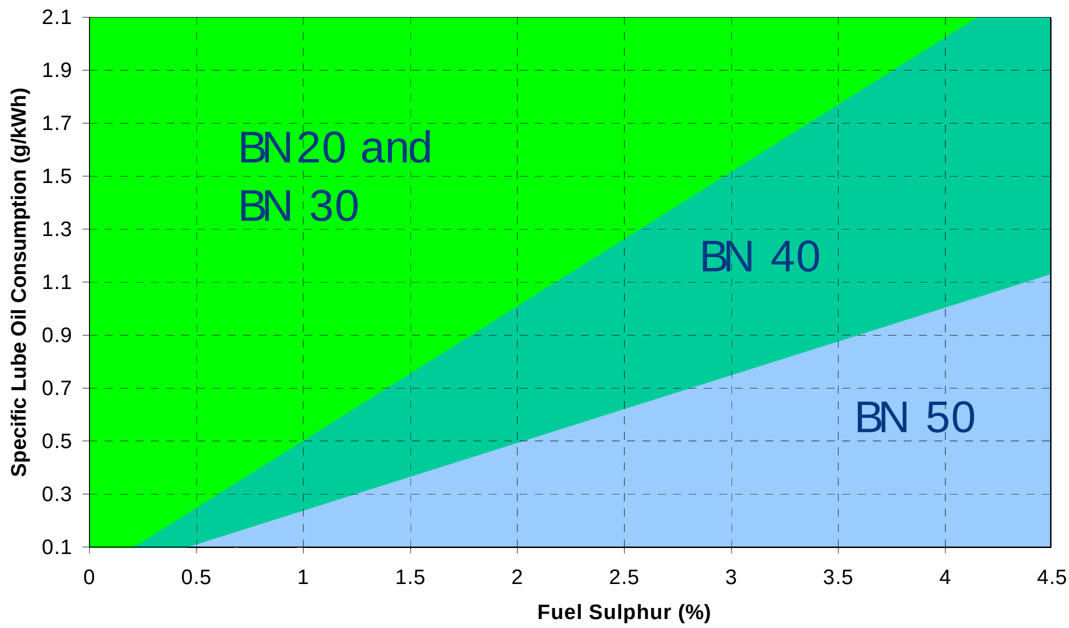
4. LUBRICATING OIL PERFORMANCE CRITERIA

4.1 Selection of the Lubricating Oil Type

This is very much the duty of the engine manufacturer, who in close cooperation with the oil formulator, must specify the type and grade of oil to be used, knowing his engines' requirements and the fuels to be used [21]. A summary of available options is shown in **Figure No. 3.** Individual deviations from this basic scheme appear less advisable due to the logistical problems to be envisaged when asking for a rare tailor-made formulation in exotic ports.

4.2 Lubricating Oil Solutions for Engine Requirements

Figure No. 3: Lubricating Oil Solutions for Engine Requirements



***) Operation with gas or low sulphur gas oil might require a much lower BN**

****) Detergency and dispersancy might be at a higher or lower level. This, to be adequate for the requirement, should be specified by the manufacturer, see Table No.1.**

Tables No. 1 and **2** summarize engine requirements using the terminology developed in **Section 2.**

These tables appear to suggest that a limited number of oil and additive properties are sufficient to tackle most problems. However, things are not that simple. The impact of the engine on the lubricating oil is more complex, forming an interactive matrix. The response of the lubricating oil components is also complex, with trigger conditions and reaction speeds of individual additives varying significantly. Most additive ingredients have interactions with others and the base oil. There are also interactions between individual surface active additives. High detergent contents, for example, make it more difficult for anti-wear additives to cover metallic surfaces [22, 23]

Interactions are also found between additives and insolubles. Higher insolubles levels in the oil in use generally result in increased wear even when the additive performance appears still satisfactory. Also, as mentioned already, dispersants, whilst rather helpful in keeping surfaces and critical passages clean, make it difficult to remove insolubles by conventional centrifuges and filters.

Table No. 1: Engine Components, Stress / Risk Factors and Protective Properties Required. The table contains simple illustrative examples only to avoid undue complexity.

ENGINE COMPONENT	DETAIL	CHARACTER OF ATTACK	LUBRICANT PROPERTY/ADDITIVE REQUIRED
1. PISTON RING	FACE	CORROSIVE & ABRASIVE WEAR	ALKALINITY/ CORROSION INHIBITOR
	SIDES	CORROSIVE & ABRASIVE WEAR	EP-ANTI-WEAR BASE OIL VISCOSITY
	BACK	DEPOSITS	DETERGENCY
2. PISTON	EXTERIOR:		
	- LANDS	DEPOSITS	DETERGENCY
	-GROOVES	DEPOSITS & WEAR	DETERGENCY, ALKALINITY, EP/AW BASE OIL VISCOSITY
	-SKIRT	DEPOSITS	DETERGENCY
	-CROWN	ASH DEPOSITS	LOW SULPHATED ASH LEVEL
	INTERIOR:	DEPOSITS	DISPERSANCY/DETERGENCY
			COMPATIBILITY FUEL/LUBE OIL
3. LINER	SURFACE	WEAR, CORROSIVE & ABRASIVE	CORROSION INHIBITOR, ALKALINITY. EP/AW, BASE OIL VISCOSITY
		DEPOSITS	OXIDATION INHIBITORS
4. BEARINGS	SURFACE	WEAR, CORROSIVE & ABRASIVE	CORROSION INHIBITOR, BASE OIL VISCOSITY
		DEPOSITS	OXIDATION INHIBITORS
5. CRANKCASE	SURFACE	DEPOSITS	DISPERSANTS/DETERGENTS
			COMPATIBILITY FUEL/LUBE OIL
6. MAINTENANCE SYSTEM	CENTRIFUGE, FILTER ;	FLUID & SOLID CONTAMINANTS	LOW DISPERSANCY
	OIL COOLERS	FLUID & SOLID CONTAMINANTS	HIGH DISPERSANCY
7. INJECTION SYSTEM	PLUNGER	DEPOSITS	COMPATIBILITY FUEL/LUBE OIL

Table No. 2: Additives – Properties and Chemical Character
The table contains simple illustrative examples only to avoid undue complexity

TYPE:	DUTY:	CHEMICAL COMPONENTS:	REMARKS:
DETERGENTS	CLEANLINESS, , ACID NEUTRALISATION (PREVENTION OF CORROSIVE WEAR), RUST PROTECTION	Ca SULPHONATE, Ca PHENATE, Ca SALICYLATE, (Ca, O, H, S)	THESE NEUTRALISE ACIDIC COMBUSTION PRODUCTS AND KEEP ENGINE COMPONENT SURFACES CLEAN
DISPERSANTS	CLEANLINESS STABILIZERS	POLY-ISOBUTYLENE, SUCCINIMIDES, ESTER SUCCINIMIDES, (N, O, H, C)	THESE SUSPEND SLUDGE, WATER AND COMBUSTION BY-PRODUCTS
ANTI-OXIDANTS	PREVENTION OF OXIDATION	AROMATIC AMINES, HINDERED PHENOLS, DITHIO CARBAMATES, ZDTP (Zn, S, P, C, H,)	SLUDGE PREVENTION, CONTROL OF VISCOSITY INCREASE
ANTI-WEAR	PREVENTION OF ABRASIVE AND ADHESIVE WEAR, IMPROVEMENT OF LOAD CARRYING	ZDTP (Zn, S, P, C, H,)	TOLERATE HIGH LOAD AT HIGH TEMPERATURE
ANTI-FOAM	REDUCTION OF SURFACE TENSION OF AIR/GAS BUBBLES TO PREVENT FOAMING	SILICONES, POLYACRYLATES	WATCH ANTAGONISTIC EFFECTS ON AIR RELEASE PROPERTIES
RUST INHIBITORS	PREVENTION OF WATER/ACID ATTACK ON IRON	NEUTRAL Ca-SULPHONATES, N – DISPERSANTS	
DEMULSIFIERS	WATER SHEDDING	ETHOXYLATED ALCOHOLS	
CORROSION FIX	PROTECTION OF YELLOW METALS, e.g. COPPER	N-DISPERSANTS, S COMPONENTS	

The above illustrates the many features of the fresh oil. Regular top-up is necessary to compensate for their consumption and decomposition. The oil maintenance system also plays an important contributory role.

Table No. 3 lists the most important performance criteria to be considered when developing a lubricant. Dedicated test methods for oil performance need to be agreed and developed where missing. This is the role of the CEC Group “Marine and Large Engines”. Limits to be met should be the affair of the individual engine manufacturer as they no doubt will differ from engine type to engine type and from application to application.

Table No. 3: Lubricant Performance Criteria and their Evaluation:
The table contains simple illustrative examples only to avoid undue complexity. In practice the type of evaluations are by no means restricted only to the ones listed below.

LUBRICANT PROPERTY:	TYPE OF EVALUATION:	REMARKS/SUGGESTIONS:
A) BASE OIL INFLUENCE:		
- BASE OIL VISCOSITY AT HIGH AND LOW TEMPERATURES	LAB TEST	SPECIFIED MIN. VISCOSITY AT HIGH TEMP. (180 °C) AND MAX. VISCOSITY AT LOW TEMP. SEEM TO BE MORE APPROPRIATE THAN VI
- EVAPORATION CHARACTERISTICS	LAB TEST	MODIFIED NOACK TEST OR SIMULATED DISTILLATION CURVE
- THERMAL AND OXIDATION STABILITY	LAB TEST	PDSC AND IN-HOUSE METHODS
B) ADDITIVE INFLUENCE:		
- ALKALINITY	LAB TEST	ASTM D2896 AND ASTM D4739
- DETERGENCY	ENGINE TEST	TEST ENGINE OR EQUIVALENT
- DISPERSANCY	LAB / ENGINE TEST	COKER TEST OR RIG / ENGINE TEST
- ANTI-WEAR / EP	ENGINE / FIELD TEST	FIELD TEST AGAINST REFERENCE LUBRICANT
- CORROSION INHIBITION	LAB TEST	-
- THERMAL AND OXIDATION STABILITY	LAB / ENGINE TEST	-
- WATER REJECTION	LAB TEST	RIG TEST AGAINST REFERENCE LUBE
- ANTI-FOAM	LAB TEST	-
- CLEANLINESS OF COMPONENTS	LAB TEST	-
- SEPARABILITY	LAB TEST	RIG TEST AGAINST REFERENCE LUBE
- FILTERABILITY	LAB TEST	-
- COMPATIBILITY WITH FUEL	LAB TEST	COKER TEST OR OTHER RIG TESTS

Getting the right balance in the dispersancy level of the oil is critical:

- High dispersancy results in a clean engine system, but this may load the lubricant with high insolubles, which then become more difficult to remove by the centrifuge. A change of the complete oil charge will be required when the insolubles content exceeds the condemning limit.

  The use of high dispersancy oils may still be preferable for high output, low weight, restricted engine room space installations operating on short maintenance periods (e.g., naval vessels),

- Low dispersancy results in a less clean engine system but nevertheless the oil is relatively clean and is less loaded with insolubles.

Overall the efficiency of the oil cleaning system must be high to achieve long oil change intervals. The efficiency of the system depends very much on the adequate dimensioning and professional operation of it to keep the engine and lubricant in a satisfactory clean condition for a sufficiently long period.

Most of today's lubricants for medium speed engines are of moderate dispersancy, with the aim of providing an acceptable compromise between the above mentioned conflicting requirements.

Contamination with water and / or other lubricant technologies can easily disturb such a fine tuned dispersancy balance and, therefore, must be avoided or remedied as soon as possible. Higher dispersancy automatically results in a higher risk of insolubles and additive fallout in the presence of water.

4.3 Lubricating Oil Consumption Aspects

The CIMAC Working Group "Lubricants" in 1999 has devoted a separate publication to this complex issue, entitled: "CIMAC Recommendation No. 17 – Guidelines for Diesel Engines Lubrication – Oil Consumption of Medium Speed Diesel Engines" [24]. This document compiles information on factors influencing oil consumption, i.e., engine design and condition, oil and fuel quality, oil system capacity, operating conditions, the service effect of oil BN depletion, system losses and system maintenance. It also looks at the technical consequences of inadequate renewal of oil quality and finally, on economic consequence of different lubrication regimes.

4.4 Lubricating Oil Degradation Aspects

The CIMAC Working Group "Lubricants" in 2004 published a separate document on this complex issue, entitled "CIMAC Recommendation No. 22 - Guidelines for Diesel Engine Lubrication – Lubricating Oil Degradation" [4].

This document compiles information on the following topics:

- Stresses imposed on the engine oils by engine components
- Causes of oil degradation
- Lubricant performance in service as influenced by effects of degradation
- Mechanisms of oil degradation and measurable responses to stresses
- Practical implications and inferences
- Suggestions for the design of more stress-resistant lubricating oils

- Analytical methods for assessing oil degradation
- Warning and condemning limits.

The document brings together insights into the mechanisms and phenomena of oil degradation, resulting from stress of the lubricant in large 4-stroke (medium speed and high speed) and 2-stroke diesel engines. Its objective is to contribute to the understanding of the complex processes resulting in oil degradation and thereby, to a degree, enable control of them [4].

4.5 Engine Inspection Reports

The most comprehensive feedback on the performance of the engine / lubricant system is provided by a professional inspection of both the engine **and** the lubricant.

Meaningful results are achieved by a disciplined execution of the following procedures:

- A qualified inspection of the engine’s reaction to a lubricant’s performance.
- A regular sampling of the crankcase charge and a consequent investigation thereof by used oil analysis (UOA).

Recommendations for such work have been developed by the CEC [*)] Group “Marine and Large Engines Special Project Group” [35]

Getting hold of representative lubricating oil samples requires a disciplined approach towards how, and in which position to take samples**.** Again the CEC “Marine and Large Engines Special Project Group” has taken the job to formulate a method. [36]

Regular samples of lubricant need to be taken and analysed in order to establish the suitability of the lubricant for continued use.

Individual engine manufacturers publish recommendations for sampling intervals together with warning and condemning limits on various lubricant properties.

The comparison of lubricant properties over time allows trends to be monitored. When sudden changes in lubricant properties are observed, additional samples should be taken to re-check results and to confirm the effectiveness of any corrective actions that have been taken.

Table No. 4: Sampling Interval

Sample Number:	To be taken after total running time (hours)
1.	50
2.	100
3.	250
4.	500
5.	1.000
6.	1.500

Samples should be taken at specified intervals and evaluated on acceptance criteria agreed between the parties concerned (for example, see table No.4).

*) CEC is the acronym for *C*oordinating *E*uropean *C*ouncil. This is a scientific inter-industry institution developing and publishing performance test methods for fuels and lubricants

4.6 Lubricating Oil Brand Change

Occasionally, engine operators report problems occurring after a changeover from one brand of lubricating oil to another without taking the necessary precautions. In the majority of cases, such problems are avoided by adopting simple engineering practice and reflecting on the current engine condition. Ideally, with the aim of minimising potential risks for the engine, like deposit formation, blocking of lubricating oil filters, lubricating oil foaming and consequential damage of engine components, the following procedure should be followed when one lubricating oil brand is replaced by another:

- If possible, change the lubricating oil brand in connection with an engine (piston) overhaul
- Drain the old lubricating oil from the lubricating oil system
- Clean the lubricating oil system if there is an excessive amount of deposits on the surfaces of engine components like crankcase, camshaft compartment etc.
- Fill the lubricating oil system with fresh lubricating oil

Whilst the above is the ideal recommendation, in a practical world this approach is not always possible. If the above procedure cannot be executed completely, any deviation should be agreed with the respective parties; the lubricant supplier and the engine builder, especially with engines still under warranty*), otherwise the responsibility for any possible malfunction and damage cannot normally be covered by the engine manufacturer or the lubricating oil supplier.

Changeover of brand by means of a simple top-up is very often undertaken routinely and normally successfully without issues. In any event, changes in lubricant chemistry are undertaken and launched by lubricant formulators from time to time (periodic lubricant performance upgrades) and are phased into the industry creating a minimum of problems only. Evidence for such was shown years ago when oil formulators and users moved to a new “Anti Black Paint/Sludge” technology. This global changeover was managed very successfully by all parties involved with a minimum of difficulties. The example, furthermore, demonstrates that changeover by top-up can be safely done provided agreed procedures are observed.

Often the concern is not simply with the compatibility of the various additive chemistries. The key is rather to avoid major disruptions/destabilisations of the various contaminants that may be present in the engine sump. The operator is well advised to co-operate with the oil supplier to ensure a safe changeover. This may necessitate some precautions in:

- Carefully monitoring of filter performance, with more regular cleaning of filters, if necessary, during the changeover period.
- Carefully monitoring of centrifuge performance, with optimisation of centrifuge operation and more regular cleaning of the centrifuge, if necessary, during the change-over.
- More frequent oil sampling during the changeover.
- Making sure that top-up quantities are kept at less than 10% of the charge during each top-up. This is no different to normal good engineering practice. A poorly maintained engine which is left to become very dirty, will show similar problems when suddenly topped-up with a large quantity of fresh oil, even without the change of brand or grade. So in general, good maintenance of the engine and good engineering practice in the topping up procedure can demonstrate significant beneficial effects.

*) Where an engine builder, for example, does not approve an oil change by top-up, the change of grade should be carried out only after the engine warranty period has expired. Otherwise it should be confirmed by the responsible engine-builder that the guarantee does not become invalid.

5. THE LUBRICATING OIL SYSTEM

The efficiency of the lubricating oil system is crucial for the engine's performance and lifetime. Much attention, therefore, has to be paid to its design, construction and operation [25].

5.1 The System Design

In order to ensure that engine requirements are met, the engine manufacturer must make sure that the following information is provided and considered:

- A principle diagram, showing all components. The oil circuit and the oil cleaning circuit should be included. The oil type to be used and a tolerable cleanliness level should be specified.
- The filter type to be installed. A filter fineness of 30 – 35 µm absolute appears to be a typical recommendation. It is, furthermore, recommended to dimension the main filter according to the normal required full flow rate and allowing for the designed pressure drop.
- The required oil flow rate.
- The lubricating oil temperature at the engine inlet.
- The inlet / outlet temperatures max. / normal / min.
- The maximum pressure drop tolerated in the oil coolers.
- The lubricating oil outlet temperature (alternatively the lubricating oil outlet viscosity, typical is 65 – 85 mm^2/s).
- The heat dissipation requirements.
- A list of all alarms and shut downs should be available as well.

Safe operation of an engine very much relies on a qualified specification of the above, together with the cleanliness level required.

5.2 The Piping Design

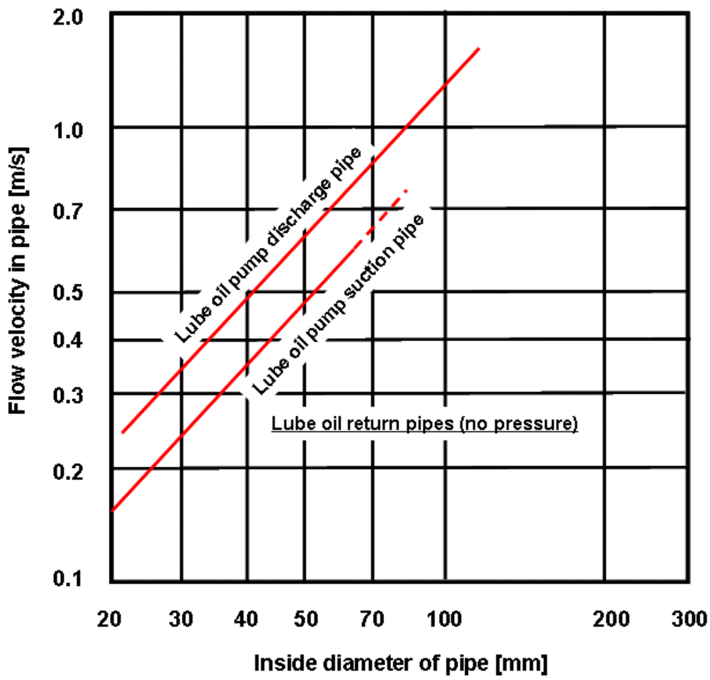
- Pipe dimensions have to be in accordance with the requirements of the classification society.
- The shortest possible pipe way design with a minimum number of bends.
- Accessibility of all weldings for mechanical cleaning (grinding).
- Use of the minimum number of flanges, preferably of the spigot type.
- Clip fittings to prevent vibrations.
- Piping layouts that absorb expansions
- Preferential use of flexible fittings
- Piping in the neighbourhood of pumps and heat exchangers must generally be arranged in a way that permits the overhaul of such units with minimum dismantling of the piping system.

- Care to be taken to minimize the number of pockets in pipe lines. Where pockets are inevitable, they must be fitted with drain cocks or valves.
- Piping should be installed for stress-free mating with the flanges of the engine and all its auxiliaries (coolers, filters, heaters, thermostatic valves, etc.)
- Install sampling cocks according to **CEC M13 T92**.
- Flow velocities of the lubricant shall be related to the inside diameters of the pipes as stated in **Figure No. 4** on the standard velocity of flow:

$$V = \frac{354 \times Q}{D^2}$$

with V = Velocity in [m/s], Q = Flow in [m^3/h] and D = inside pipe diameter in [mm]

Fig No. 4: Standard Flow Velocity in Oil Pipes



5.3 The Cooling Circuit

As it is mandatory that the lubricating oil inlet temperature is meeting the specification of the engine manufacturer (normally 50 - 65 °C), the lubricating oil cooler capacity must be adapted accordingly.

The lubricating oil cooler can be cooled by fresh water or by sea water.

The following information is needed for calculating the dimensions of the cooler:

- Heat dissipation
- Lubricating oil flow
- Maximum pressure drop on the oil side (0.5 bar is typical)
- Maximum pressure drop on the water side (0.2 bar is typical)
- Lubricating oil outlet temperature of engine (65 – 75 °C is typical), ie inlet to oil cooler
- Sea water inlet temperature (32 °C is typical)
- Fresh water inlet temperature (36 °C is typical

5.4 Acceptance

Documentation on the lubricating oil circuit when designed and constructed according to above specification should be sent to the engine manufacturer for acceptance.

5.5 Lubricating Oil Storage and Handling

Because correct lubrication is vital to the operation of diesel engines, it is reasonable to accept that lubricants are given the same meticulous care as is common practice for engine spare parts. It cannot be over-emphasized that even high quality lubricants can cause difficulties in service, when stored and handled inadequately.

A storage tank, therefore, before being filled for the first time, should always be inspected to ensure that it is clean and free from rust, dirt and other contaminants. The filling pipe, the venting pipe and the breather should also be inspected. When already in service, the filling pipe should be drained to ensure that it is free from other liquids.

As it cannot always be guaranteed that the new oil is free from particles when taken on board, a once-through filtration (filter size 6 µm max.) is highly recommended.

Caps and valves of filling connectors on deck should be checked after filling the storage tank to ensure that they are closed.

Where a small quantity only of a particular grade is stocked in drums, these should be stored indoors and in a horizontal position.

If for any reason it is necessary to add oil to the system in service, this should be done through a filter or via the lubricating oil purifier.

Not more than 10 % and preferably less than 5 % of the total system content should be added at a time. The reasons for this are to avoid potential risks of sludge precipitation and difficulties in interpreting used oil analytical data when samples are taken. Larger topping up quantities could also affect the balance of the used oil characteristics as explained in paragraph 4.6.

If the oil has to be exchanged completely, the sump and all tanks must be cleaned manually and inspected before the new charge is filled in. In such cases it is also important to circulate and purify the new oil before the engine is started up again. Alternatively, a small quantity of the fresh oil can be circulated for flushing and draining.

5.6 Preparation of the Lubricating Oil System

When an engine, its systems, or the connecting pipes have been installed, or opened for repair, a certain amount of particles may often enter the system. It is essential for the engine's later performance and life time that such particles are completely removed.

During the manufacturing of the pipe system the following procedures are mandatory:

- To grind all weldings inside the pipes and elsewhere with the aim to remove welding burrs,
- To clean with acid all pipes before fitting,
- To flush all inside surfaces before start up very carefully,
- To ensure that open pipe ends and flanges in the engine and the pipe system are blanked off.

5.6.1 Flushing of the Lubricating Oil System

- Develop a flushing diagram and procedure
- Make sure that all flushing is executed in one direction only
- By-pass all pipe ends just before the engine
- Inspect all tanks before filling them with oil
- Fill the flushing oil into the system through a filter
- The flushing oil flow must be turbulent (Reynolds figure above 3000)
- The oil temperature must be 65 °C minimum
- Pipe vibrators or shock facilities must be fitted
- A flushing filter with a mesh finer than the original system filter must be fitted during the flushing process
- The purifier must be in service during the entire flushing process.

The flushing must be continued until the predetermined cleanliness level is achieved (see paragraph 7.5.8). Normally, the cleanliness level is specified by the engine manufacturer.

When the interior cleanliness of the pipe system is found acceptable, the lubricating oil system should be converted back to the original status. This must include the cleaning of main filters and connecting pipes between the flushing filters and the engine inlet.

Running-in filters are occasionally used and these are fitted before the actual flushing starts.

It is essential that all oil pumps and the lubricating oil maintenance system are started and kept running as long as possible before the engine is finally started. This helps to remove a maximum amount of particles still left inside the engine before it is started for the first time.

Normal practice is to use the actual lubricating oil assigned for the engine as the flushing medium. However, a thin flushing oil compatible with the engine lubricant can also be used.

5.7 Running-In

It is well known that many contamination products are released during the running-in process. Therefore it is an advantage to remove such contaminants as early as possible. This should be done as follows:

- Keep the flushing filter in the system during the entire running-in period and
- Install and run an extra off-line filtration during the running-in period as well.

After the cleaning part of the running-in process is finished, the genuine “breaking-in part” of the procedure is to follow. Here, the purpose of the job is to bring the engine and its gliding components like bearings, piston rings, liners, etc. as soon as possible into a surface condition that allows for a safe full load operation without scuffing. Such status is achieved when the amount of blow-by gases has reached an agreed (low) volume or, when the surface of the piston rings on inspection shows an even running surface on the entire circumference.

The procedures to be followed are prescribed by the OEMs and must be strictly followed when the engine is new as well as when an engine is equipped with new pistons, piston rings and liners during an overhaul.

5.8 Keeping the Lubricating Oil System in Service clean

When executing an overhaul or repair during later service there is always a risk of particles entering the engine. Therefore it is essential that maximum precautions are taken to keep these out of the engine and the entire lubrication system. To prevent contamination with particles from the outside all openings in the lubricating oil system must be blanked off during such periods.

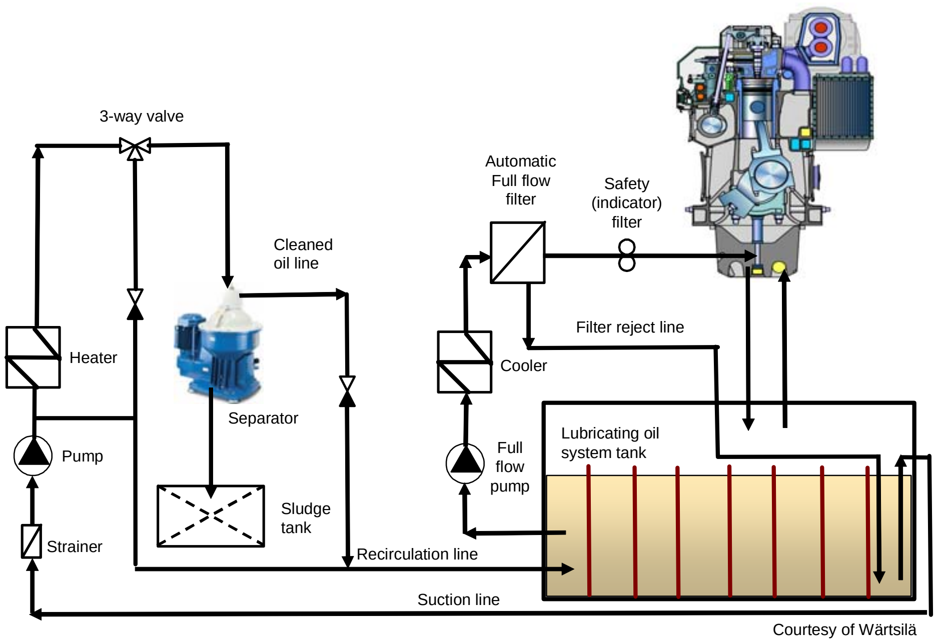
6. THE LUBRICATING OIL TREATMENT SYSTEM

The design as well as the safe and effective operation of the lubricating oil treatment system and its components are crucial for the longevity and economic use of the diesel engine. As such CIMAC Working Group “Lubricants” has devoted a separate publication to this complex issue. It deals with the purpose, effect and methods of lubricating oil cleaning. This brochure is published as “CIMAC Recommendation No. 24 - Treatment of the System Oil in Medium Speed and Crosshead Diesel Engine Installations” [25].

The treatment system is shown in **Figure No. 5,** and sources of contamination are shown in **Figure No. 6**

In some marine installations only one lubricating oil separator is installed to treat the lubricating oil from two or three auxiliary engines, or in some dry sump engines a common overflow tank is used. Owners should note that where a common overflow tank is used the lubricating oils of the individual engines will be mixed to some extent making the evaluation of used lubricating oil condition of each engine more inaccurate.

Figure No. 5: The lubricating oil treatment system



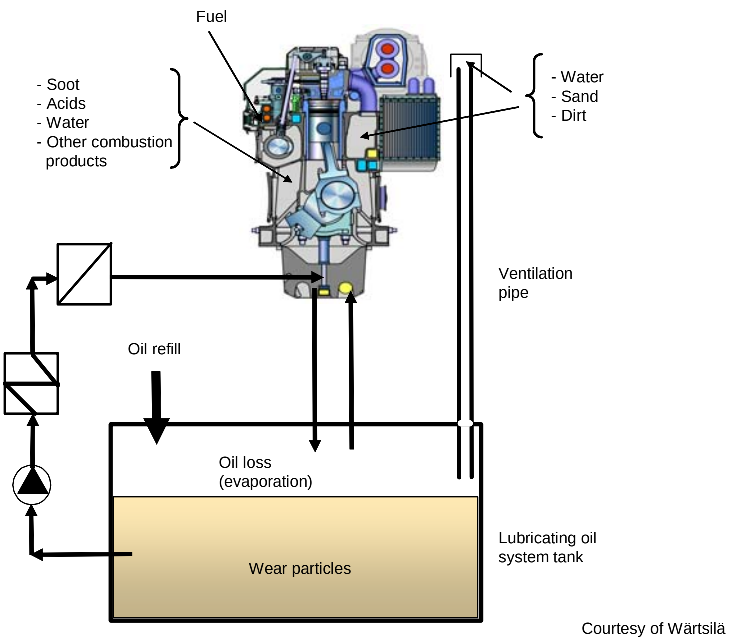
7. LUBRICATING OIL ANALYSIS AND ITS SIGNIFICANCE

7.1 The Purpose of Lubricating Oil Analysis

The main reasons for analysing used oils are as follows:

- To determine the condition of the lubricant and to confirm whether or not it is fit for further service.
- To detect and prevent trouble with lubricated parts of the engine if possible at an early stage.
- To assist in investigating the cause of engine problems [26].

Figure No. 6: Contamination sources



7.2 Drawing of Samples

The results from any analysis, either in the laboratory or on site, will reflect the condition of the sample. Care must be taken, therefore, to ensure that representative oil samples are obtained. The details are described in paragraph **4.5** and also in [36].

7.3 Sampling Intervals

Sampling intervals are recommended in paragraph **4.5** for approval purposes. Intervals of 500 – 1000 hours or more frequently will be ideal for routine oil analysis.

7.4 Information Required for Lubricating Oil Analysis

1) Name of vessel or plant
2) Owners
3) Date, when sample drawn
4) Date and port, where sample handed in

5) Oil brand, product name, nominal viscosity
6) Hours in service
7) Engine model and manufacturer
8) Position in lubricating oil system from which the sample is drawn
9) Type of fuel used (including sulphur content)
10) Date, when previous sample drawn from same source
11) Quantity of lubricating oil in system and top-up since last sample
12) Any reasons for analysis being required (in case a non-routine sample)

7.5 Properties to be Tested

The significance of tests and the relevance of information obtained thereby are discussed in the following paragraphs. The methods used are dependent on the purpose of the oil analysis. Test items, which are typically carried out as routine oil analysis are discussed in this section. Quality limits (used oil condemning limits) are dealt with in the **section 8.**

7.5.1. Viscosity

The test method is described in ASTM D 445 (ISO 3104).

In summary, the test method uses a glass viscometer which is charged with a sample of the oil to be evaluated and allowed to equilibrate in a constant temperature bath. The oil is subsequently allowed to flow under gravity down one leg of the viscometer through a capillary into a measuring bowl. The time taken to pass the two timing marks is noted. The product of this time and the calibration constant of the viscometer give the kinematic viscosity of the oil analysed in $mm^2\ s^{-1}$. The viscosity of the oil in use is generally determined at 40 or 100 °C.

Viscosity is the most important single property of engine lubricants, since it determines not only oil volumes transported to the piston undercrown and cylinder liners/piston rings, but also the oil film thickness in bearings.

The viscosity of a lubricating oil in use may change in service, mainly by contamination of the oil with combustion soot and lubricating oil originated compounds (e.g. calcium sulphate), but also due to oxidation, thermal degradation, contamination with fuels, water etc. Accordingly, changes in viscosity should be considered always in relation to other analytical data, such as TAN, pentane / heptane insolubles (see 7.5.3) and water content for contamination, and a flash point drop for dilution by fuel. In cases where these data reveal nothing unusual, a change in viscosity may also indicate that a mixing of different lubricants has happened in the system.

Both a viscosity decrease and a viscosity increase in the lubricating oil can become a risk for the engine. Viscosity decrease may reach a limit where it is difficult to maintain full-film lubrication in the bearings. A moderate increase of viscosity may normally be tolerated, unless the oil flow to the piston undercrown is reduced to a dangerously low level.

Engine oils, when heavily contaminated in use, can show non-Newtonian behaviour. This means that used engine oils will show a slightly lower actual viscosity in the bearings during operation than when measured with the viscometer. For engines which are known to be critical in bearings it is, therefore, not recommended to reduce the viscosity of the oil in use by topping up with fresh oils of lower viscosity.

7.5.2 BN (Base Number)

The alkalinity of a lubricating oil is defined as the quantity of hydrochloric acid or perchloric acid required to neutralise one gram of oil, expressed in terms of the equivalent number of milligrams of potassium hydroxide.

There are two methods ASTM D2896 (ISO 3771 with perchloric acid) and ASTM D4739 (ISO 6619 with hydrochloric acid) for determining the BN. Most engine manufacturers and oil suppliers prefer to assess BN by D2896 rather than D4739.

The BN is a measure of an oil's ability to neutralise strong acids, caused by combustion products condensing on the cylinder walls and elsewhere within the engine. Sulphur in the fuel is converted to sulphur oxides during combustion and, although the majority of this is expelled with the exhaust gases, a small proportion of SO_3 remains within the combustion zone. Together with the water formed during the combustion process it condenses on the cylinder walls as sulphuric acid. This acid must be neutralised by the alkalinity of the lubricant. Otherwise serious corrosive wear of the cylinder walls and the piston rings will occur. This neutralisation takes place with the formation of either calcium or magnesium sulphates (depending on the additive contained in the oil) which inevitably become part of the insolubles burden carried by the oil when returning to the crankcase.

Fuel sulphur content and temperature influence the dew point of the sulphuric acid at much higher combustion pressures such as inside the diesel cylinders. This is difficult to measure in practice. Calculations on the basis of reasonable assumptions, however, show that elevated pressure has a very significant effect [27, 28]. See **Figure No.7.**

This figure cannot indicate the severity of corrosive wear to be expected in the absence of alkalinity from the lubricating oil. But for a given fuel sulphur level it is clear that the acid condensation temperature increases with the pressure. Also the acid production increases with the fuel sulphur content at any particular temperature, provided this is below the dew point.

Figure No. 7: The influence of fuel sulphur content and combustion pressure on the dew point of sulphuric acid, Source: Shell, Dr C Schenk, 2000

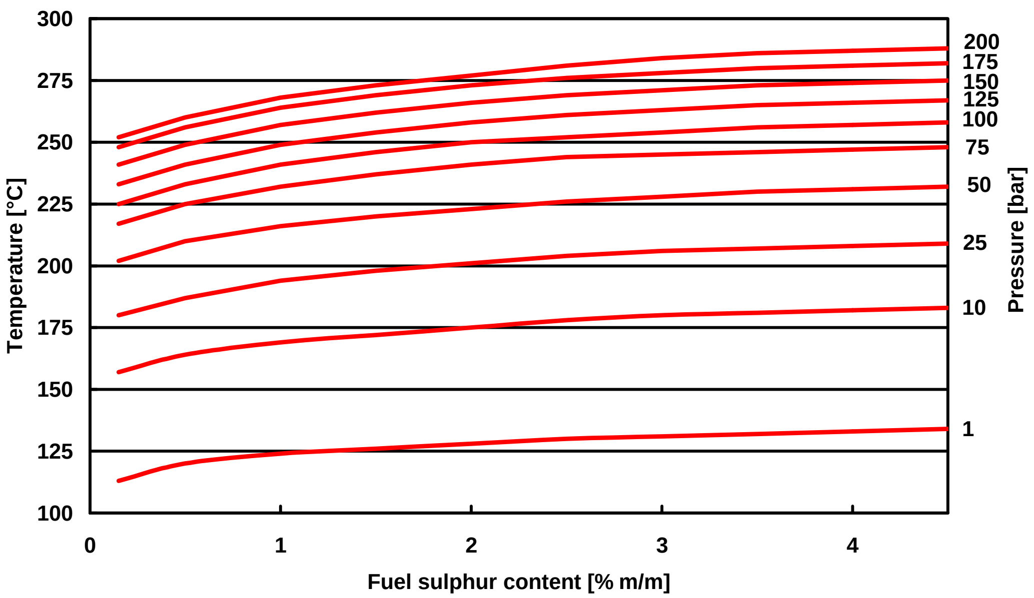
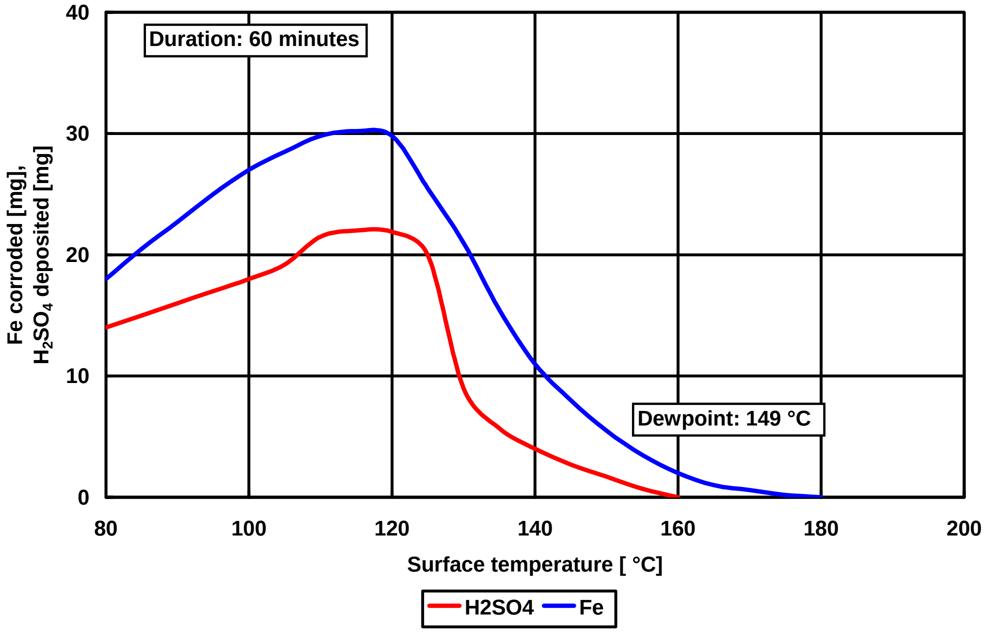


Figure No. 8: Effect of surface temperature on acid condensation and corrosion, Source: Shell, P R Belcher, 1971



A further complication is the effect of temperature on the corrosion rate. This problem has been investigated at atmospheric pressure, but is expected to apply similarly at higher pressures as well. It has been found that the rate of corrosion increases to a maximum when the temperature is about 30 °C below the dew point. When the temperature is further reduced, the corrosion rate will fall sharply [29]. See **Figure No.8**.

In practice, both a temperature and a pressure gradient will be present along the cylinder liner surface during the power stroke. Whilst experience has shown that most of the liner wear occurs in the region of top dead centre of the top piston ring, the corrosive component of wear is not necessarily eliminated by maintaining only the upper part of the liner at a temperature near, better above, the dew point, say at about 150 °C.

Research has demonstrated that corrosive wear in the upper and hotter part of a cylinder liner can be caused by condensed acid swept upwards from the lower cold region [30]. It is suggested that engines designed in such a way that temperatures are kept above the dew points on the entire travel of the piston rings between TDC and BDC. The formation of sulphuric acid also contributes to an increase of the lubricant's viscosity and content of pentane insolubles. Soot generally contains sulphuric acid. In consequence, good combustion is important to help fight corrosion as well.

When a lubricating oil is new in service, the BN normally drops sharply for a short while, but then gradually levels out to a steady equilibrium value. Thereafter, this equilibrium will continue indefinitely, provided the sulphur content of the fuel and the lubricant consumption rates remain reasonably stable. This clearly represents a condition where the addition of alkalinity in the make-up oil just balances the amount of sulphuric acid to be neutralised on the cylinder liner walls. The "sulphur conversion" ratio of the engine, (i.e. the ratio of sulphur condensed as sulphuric acid, to the total sulphur ingested with the fuel), can be determined at any time during the life span of an oil charge [31].

It should be emphasized that this ratio is approximately constant for a particular engine design with fixed operating conditions and independent from the sulphur level of the fuel. However, it is significantly influenced by the temperature of the cylinder liners.

The other factor influencing BN equilibrium level in service is the lubricating oil consumption. In the unlikely event of zero oil consumption, the BN of the crankcase oil would never stabilize but gradually fall to zero in due course. An appropriate oil consumption, therefore, is very important and when this is provided, equilibrium conditions usually are attained after a few thousand hours (see paragraph 2.2). It is essential, therefore, to incorporate sufficient alkalinity into the oil, so that the equilibrium BN achieved is still adequate under the most adverse conditions of high fuel sulphur content and low oil consumption. Hence, the apparent economy of designing engines for an extremely low oil consumption may well be offset by the need for more frequent oil changes, or the use of a lubricating oil of much higher BN.

The actual minimum BN equilibrium level of a crankcase oil must be sufficiently high, to be considered as acceptable in a splash-lubricated engine operating on HFO.

In practice, a proportion of the alkalinity included in the formulation is likely to serve as a multi-purpose detergent additive, on which the cleanliness of the piston depends as well. Thus, while it may be acceptable for the control of corrosive cylinder wear to allow the BN to fall, this may well be inadequate for piston cleanliness, in that the BN also provides a rough indication of the detergency reserve available. Generally carbonaceous piston crown and land deposits, unless grossly excessive, have little effect on engine operation, especially with the advent of anti-polishing ring. Deposits in piston ring grooves, on the other hand, can prevent free movement of the rings, leading to liner scuffing, blow-by and rapid engine deterioration.

Lubricating oils used in engines burning HFO, therefore, must be able to minimise such deposits. Such can be achieved by adequate detergency of these oils.

Ring groove deposits originate mainly from unburnt or incombustible components in the fuel, products of neutralisation of the sulphuric acid condensate, and potentially from the oxidation of the lubricating oil itself, which can result in insoluble resins. Depending on the ring groove temperature, deposits will be found therein. The recommended maximum temperature in piston ring grooves also depends on the residence time of the lubricating oil in the piston ring grooves [5]. Experience suggests it would be desirable to keep the temperature in piston ring grooves well below 220 °C for conventional mineral lubricants.

The cleanliness of the piston undercrown is important as well and there is a need to control deposit formation in this region. The surface temperature of the piston undercrown, therefore, should be controlled to below 250 °C.

When operating in humid climate, there is a risk that excessive quantities of condensed water enters the cylinders together with the scavenge air. This problem is likely to be more acute in modern, highly rated engines having rather high scavenge air pressure. When the temperature of the charge air cooler tubes is low, moisture can condense on them and the resulting water droplets will be carried over into the cylinder together with the scavenge air. This water may be very harmful because it tends to wash the oil film off from the cylinder walls and, furthermore, it can contribute to corrosion by reacting with the sulphuric acid derived from the combustion of the fuel sulphur. Severe scuffing resulting in increased wear can thus occur on the cylinder liner and piston rings during time spans, in which the engine is operated under humidity and temperature conditions as mentioned above. Additionally, increased risk of corrosion of piston ring grooves, piston crowns and inlet valves as well as deposit formation to the piston cooling gallery are possible consequences due to the presence of water in the scavenge air.

Occasionally, the quantity of condensed water passing into the cylinders can be very large. Much effort, therefore, has been devoted by engine manufacturers to design hardware that is capable of removing water from the scavenge air. Although effective, such equipment is expensive and often difficult to install, especially if the engine design is not originally configured to accept such an equipment. To avoid water condensation as far as possible, the cooling water inlet temperature to the charge air coolers could be controlled according to the humidity and temperature of the inlet air. It has been found that controlling of air temperature alone does not necessarily prevent condensed water entering the cylinders. When the charge air cooler tubes are too cold, the water will condense in relatively large droplets. These subsequently will reach the cylinder liner walls before having sufficient time to evaporate.

7.5.3 Insolubles

Currently, there are various methods for determining of insolubles in used lubricating oils. Two example methods are explained below:

ASTM D 893 (centrifuging)

1) Procedure A

A sample of used lubricating oil is mixed with pentane and centrifuged. The oil solution is decanted and the precipitate is washed twice with pentane, dried, and weighed to give the pentane insolubles.

For toluene insolubles a separate sample of the oil is mixed with pentane and then centrifuged. The precipitate is washed twice with pentane, once with a toluene-alcohol solution and once with toluene. The insoluble material is dried and weighed to give the toluene insolubles.

2) Procedure B

A sample of used lubricating oil is mixed with pentane-coagulant solution and centrifuged. The precipitate is washed twice with pentane, dried and weighed to give coagulated pentane insolubles.

For coagulated toluene insolubles a separate sample of the oil is mixed with pentane-coagulant solution and centrifuged. The precipitate is washed twice with pentane, once with toluene-alcohol solution and once with toluene. The insoluble material is then dried and weighed to give the coagulated toluene insolubles.

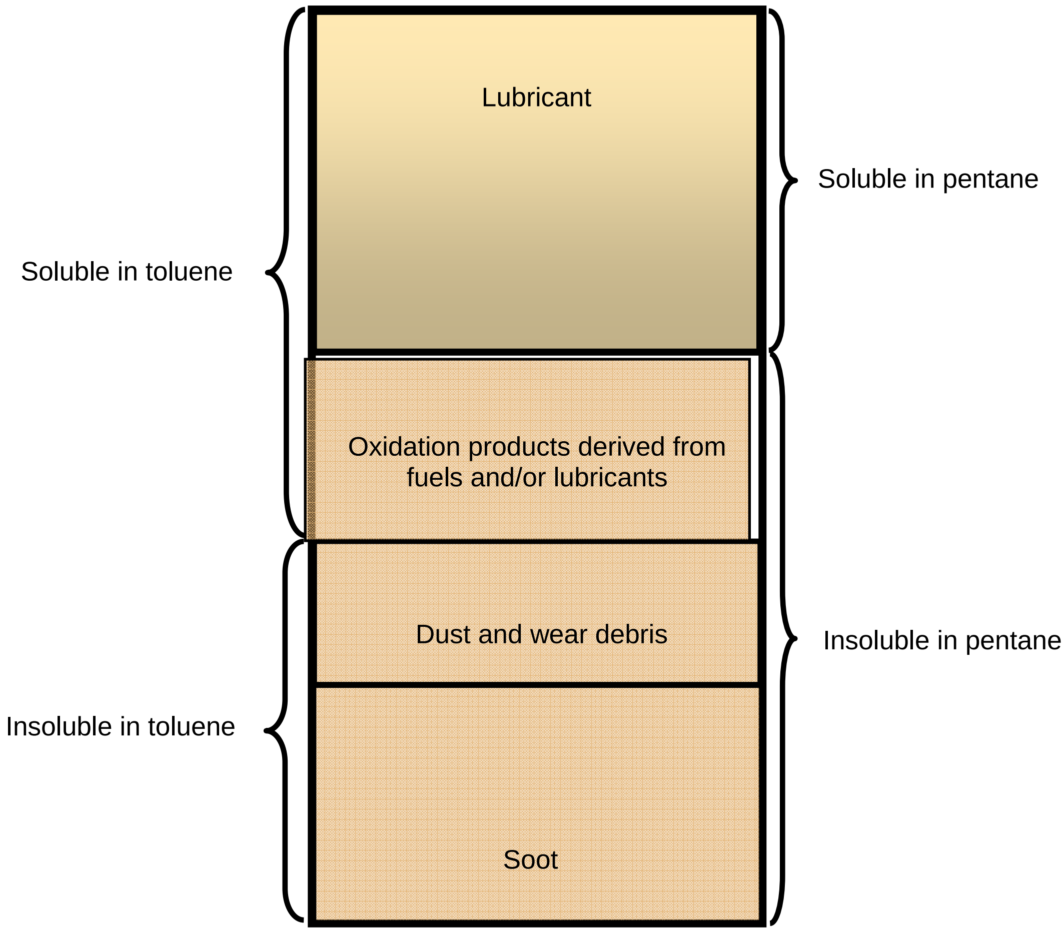
ASTM D 4055 (membrane filtration)

A sample of used lubricating oil is mixed with normal pentane in a volumetric flask. The solution is filtered through a 0.8 µm membrane filter. The flask, funnel and filter are washed with additional pentane to ensure a complete transfer of all particles onto the filter. The filter and its particulates are dried and weighed to give the pentane insolubles.

Pentane insolubles indicate the quantity of solid contaminants in the oil. These may include combustion products inclusive soot and neutralised calcium compounds derived from the lubricants additives, rust, wear debris and oil oxidation products. Such contaminants make the viscosity of a crankcase oil increase and may lead to the formation of deposits on piston undercrowns. Also, the heat transfer in oil coolers may be reduced by such deposits.

The difference between pentane and toluene insolubles is shown in **Figure No. 9.**

Figure No. 9: Pentane and Toluene Insolubles



Occasionally, hard deposits are formed on piston crowns and lands. Where such hard deposits are removed from the pistons by mechanical force, they may cause premature damage to bearings. Such hard deposits on pistons are believed to be caused by abnormal high temperatures and by long exposure to the combustion flame. The formation of such hard deposits cannot be cured by changing to another oil brand or another type of oil. Improvements can be achieved by better combustion and / or maintenance. In particular, it must be considered that charge air coolers and exhaust economizers tend to clog.

The accumulation of insolubles can be minimised by effective purification and commensurate operating conditions

7.5.4 Water Content

The test method is described in ASTM D 95 (ISO 3733) [32].

The used oil sample is heated under reflux with a water immiscible solvent, generally a petroleum distillate. The solvent evaporates with the water, and the two are subsequently separated in a trap. The water is collected in the graduated section of the trap and the solvent returns to the still.

When the amount of sample is limited such that D95 cannot be run for high accuracy, alternative Karl Fischer methods may be considered, which require much less sample. One example is ASTM D6304. Procedure C of this method is preferred. In this procedure, the use of an evaporator helps to eliminate any contact of the Karl Fischer reagent with lubricating oil additives thus preventing interference with the measurement.

In the past non-additive oils as used in the systems of two stroke crosshead diesel engines were water-washed in the course of the centrifuging treatment to remove traces of strong acids and to coagulate insolubles. Today, with alkaline lubricants, there is no useful purpose in water washing.

The risk of accidental water contamination from water leakages must, however, be considered in the lubricating oils of medium speed diesel engines.

Middle alkaline lubricants can form water-in-oil emulsions which can be difficult to break even in centrifuge treatment. Such emulsions, if circulated, will reduce the load carrying capacity of the oil in bearings. This may lead to failures. Emulsified oil, therefore, should be replaced as soon as possible.

As mentioned in paragraph 2.3., alkaline and most other additives are sensitive to depletion by water. With water they form insoluble sludge, which may be removed in the centrifuge. It is evident that the water tolerance of a used oil is worse when compared with the same oil when new.

Little damage will be found in most cases of accidental water contamination to fresh oils in storage. However, when an oil is contaminated during service by a continuous water leakage, additive depletion will be inevitable. Even when the water can be removed successfully by centrifuging, the charge should be analysed as soon as possible to confirm that it is in acceptable condition. Water washing is not only useless but also detrimental to the additive composition and its performance. Traces of water in the lubricating oil, however, are inevitable as mentioned above: They can result, for example, from salt water out of leaking oil coolers, fresh water from the cylinder cooling jackets, and from condensation.

Water affects the viscosity of the system oil and may form an emulsion with the lubricant. It is, therefore, desirable to keep the water content as low as possible by centrifuging. When it exceeds 0.2 % volume, the appropriate operation of the centrifuge should be carefully checked and, if necessary, adjusted to ensure optimum oil / water separation. Continuous separation of lubricating oil is always recommended even when the engines are stopped.

7.5.5 Salt Content

The salt content need not be evaluated provided the water content is less than 0.2 %. The test method is described in IP 77:

The used oil sample is extracted with water in the presence of a solvent and a demulsifying agent in a TEL extraction apparatus (IP 248 / ASTM D 2547). The halides in the extract are determined volumetrically after the removal of sulphides. The result is recorded as sodium chloride.

Salt is an indicator of contamination with sea water. Sea water is corrosive and potentially harmful. Whether corrosion will actually occur in a particular engine depends on a number of factors. For example; how much salt is in the oil, whether or not water and strong acids are also present, and whether the oil has (still) sufficient anti-corrosive properties.

Highly additivated oils normally provide reasonable protection against salt water corrosion. A small salt content, therefore, is tolerable. “Water washing” of the oil can reduce the concentration of salt in the oil because salt is more readily soluble in water than in oil and, therefore, will be removed with the water effluent from the centrifuge. However if the insolubles content is high, there is a higher risk of stable emulsion formation. "Water washing", therefore, is not recommended for such oils and the only solution is dry centrifuging when salt is detected in the oil.

Regardless of the type of oil in use, if the salt content reaches 0.005 % m/m (50 ppm), the origin of the contamination should be traced and corrective measures taken.

Salt contents are reported in percent of the oil sample and not of the water present in the sample.

7.5.6 Flash Point

The test method is described in ASTM D 93 (ISO 2719) [33]:

The used oil sample is heated at a slow, constant rate under continuous stirring. A small flame is directed into the cup at regular intervals with simultaneous interruption of the stirring. The flash point is the lowest temperature at which application of the test flame causes the vapour in the cup to ignite.

When the amount of sample is limited such that D93 cannot be run, alternative closed cup flash point methods, such as ASTM D6450 or D7094, may be used. Both methods require only a small amount of sample and results are similar to those from D93.

A drop in closed flash point indicates contamination of the lubricant by fuel, although with HFO no significant change may be apparent. For guidance, it is advisable to check for fuel leakages when the closed flash point drops by 30 °C or more.

When more than 0.5 % of water is present in a sample, it may not be possible to evaluate the flash point properly.

A reduced Flash Point normally indicates that there is a fuel leakage in the lubrication system and that the gas / air atmosphere within the crankcase is at risk of becoming inflammable. It should be noted that limits for safe / unsafe operation expressed in temperature values can be misleading to indicate risks because crankcase explosions have occurred at high flash points as well. Two preconditions must exist for initiating a crankcase explosion:

- an inflammable gas / air atmosphere
- a "Hot Spot".

A hot spot can include a hot run bearing, a fire outside or inside the engine, piston crown failure etc. Defective or switched off oil mist detectors can risk flammable mist from hot spots from being detected.

Because a significant number of incidents of crankcase explosions occur annually, the CIMAC Working Group "Lubricants" has started a project to investigate this phenomenon.

7.5.7 Metal Contents

There is no generally accepted standard method to determine the wear metal contents of used lubricating oils, despite the fact that this information is considered useful by most operators and shipowners.

Two techniques are widely used to determine the wear metal contents of lubricating oils. One is based on Plasma Emission Spectrometry (PES) and the other on Atomic Absorption (AA).

In the first method, a diluted sample of the used oil is injected into a plasma flame where its different atoms are excited. The specific emission intensity for each element is compared with standards similarly prepared.

For the second method a diluted sample is burnt in the flame of an AA spectrometer. The absorbance characteristic of each element is measured and compared with the standard.

The method ASTM D 5185-91 [34] is currently recommended for the determination of additive elements, wear elements and contaminant elements in used oils. An inductive coupled plasma atomic emission spectroscopy (ICP-PES) technique is employed for the analysis. In [35] the **CEC M-13-T-92** method (reproduced by permission of CEC) includes a summary of the method together with data on repeatability and reproducibility for a variety of elements at selected concentrations of 1, 10, 100 and 1000 ppm.

The Standard of Reference method for the quantitative determination of elemental concentrations in un-used oils remains the technique of AA, using ASTM D 4628.

Whatever the method used, particles greater than 5 µm are not quantitatively detected with the consequence that the wear element concentration may be underestimated in cases of particularly high wear. Here ferrography and similar methods can help.

It must be realised that, according to the type of apparatus, sample preparation, standards used, plasma used and selected wave lengths, the results obtained can be very different. When comparing and plotting results for trend analysis, therefore, it is important to ensure that the data are generated by the same laboratory, the same apparatus and the same method.

Spectrometric examination provides data on the content of metals originating from the wear of engine components and / or by contamination, but furthermore, on the concentration of metallic salts in the additives.

Additive Elements in % m/m:

Ca, Mg, P, Zn, Mo, B, N: Their concentration can serve for the identification of the lubricant in use, or as an indication that the lubricant analysed has been mixed or contaminated by another type, grade or brand.

Wear elements in ppm:

Fe, Cr, Al, Pb, Sn, Cu: These may indicate wear of bearings, piston rings, cylinder liners and other engine components.

Contaminations in ppm:

Na, V, Al, Si, Cl and Ni are possible indicators of fuel derived contamination. Mg, B, Cl and Na may derive from sea water, Na and B from cooling water and Si also from dust. But note Si can also be present as anti-foam additive.

Control limits cannot be generalised for metals, at least not until sufficient data and experience with a particular combination of the engine and lubricant have been accumulated. Results, therefore, will have to be assessed by comparison with the previous analytical history, i.e. trend analysis

7.5.8 Particle Count

For hydraulic oils particulate counting under a microscope has been a common practice for years, and for evaluation processes ISO (and other) methods have been published. These methods cannot be applied to engine oils in use, because the particulate contents in a used engine oil, even under optimum conditions, far exceed any range covered by the hydraulic oil methods. They can, however, be a useful tool to check the cleanliness of fresh oil and the effect of flushing as described in **Section 5.** Typical acceptance criteria for the oil cleanliness may be ISO 19/16 class.

8. QUALITY LIMITS OF THE LUBRICATING OIL IN USE

The limiting values included in **Table No. 7** hereafter shall be considered as general recommendations. In the first place condemning limits and required actions as specified by engine manufacturers shall be followed.

Table No. 7: Limits for Precautionary and Mandatory Action

PROPERTY	METHOD [1)]	UNIT	PRECAUTIONARY ACTION [2)]	MANDATORY ACTION [3)]	REMARKS
VISCOSITY	ISO 3104	$mm^2 s^{-1}$ @ 40 °C	- 20% / + 25%	- 25% / + 45%	
		$mm^2 s^{-1}$ @ 100 °C	- 15% / + 15%	- 20% / + 25%	
BASE NUMBER	ISO 3771	mg KOH/g	-	< 5	FOR ISO-F-DMX…B
			-	< 15	FOR ISO-F-DMC
			< 25	< 20	FOR ISO-F-RMA…K
WATER CONTENT	ISO 3733	% V/V	> 0.2	> 0.4	
FLASH POINT	ISO 2719	°C	< 190	< 170	
n-PENTANE INSOLUBLES	ASTM D 893/B	% m/m	> 1.5	> 2.0	

1) Alternative test methods can be used in case these will have a known and acceptable correlation with the recommended test methods included in the table.
2) Precautionary limits are for guidance only.
3) The “mandatory action” limits apply only in cases where there are no specific recommendations from the engine manufacturer.

Additional tests:
- on chlorides: ASTM D 878 (when water present above mandatory action limit)
- on fuel dilution: ASTM D 3524 (when viscosity and / or flashpoint below mandatory action limit)
- on toluene insolubles: ASTM D 893B (when n-pentane insolubles above mandatory action limit)

9. TROUBLE SHOOTING LIST

This section covers a number of negative phenomena, which can be experienced when operating four-stroke medium-speed diesel engines. Listed against each phenomenon/problem, are items/factors which can have an influence. Although occasionally claimed, serious operating difficulties resulting from lubrication are not very common in medium-speed diesel engines. It may be of value, however, to consider briefly the problems listed below in connection with the possible reasons for the failure in question.

1) Piston Ring Sticking

- Fuel quality
- Poor lubricating oil quality (detergency, oxidative and thermal stability); poor oil maintenance
- Excessive thermal overload
- Insufficient cooling of piston / cylinder liner
- Improper combustion process
- Excessive blow-by due to worn components (cylinder liner, piston ring grooves, piston rings)
- Poor engine maintenance; Use of inadequate spare parts
- Low oil consumption leading to long residence time of lubricant on piston ring / ring groove area

2) Piston Ring and Cylinder Wear

- Improper filtration of intake air containing corrosive / abrasive particles
- Access of condensed water from intercooler to combustion chamber
- Too low/high viscosity of the lubricant
- Insufficient oil feed
- Low water jacket temperature
- Fuel quality
    - Too high ash content
    - Combination of high sulphur content, presence of water / humidity and too low cylinder liner temperature
    - Poor ignition / combustion properties
- Improper treatment of fuel
    - Presence of high amount of abrasive particles including catalyst fines (Al+Si)
    - Presence of high amount of free water
- Quality of lubricant (detergency, oxidative and thermal stability, viscosity)
- Improper treatment of lubricant
- Too late combustion period
- Too high cylinder liner temperature
- Bore polishing
- Improper cylinder liner finish (honing) after overhaul
- Improper running-in
- Frequent cold starts without pre-lubrication
- Frequent overloading of the engine
- Fouling of the charge air cooler, turbocharger and exhaust gas boiler, leading to high thermal load

3) Combustion Chamber Deposits

- Wet or corrosive gaseous fuel in gas or dual fuel engines
- Improper fuel quality

- Improper combustion
- Improper air filtration
- Excessive valve stem clearance
- High oil feed rate
- Worn piston rings or such without tension
- Low cooling water temperature
- Continuous overload operation. Excessive vanadium and/or sodium content in fuels.

4) Crankcase Deposits

- Insufficient dispersancy of lubricant
- Improper oil filtration / purification of lubricant
- Insufficient capacity / efficiency of the purifier
- Filter element not replaced
- Improper combustion resulting in high insolubles content in lubricant
- High oil temperature
- Excessive blow-by
- Clogged crankcase breather or ventilation
- Inadequate piston cooling
- High insolubles content of lubricant

5) Bearing Wear or Failure

- Defective assembling and / or misalignment of bearing and / or associated parts
- Insufficient lubricating oil feed to bearings
- Improper pre-lubrication of bearings during cranking and start-up
- Unsuitable lubricant quality (presence of insolubles or water, wrong viscosity, other contamination, etc.)
- Improper lubricating oil temperature, pressure and / or viscosity
- Insufficient treatment (separation, filtration) of lubricating oil
- Lubricating oil quality
- Presence of too much abrasive particles / corrosive contaminants.
- Presence of too much water / air / foam / insolubles
- Presence of mechanical impurities as a consequence of engine overhaul
- Improper maintenance / function of lubricating oil filtering system.
- Use of bearings with unsuitable material
- Vibrations
- Unsuitable design (rigidity)
- Migrating electrical currents.
- Over-speeding of an engine, especially after overhaul and during start-up

6) Wear of Crankshaft

- Refer to paragraph no. 5: “Bearing Wear or Failure”
- Electro-corrosion due to short circuits

7) High Oil Consumption

- High cylinder oil feed rate and resulting splash.
- Oil leakages
- Defective ring grooves and rings (worn and / or stuck)
- Ineffective oil scraper ring
- Worn cylinder liners
- High oil pressure

- Low oil viscosity
- Unsuitable piston / piston ring design
- Faulty design of oil distribution holes in piston ring grooves
- Wrong fitting of the oil scraper ring (e.g. upside down)
- Poor combustion. In consequence excessive sludge formation and frequent discharge thereof.
- Improper cylinder liner surface finish (too much oil retention due to excessive honing)
- Liner lacquering
- High volatility of lubricant
- Excessive foaming of lubricant
- Too smooth liner surface due to bore polishing; worn anti-polishing ring

8) High Oil Temperature

- Clogged lubricating oil cooler
- Clogged lubricating oil piping
- Pump failure
- Insufficient cooling
- Bearing overheated
- Continuous overload operation
- Late combustion
- Insufficient amount of lubricating oil in the system
- Insufficient lubricating oil circulation rate
- Unsuitable design of lubricant system (high temperatures, low coolant supply, etc.)

9) Premature Loss of Alkalinity (BN) of Lubricants

- High sulphur content of fuel
- Oil consumption too low
- Cylinder liner temperature too low
- Access of drain water condensed at air intercooler
- Access of sea water due to improper design of intake air ventilation
- Extended low load operation
- Improper / bad combustion (see item 10)
- Wet centrifuging
- Neglected top up with fresh oil resulting in reduced oil quantity
- Top up with oil of lower alkalinity
- Excessive blow-by into crankcase
- Raw fuel contamination of lubricant

10) Premature Increase of Viscosity

- Increase of insolubles in used oil due to poor combustion
- Insufficient capacity of oil cooling system
- Fuel with high carbon residue
- Low oil consumption
- Oil with higher viscosity used in engines with separate cylinder lubrication
- High volatility of the lubricant
- Faulty operation of the oil cleaning system
- Blocked filter elements
- Insufficient capacity of the filter
- Too much sulphuric acid in the lubricating oil due to low cylinder liner temperature
- Raw heavy fuel contamination

11) Foaming of the Lubricant

- Faulty design of the lubricating system
- Air leak / inhalation into the lubricating system
- Insufficient anti-foaming performance of the lubricant (this should meet the anti-foaming requirements of MIL-PRF-2104G)
- Anti-foam additive removed by fine filter and adhesion to metallic surfaces
- Contamination by grease and / or rust preventives (complete replacement of the oil charge recommended)
- Insufficient air release properties of the lubricant

10. GLOSSARY

Absorption	Variation of peaks at specific wave lengths in FTIR (DIR), indicating deterioration, oxidation, nitration, reduction in additive concentration. See also "DIR" and "FTIR".
Abrasive Wear	Wear caused by abrasive particles
ACEA	Association des Constructeurs Europeens de l'Automobile (Association of European Automotive manufacturers)
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.
Acidity	In lubricants, acidity denotes the presence of acidic constituents whose concentration is usually defined in terms of an acid number. The number denotes mg KOH consumed when 100g of the oil sample is titrated under the condition of the test method.
Additives	A chemical compound or compounds added to a lubricating oil for the purpose of imparting new properties or enhancing existing properties.
Adhesive Wear	Wear caused by metal to metal contact due to oil film break down e.g. scuffing
Air/Fuel ratio	Ratio of air mass to fuel mass present in cylinder at start of combustion.
AN	Acid Number, has replaced TAN (Total Acid Number)
Aniline Point	The lowest temperature at which a hydrocarbon fluid is completely miscible with an equal quantity of aniline. The higher the reading, the lower the aromatic content, and hence the smaller the effect on rubber.
Antifoam Agent	An additive used to suppress the foaming tendency of petroleum products in service. May be a silicone oil to break up surface bubbles or a polymer to decrease the number of small entrained bubbles.
Antiwear Agent	Additives or their reaction products which form thin, tenacious films on highly loaded parts to prevent metal-to-metal contact.
API	American Petroleum Institute
API Gravity	An arbitrary scale adopted by the American petroleum Institute for expressing the relative density of an oil. $\text{Degrees API} = \left(\frac{141.5}{\text{rel. density @ 60°F}} \right) - 131.5$
Aromatics	Hydrocarbons of ring structure having the smallest hydrogen to carbon ratio.
Ash	Inorganic, non combustible solid residue remaining after ignition. Some additives, particularly conventional detergent additives, leave behind a powdery residue after combustion. Excess ash can cause engine malfunction if allowed to build up in the combustion chamber, cylinder liner ports and turbochargers.
Ash (Sulphated)	The ash content of an oil, determined by burning the oil and complexing the metals in the residue with sulphuric acid. Expressed as % by mass.
Asphaltenes	Components of asphalt which are insoluble in petroleum naphtha but are soluble in aromatic solvents. They are made up largely of high molecular weight polynuclear hydrocarbon derivatives containing carbon, hydrogen, sulphur, nitrogen, oxygen and usually nickel, iron and vanadium.
ASTM:	American Society for Testing Materials
Bactericide	A biocide specifically formulated to kill bacteria.
Barrel	A unit of volume measurement used for petroleum and petroleum products. a barrel = 42 US Gallons, ~ 35 Imperial Gallons or ~ 159 litres.
Base	A compound which reacts with an acid to produce a salt plus water.
Base Number	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.
Beta Value	Defined as the number of particles bigger than the specified size after filter. See ISO 4572.
BFOC	See "SFOC" - the preferred term.
Biogas	Gases derived from microbial or biochemical decomposition processes. Main components: methane, carbon dioxide, often H_2S.

Bitumen	A viscous liquid or solid consisting of hydrocarbons and their derivatives which is soluble in an aromatic solvent such as benzene. It is non volatile and softens when heated. Bitumen may be black or brown in colour and possesses waterproofing and adhesive properties. It is obtained from refinery processes but is also found as a natural deposit.
Black Oils	Asphaltic materials are added to lubricants used for open gears and steel cables to impart extra adhesiveness, giving them the characteristic black colour.
Blending	The intimate mixing of various components, including base oils and additives, in the preparation of a product of specified properties.
Blow-by	Passage of combustion gases past the piston rings of internal combustion engines, resulting in contamination of the crankcase oil.
Boundary Lubrication	Lubrication between two rubbing surfaces without the development of a full fluid lubricating film. It occurs under high loads and requires the use of antiwear or EP additives to prevent metal-to-metal contact.
BSOC	See "SLOC" - the preferred term.
Bulk Modulus	The reciprocal of the compressibility of an oil. The higher the Bulk Modulus of a fluid, the greater its incompressibility.
Cams	Eccentric lobes attached to a camshaft and driven by a crankshaft which are used in most internal combustion engines to open and close valves and sometimes operate fuel pumps.
CARB	California Air Resources Board.
Carbon Residue	Coked material remaining after an oil has been exposed to high temperatures (without oxygen) under controlled test conditions. Carbon residue is thus an indicator of the coke forming tendencies of an oil. It can be expressed as Conradson (CCR), Ramsbottom (RCR) or Micro-Carbon Residue (MCR).
Catalyst Fines	Small (typically less than 50 micron) particles of aluminium silicate used as a catalyst in catalytic cracking (cat cracker) refineries. They are sometimes carried over in the refinery process and can be found in residual fuels. They are very abrasive and can cause excessive wear in engine parts - particularly fuel pumps, injectors, cylinder liners and piston rings.
Centipoise (cP)	See Poise
Centistoke (cSt)	See Stoke
Cetane Index	A measure of the ignition quality of a distillate fuel, that is the relative ease with which the fuel will ignite when injected into a compression - ignition engine. Cetane Index is calculated from the API gravity and the mid boiling point of the fuel. High Cetane Indices indicate shorter ignition delays and are associated with better combustion performances.
Cetane Number	Similar to Cetane Index but is derived from a standard engine test rather than by calculation.
Chemisorption	Many gases react with surfaces by chemically bonding. In contrast to physisorption, chemical adsorption (chemisorption) involves the formation of strong chemical bonds between adsorbate molecules and specific surface locations known as chemically active sites. Chemisorption is thus used primarily to count the number of surface active sites which are likely to promote chemical and catalytic reactions.
CHP	Combined Heat & Power. Term for all engines generating heat and power (co-generation)
Cloud Point	The temperature at which a cloud or haze begins to appear when an oil, which has been previously dried, is cooled under prescribed conditions. Such a cloud or haze is usually due to the separation of wax from the oil.
COC	Flash point measured by Cleveland Open-cup
Cold Filter Plugging Point(CFPP)	A measure of the ability of diesel fuels to flow at low temperature. A fuel with a low CFPP is capable of being used satisfactorily at low ambient temperatures and not cause blockages in fuel systems through the precipitation of wax particles.
Copper Strip Corrosion	A qualitative measure of the tendency of a petroleum product to corrode pure copper.
Corrosion Inhibitor	A substance added to a lubricant to protect against metal corrosion.
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.
CSR	Continuous Service Rating – typically 80-90% MCR
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.
Demulsibility	The ability of lubricant to withstand the formation of an emulsion with water. This property is measured by a test which times the separation of a well-mixed sample of oil and water, and gives a 'demulsification Number' or 'Value'.
Density	Mass per unit volume.
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.
Detonation	Uncontrolled ignition/combustion with very high flame speed. Severe pressure waves with hard noise known as knocking. High risk of mechanical/thermal damage.
Dew Point	The temperature at which water vapour in the air starts to condense to liquid.
Differential Infrared Spectroscopy (DIR)	Method to compare fresh and used oils by showing different peaks at different wavelengths. Used to determine deterioration of engine oils with reference to oxidation, and nitration. See FTIR.
Differential Infrared Spectroscopy (DIR)	Method comparing fresh and used oil by showing different peaks at specific wave lengths. Method widely used to assess deterioration of gas engine oils with reference to oxidation and nitration.
Digester Gas	See "Sewage Gas".
Dilution of Engine Oil	Contamination of crankcase oil by unburnt fuel leading to reduced viscosity and flash point.
Dispersant	An additive designed to disperse oil insoluble sludge in suspension, thus preventing harmful deposition in oilways.
Distillate	A product obtained by condensing the vapours distilled from petroleum or its products.
Distillation Range	The range of temperatures, usually determined at atmospheric pressure by standard apparatus, over which boiling, or distillation, of a liquid proceeds. Only a pure substance has one definite boiling point at a particular pressure. Petroleum have a range of boiling points because of their varying complex range of hydrocarbon compounds.
Drop Point	The temperature at which a grease passes from a semi-solid to a liquid under specified test conditions.
Dry Gas	Natural gas containing no hydrocarbons heavier than butane and pentane. Can contain up to 99 % methane.
Dry Sump	Engine lubricating oil system with an external tank reservoir.
Dual Fuel	Term used for gas engines running on combustible gas ignited by controlled "pilot" injection of 1 – 10 % fuel with adequate ignition quality, i.e., gas oil or heavy fuel oil.
Dumb bell Blend	A blend of (usually two) components with an extreme of a particular blend parameter, such as viscosity, density, distillation curve.
Emulsibility	The ease in ability of fluids to form emulsion (see emulsion)
Emulsifier	A type of surfactant effective at producing stable emulsions.
Emulsion	An intimate mixture of fluids which are non soluble in each other. An emulsion is said to "break" when the fluids separate.
End Point (final Boiling Point)	The highest temperature indicated on the distillation thermometer when a light distillate is subjected to one of the standard laboratory methods of distillation.
Engine Deposits	Accumulations of sludge, varnish and carbonaceous residues on engine components.
Engine Test	Use of an internal combustion engine to evaluate lubricants. Parameters such as piston ring groove fill (by deposits), piston varnish, component wear, oil viscosity etc. are measured - to apply a performance rating.
Esters	Compounds of alcohols and fatty acids which form the major constituent of many synthetic lubricating oils.
Eutectic	A mixture of compounds (e.g. vanadium and sodium) resulting in a low melting point
Extreme Pressure (EP) Lubricants	EP oils and greases contain additives which, under the effects of high temperature and pressure, form a protective film on metallic surfaces, preventing metal-to-metal contact if the normal hydrodynamic film breaks down under high pressure.
FCC Fine	See catalyst fines
Ferrography	Ferrographic Analysis. A method for detecting wear metal particles “graded” by a magnetic field for further study using photo sensor or a microscope.

Fire Point	The lowest temperature at which an oil vaporises rapidly enough to burn for at least five seconds after ignition under standard conditions.
Flash Point	The lowest temperature to which a combustible liquid must be heated to give off sufficient vapour to form a momentarily flammable mixture with air when ignited under specified conditions.
Floc Point	A measure of the tendency of an oil to flocculate - or precipitate wax - under prescribed conditions. It is mainly applicable to refrigeration oils.
Four Ball EP Test	Method for determining extreme pressure (EP) properties of fluids. One steel ball under load rotates against three stationary balls in the form of a cradle. Heated test fluid is subjected to a series of timed tests at increasing loads until welding occurs. Wear is described by scar diameter plus load to weld in kg.
Friction	The resisting force encountered at the common boundary between two bodies when, under the action of an external force, one body moves, or tends to move, relative to the other.
FTIR	Fourier Transformation of InfraRed spectroscopy. Digital generation of spectral information. See DIR.
FTIR	Fourier Transformation InfraRed Spectroscopy
FZG Gear Test Rig	A method for determining the load carrying ability of lubricants. Calibrated spur gears are operated at fixed speed and controlled initial oil temperatures for 15 minute stages. The load on the gear teeth is increased after each stage. Performance is judged by the number of stages run up to a defined weight loss of the test gears or visual assessment of damage to the tooth flanks. Maximum number of stages is 12. Normal reporting format is to quote the failed stage.
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.
GPC	Gel Permeation Chromatography
Grease	A lubricant composed of an oil, or oils, thickened with a soap or other thickener, to a semi-solid or to a solid consistency.
H_2S	Hydrogen Sulphide, acidic, poisonous, flammable gas found in bio and natural gases. Disagreeable odour. Robust alkalinity of gas engine lubricant required when present.
Hot Corrosion	Corrosion phenomena of hot components (piston crown, exhaust valve etc) by the combination of vanadium and sodium compounds at critical ratios and high temperature.
Hydrocarbons	Chemical compounds which consist entirely of carbon and hydrogen. They form the basic composition of all fuels and lubricants derived from petroleum.
ICP (or PES)	Inductively Coupled Plasma Emission Spectrochemical Analysis. A method for detecting elements (mainly metals) in oil at ppm level by using plasma emissions
Immiscible	Liquids incapable of forming homogeneous mixture, e.g. oil plus water.
Inhibitor	A substance which is added in a small proportion to a lubricant to prevent or retard undesirable changes in the quality of the lubricant, or in the condition of the equipment in which the lubricant is used.
Insolubles	Contaminants found in used oils due to dust, dirt, wear particles, oxidation products, combustion products etc., often measured as pentane / heptane or toluene insolubles to reflect insoluble character.
IP	Institute of Petroleum
JIS	Japanese Industrial Standard
Kinematic Viscosity	Measure of a fluid's resistance to flow under gravity at a specific temperature (usually 40°C or 100°C)
Knocking	Hard metallic noise heard when engine fires in uncontrolled mode. See "Detonation".
Lambda Value	Ratio of combustion air actually charged to combustion air theoretically required. LV = 1 is defined as "stoichiometric condition". Lean burn engines run at LV > 1.
Landfill gas	Produced by anaerobic decomposition of household and industrial waste. Generally contains 40 – 60 % methane, 40 – 50 % CO_2, and 10 % N_2. May also contain H_2S, chlorinated hydrocarbons and silicon compounds.
Lands	The vertical surfaces of the piston crown and the areas between the piston rings.
Lean Burn Engine	Gas engines running on air excess, except in pre-chambers where gas is ignited. See also "Lambda Value" and "Stoichiometric Condition".
Liner Lacquers	Hard resin like coatings formed on the surface of liners filling the honing grooves. Such lacquers may lead to increased oil consumption.

LPG	Liquefied Petroleum Gas. Consists mainly of propane or butane or mixtures thereof. Liquid at ambient temperature when kept under pressure.
Lubricant	Any substance reducing friction between moving surfaces.
m/m	Mass/mass
MCR	Maximum continuous rating (of an engine). The rating at which the manufacturer sets for operation at 100% loading
Methane No. (MN)	Figure rating the anti-knock performance of a gaseous fuel. Pure methane was given the methane number 100, hydrogen has 0. Other gases may have higher or lower MNs. Gas mixtures may have wide ranges due to changes in composition.
MIL-	US Military specifications
Mineral Oil	Oil derived from mineral sources, notably petroleum.
Miscible	Opposite of Immiscible. See “Immiscible”.
Multigrade	'Multigrade' is a term used to describe an oil with low temperature and high temperature viscosities that fall within the limits of two different SAE numbers.
Naphthenic Base Stock	A type of base stock prepared from Naphthenic crudes (crudes containing a high percentage of ring type aliphatic hydrocarbons). They are characterised by high specific gravity plus low viscosity index.
Natural Gas	Gas from gas or oil fields. Mixture of gases, mainly methane, varying amounts of propane, butane, CO_2, N_2, occasionally H_2S. Transport normally by pipeline, occasionally liquefied by cooling to - 165 °C max (LNG = Liquefied Natural Gas).
NCR	See “CSR” - the preferred term.
Neutralisation Number	A measure of the acidity or alkalinity of an oil. The number is the mass in milligrams of the amount of acid (HCI) or base (KOH) required to neutralise one gram of oil.
NG 1, 2, 3	Gas engine oil classification system proposed by SAE/ASTM. Categories are: NG1 – stoichiometric engines, NG2 – lean burn engines, NG3 – automotive gas engines.
Nitration	Process in which nitrogen oxides formed during combustion attack the lubricant, resulting in additive depletion, viscosity increase and deposit formation.
NLGI Number	A numerical scale devised by the U.S. National Lubricating Grease Institute for classifying the consistency range of lubricating greases. The higher the number, the 'stiffer' or less viscous the grease and vice versa.
Non-Newtonian Behaviour	Behaviour of a fluid (e.g. lubricating oil) with viscosity characteristic Behaviour of lubricating oils demonstrating viscosity depending from shear rate at low temperatures.
OEM	Original equipment manufacturer, e.g. engine designer
OSF	Oil Stress Factor
Oxidation	Process in which oxygen reacts with hydrocarbon molecules, forming insoluble carbonaceous residues and resins. This results in viscosity increase and deposit formation
Oxidation Catalyst	Used in very lean burn engines, operating at 250 – 500 °C, able to reduce hydrocarbons and carbon monoxide. Sensitive to some additive components, in particular phosphorus. A limit of 300 ppm max. in the oil, therefore, is often placed.
Oxidation Inhibitor	An additive, which reduces oxidation e.g. that of the oil.
Oxidation Stability	A measure of resistance of a product to oxidation mechanism.
Paraffinic Base Stock	A type of base stock prepared from Paraffinic crudes (crudes containing a high percentage of open-chain aliphatic hydrocarbons). They are characterised by low specific gravity and high viscosity index.
Penetration	Measure of consistency (hardness) of a grease. All penetration measurements are in inverse scale of consistency - that is, the softer the consistency, the higher the penetration number.
Peptisation	Disperse in a medium into a colloidal state (a continuous liquid phase in which solids are suspended in the liquid)
Petrolatum	Also referred to as "mineral Jelly" or "petroleum jelly", petrolatum is a salve like mixture of oil and microcrystalline wax obtained from petroleum.
Petter WI	Single cylinder gasoline engine. Evaluates oil oxidation by viscosity increases and copper/lead bearing weight loss. Duration is 36 hours at 1500 rpm with sump oil temperature at 137°C.
pH	A measure of acidity or alkalinity in terms of the logarithm of the hydrogen ion concentration with the sign reversed.

	pH 0 = extreme of acidity pH 7 = neutral pH 14 = extreme of alkalinity
Physisorption	Absorption with no chemical bonding
Pilot Fuel	Small quantity of liquid fuel injected into combustion chamber of dual fuel engine to effect ignition of a gas with poor ignition quality. Pilot fuel is normally gas oil but occasionally heavy fuel oil.
PMCC	Flash point measured by Pensky-Martens Closed-cup
Poise (P)	The standard unit of dynamic viscosity, usually quoted as centipoise (cP).
Polishing (Bore)	Excessive smoothing out of the surface finish of the engine cylinder liner to a mirror-like appearance, resulting in poor retention of oil and poor ring sealing, potentially leading to high oil consumption and scuffing.
Polyalphaolefin	A synthetic lubricant produced by polymerisation of unsaturated hydrocarbons.
Pour Point	The lowest temperature at which a lubricant will pour or flow under specified conditions. Gives an indication of the lowest operating temperature for which an oil is suitable.
Pour Point Depressant	An additive used in a small proportion to lower the pour point of a lubricant by modifying the formation of wax crystals so that they do not agglomerate.
Precipitation	Dropping out of solids from solution
Pumpability	The characteristics of an oil that permit satisfactory flow to and from the engine oil pump and subsequent lubrication of moving components.
Refining	Series of processes for converting crude oil and its fractions to finished petroleum products, including thermal cracking, catalytic cracking, polymerisation, alkylation, reforming, hydrocracking, hydroforming, hydrogenation, hydrogen treating, solvent extraction, dewaxing, deoiling, acid treating, clay filtration and de-asphalting.
Residual Fuel Oil	Heavy fuel oils produced from the residue of the fractional distillation process rather than from the distilled fractions.
Ring Sticking	Resistance to free ring movement due to deposits.
Rings	The circular metallic elements that ride in the grooves of a piston and provide compression sealing during combustion. Also used to spread oil for lubrication of the cylinder liners.
Rust Preventive / Rust Inhibitor	Additive for coating metal surfaces with a film that protects against rust.
S.I.P.W.A	Sulzer Integrated Piston Ring Wear-detecting Arrangement. This equipment monitors the rate at which piston rings wear in crosshead engines.
SAE:	Society of Automotive Engineers
Sampling cock/tap	Cock/tap at a suitable, representative point of a lubricating or fuel system for taking representative samples.
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.
Selective Catalytic Reduction (SCR)	Exhaust gas treatment system with urea or ammonia injected into exhaust gas to reduce NO_x. Catalyst poisoned by sulphur.
Semi-synthetic	Blend of mineral and synthetic base oils
Sewage gas	Particular form of biogas generated by bacterial decomposition of sludges from sewage. Generally contains 50 – 70 % methane, 20 – 30 % CO_2 and often H_2S.
SFOC	Specific fuel oil consumption, based on g/kWh or g/bhph
Shear Stability	The property of resisting physical change under high rates of shear when applied to a Viscosity Index Improver. It is the ability of the VI improver molecules to withstand breakdown into smaller molecules.
Silica	Abrasive contaminant e.g. catalytic fines, dust particles (e.g. from landfill gas). Very abrasive, resulting in excessive wear.
SLOC	Specific lubricating oil consumption, based on g/kWh or g/bhph
Sludge	Oil insoluble products formed from lubricants and/or fuels used in internal combustion engines, and deposited on engine parts other than those in contact with the combustion space.
Solvent Extraction	Refining process used to separate reactive components (unsaturated hydrocarbons) from lubricant distillates in order to improve the oils oxidation stability, viscosity index and response to additives.
Sour gas	Natural gas that contains a significant amount of H_2S (up to 5 %).

Spark Ignited	Term used for gas engines in which the air/ fuel charge is ignited by spark plugs.
Stoichiometric Condition	The theoretically exact amount of air needed for complete combustion of the fuel.
Stoke (St)	The unit of kinematic viscosity, i.e., the measurement of a fluid's resistance to flow defined by the ratio of the fluid's dynamic viscosity to its density; usually quoted as centistokes (cSt).
Straight Run	Fuels produced by distillation without cracking or alteration to the structure of the constituent hydrocarbons.
Sulphur Conversion Ratio	See [Rec 13, p.37]. The ratio of: $\frac{\text{sulphur which condensed as sulphuric acid}}{\text{the total sulphur ingested with the fuel}}$
Surfactant	A compound able to reduce surface tension and commonly used to achieve emulsification, wetting or detergency.
Sweet gas	Natural gas containing less than 10 ppm H_2S.
Thermal Cracking (Visbreaking)	An oil refinery process in which the reaction is produced by the action of heat and pressure.
Thermophoresis	Describes the interaction of heat and particles of various sizes.
Three Way Catalyst	Generally used in stoichiometric engines to convert harmful combustion components to H_2O, CO_2 and N_2.
Timken OK load	Measure of the EP properties of a lubricant. Lubricated by the product under investigation, a standard steel roller rotates against a block. Timken OK load is the heaviest load that can be carried without scoring.
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.
Turbine	A piece of equipment in which a shaft is steadily rotated by the impact of a current of steam, air, water, or other fluid directed from jets or nozzles upon blades of a wheel or series of wheels.
Turbocharger	Compressor driven by exhaust gas driven turbine supplying air at higher pressure to the engine to increase power.
Valve Guttering and Torching	Damage to exhaust valves due to high temperature corrosion and erosion.
Valve Recession	Excessive wear of valve seat and face caused by combined effects of metal abrasion, high temperature corrosion, functional sliding and adhesion.
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.
Viscosity Index (VI)	A value indicating a fluid's change of viscosity with temperature.
Viscosity Index Improver	An additive employed to raise the VI of a mineral oil and other products.
Volatility	Amount distils off or vaporises with temperature - highly volatile means large amount
Wet Gas	Natural Gas containing heavier hydrocarbons like ethane, propane, butane plus small quantities of hydrocarbons liquid at ambient temperatures.
Wet Sump	Engine lubricating oil system in which the crankcase serves as the oil tank; a system without an external tank reservoir; common in smaller 4-stroke engines.
Wobbe Index	Ratio of a gas's calorific value to the square root of its specific gravity. Indicates thermal input provided by gas at given temperature.
Zeppelin	Big gas container carrying militant non-smokers.
Zinc (ZDDP/ZDTP)	Commonly used name for zinc phosphorous compound used as anti-wear and anti-oxidation inhibitor.

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12. APPENDIX: Acknowledgement, Membership & Disclaimer

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