CONSEIL INTERNATIONAL
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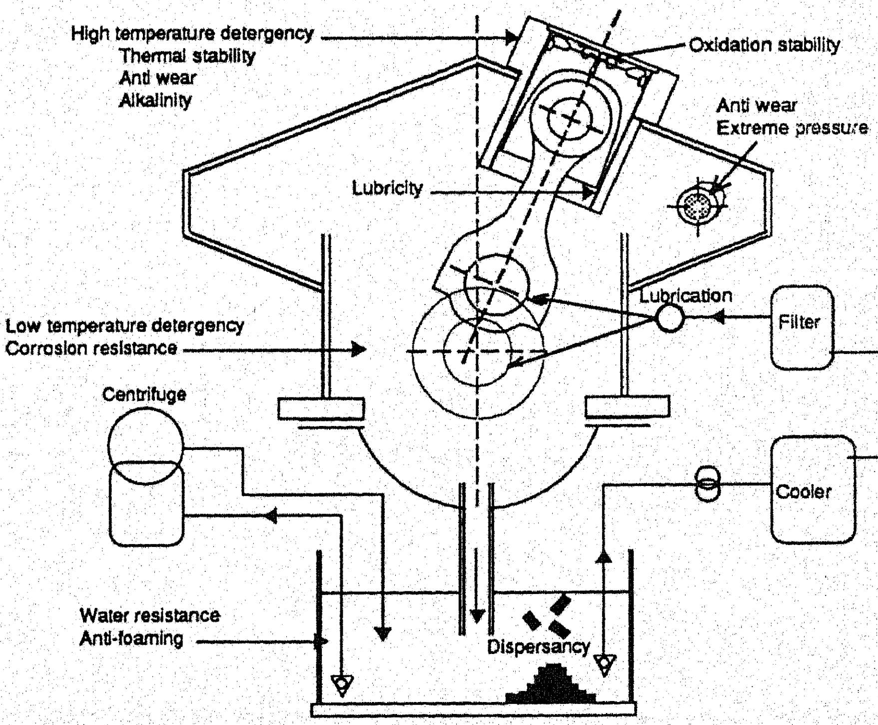
INTERNATIONAL COUNCIL
ON COMBUSTION ENGINES

GUIDELINES FOR THE LUBRICATION OF MEDIUM SPEED DIESEL ENGINES

RECOMMANDATIONS POUR LA LUBRIFICATION DES MOTEURS DIESEL SEMI-RAPIDES



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CONSEIL INTERNATIONAL
DES MACHINES A COMBUSTION

INTERNATIONAL COUNCIL
ON COMBUSTION ENGINES

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

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

The National Member Associations and previous CIMAC Recommendations are listed in the back of this publication.

This document has been elaborated by the Working Group "Lubricants" and approved by CIMAC on May 10th, 1994.

Le présent document a été élaboré par le Groupe de Travail "Lubrifiants" et approuvé par CIMAC le 10 mai 1994.

GUIDELINES FOR THE LUBRICATION OF MEDIUM SPEED DIESEL ENGINES

REPORT OF THE CIMAC WORKING GROUP "LUBRICANTS"

Preface:

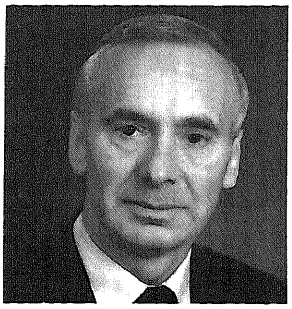
This document brings together current practices in the lubrication of Medium Speed Diesel Engines. Its objective is to offer comprehensive guidelines for the efficient and reliable operation of machinery.

The document does not replace the recommendations of engine builders, equipment manufacturers and oil suppliers, which evolve with designs and applications.

10 May 1994

CIMAC assumes no legal responsibility for any consequence of the application of these Recommendations.

FOREWORD OF THE PRESIDENT



CIMAC Working Groups have a long tradition of preparing recommendations and guidelines for the internal combustion engine industry.

CIMAC takes advantage of its wide international and competent membership.

Reliability and availability are today of paramount importance. Inherent engine design reliability must be complemented by a suitable periphery and by a reasonable choice of such media as fuel, lube oil etc.

After CIMAC issued worldwide acknowledged heavy fuel recommendations, it was logical to devote attention to lubricants and lubrication systems.

The Working Group "Marine Lubricants", chaired by Mr Ole Grone, started work in 1987 and dealt - as a first step - with the medium speed engines. Between 1987 and 1993, experts for the Diesel engine industry, oil companies, equipment suppliers, etc agreed upon what is being issued now as a recommendation for the industry.

Its contents are of practical use for diesel engine users, manufacturers, shipyards, engineering companies, oil suppliers, etc.

In a second step, started in 1994, the lubrication of two-stroke slow speed Diesels will be considered.

I am convinced, that the recommendation issued in the enclosure will be appreciated and used by the industry over the world.

Dr G Lustgarten

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GUIDELINES FOR THE LUBRICATION OF MEDIUM SPEED DIESEL ENGINES

GUIDELINES FOR THE LUBRICATION OF MEDIUM SPEED DIESEL ENGINES

INTRODUCTION

Fuels and lubricants are often associated with problems in medium speed diesel engines. That is why CIMAC identified both topics for need of better understanding.

In view of the efficient work of the Working Group on "Fuels", another working group on lubricants, was formed in '87 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 diesels respectively. The composition of the CIMAC Working Group "Lubricants" is given in Appendix 1.

This report compiles insights generated by the Groups' members who represent users, engine and equipment manufacturers, institutions as well as additive and lubricant suppliers, into the lubrication of medium speed diesels.

The sections of this report deal with:

- the engine and its lubrication system
- the lubricant
- the maintenance system
- the cleaning system
- used oil analysis and its significance
- quality limits of the oil in use and
- a trouble shooting list.

By compiling the Working Groups' conclusions on these topics the work is not over. The ultimate target, as given in the Terms of Reference, remains unchanged:

> "To recommend for a variety of existing and forthcoming fuels suitable lubricant types to be used in todays and future engines."

Work on this is in progress and these guidelines form a platform for better understanding of this target.

1. THE ENGINE AND ITS LUBRICATION SYSTEM

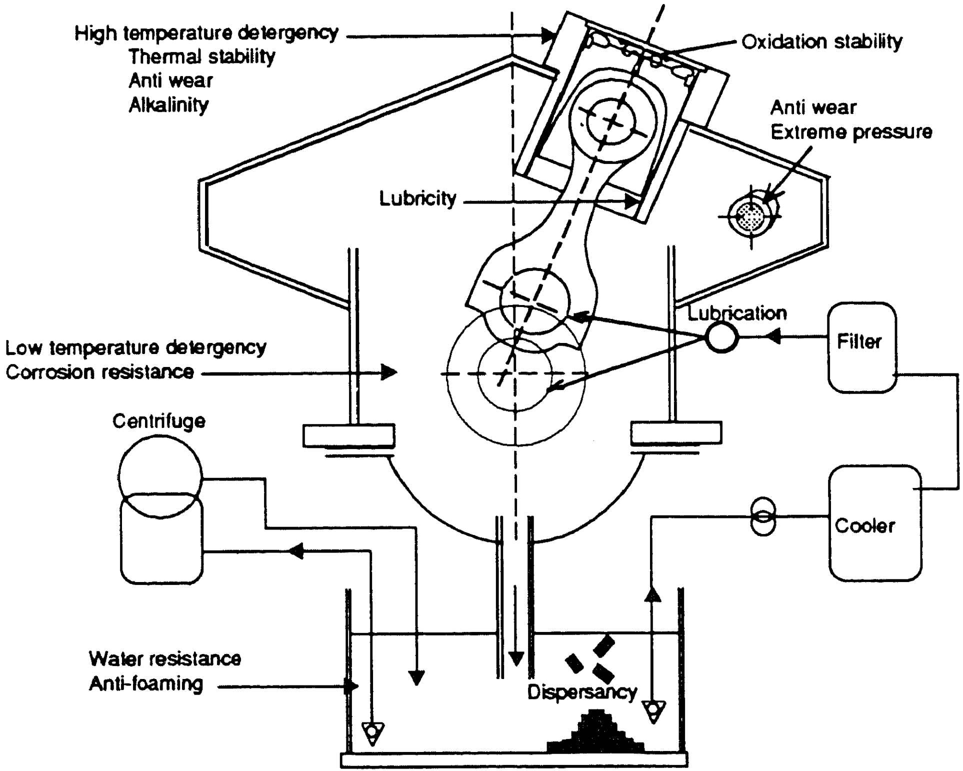
1.1 The Engine

The most common medium speed engine in the 90's is of the trunk piston type, 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.

This results in substantial stresses not only on mechanical components, but also on the lubricating oil. To cope with these, the lube oil must be particularly tailored to the task as illustrated in Figure No. 1.

Figure No. 1:
Properties of the Lubricant required on its Way through the Engine



(S.E.M.T., J.F. Chapuy, 1987)

1.2 The Lubrication System

1.2.1 Bearing Lubrication

The oil enters the engine in a "clean" condition (for details, see section 4), it passes the main lube oil header to reach the main bearings.

At this point, the first task of the oil becomes relevant: LUBRICATION. Between the crank shaft journals and the bearing, there must be an oil film of a defined thickness. To achieve this, the viscosity grade is to be selected by the engine designer taking into account the engine characteristics and temperature requirements.

Next, the oil is circulated through a passage in the crankshaft to reach the big end bearing of the connecting rod. Here again, the oil has to provide an oil film strong enough to resist the impact resulting from the combustion pressure on the pistôn head.

After that, the oil passes the connecting rod's hole towards the small end bearing of the gudgeon pin where again a reliable oil film is required for lubrication. A further important task of the lube oil is to cool the bearings, i.e., to remove the friction heat.

1.2.2 Piston Cooling

After passing the gudgeon pin, the lube oil enters the piston interior where it is used as a coolant medium. The oil (generally by shaker effect or by jet cooling) is used to cool the piston head. For that purpose, the oil must show good resistance against deterioration at high temperatures whilst air (oxygen!) is present. This property is generally known as OXIDATION STABILITY.
After that, the oil 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 drillings or via the shaker chamber.
- Forced lubrication from outside the cylinder (either with fresh oil or with the oil in use), using an additional lubricant dosing pump and quills positioned in the cylinder liner wall.

All three methods need similar oil characteristics to be effective between piston, ring pack and liner. These are described in the following:

- Viscosity and Viscosity Index

  To avoid metal to metal contact it is mandatory to have a stable and sufficiently thick oil film between ring and liner. As the oil in that region is of higher temperature and thereby lower viscosity than when entering the engine, the VISCOSITY INDEX (VI), expressing the temperature dependence of the viscosity, is of importance for the protection of these components.

- 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.

- Oxidation Stability
  Again required as the lubricant, additional to the exposure to high temperature, is in intensive contact with air.

- Detergency

  The oil has to clean and to keep clean the liner, the piston, the ring pack and the ring grooves from combustion products of fuel and lubricant. This property of the lubricant is called High Temperature DETERGENCY.

  After lubricating piston and liner, the oil returns to the sump through the crankcase where it is acting as a cleaning agent to remove deposits from crankcase walls and from engine components in motion such as connecting rod, crankshaft, counterweights, etc. This cleaning effect is called the Low Temperature DETERGENCY.

- Lubricity

  With the aim to ensure hydrodynamic lubrication, the lubricant must be capable of "covering" surfaces to be protected. Therefore good spreadability characteristics are required, as well as a reliable cohesion to the metallic surfaces.

- Anti-Wear and Extreme Pressure

  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 where possible abrasive and adhesive wear.

- Alkalinity

  This property permits the oil to react against corrosive wear by neutralising acidic combustion products from the fuel sulphur. The ALKALINITY is defined by the BASE NUMBER (BN) (previously referred to as TBN).

1.2.4 Other Lubrication

We must consider that the oil, besides passing the internal regions of the engine, is additionally supplied to:

a) - the camshaft and gear train. In this area, the oil is stressed by extreme pressures, either in gears or between rollers and cams. Here, the already mentioned characteristics ANTI-WEAR and EXTREME PRESSURE protection are needed.

b) - the injection system, oil barrier. The main property required here is the FUEL/LUBE OIL COMPATIBILITY.

c) - the valve train/rocker arm-assembly and valve guides.
The requirements of the oil in this area are:

- detergency and dispersancy at relatively low temperature,
- lubricity,
- oxidation stability against blow-by gases passing the exhaust valve guides,
- neutralisation ability (alkalinity).

Above and additional characteristics required from the oil are described as follows:

Compatibility with Heavy Fuel

Plunger sticking by deposit formation in fuel pumps is sometimes initiated by asphaltenes drop-out from the fuel, due to incompatibility with the lube oil. With the aim to prevent this, ideally the lubricant and the fuel should be compatible at prevailing temperatures. This is difficult if not impossible to achieve. Contamination, therefore, should be reduced to a minimum by design and maintenance efforts.

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, liner and elsewhere in the entire engine. All these impurities must be transported by the oil to the purifier where most are removed. The dispersancy also is very important when the oil returns to the oil tank. It will prevent settling of impurities which would lead to thick sludge in the bottom of the tank.

Corrosion Protection

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

Oxidation Stability

Oxidation stability again is required to prevent the oxidation of the oil due to high temperatures and oxygen surplus in blow-by gases and trapped air.

Evaporation Characteristics

Evaporation can contribute to lube oil consumption because the oil, as said already, is often facing very high temperatures during its way through the engine, in particular in the liner region.

Water Resistance

The oil must be water tolerant and still lubricate 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 purifier. They should not emulsify with the water seal. Furthermore, the filterability must be ensured, whatsoever the water content is. It must be noted, however, that certain filter designs do not work at all when the oil contains water.

Anti Foaming

The oil is circulating quite fast through the engine (more than 10 times per hour). During this circulation, air and oil are mixed intensively. Therefore, the oil must be able to control foaming because such is very dangerous for the bearings. Anti foaming characteristics need to be carefully balanced with the air release properties.

1.3 Adaption of the Lube Oil to the Engine and the Fuel

Most large medium speed engines have a "dry sump" system. Here the oil is not kept in the engine's crankcase, but pumped into a separate oil tank. This is in contrast to the "wet sump" where the oil remains in the crankcase sump.

It is common practice to allow for an oil quantity of 1.2 kg/KW for the "dry sump" system and 0.35 kg/KW for the "wet sump" system.

Normally, various versions of an engine model with many modifications and adaptions to customer's requests, different fuels and service conditions are produced. According to the engine design and fuels intended to be used, the following lube oil performance levels need to be specified and accordingly provided:

- viscosity,
- detergency and dispersancy,
- BN (Base Number),
- anti-wear / extreme pressure,
- compatibility with fuel.

These requirements are to be specified by the engine designer.

When adapting the lube oil to the engine it must be considered that the oil during service is suffering from the engine's and the fuel's impacts. It is crucial, therefore, to ensure that only a controlled quality of used oil re-enters the engine. This oil is to be fed into the engine at a specified flow rate, a given temperature and pressure. These data may vary as specified by the engine designer.

The oil re-entering the engine must be as free as technically feasible from detrimental impurities, such as metallic particles, rust, soot, water, and all by-products from the combustion as well as raw fuel contamination. For this reason, the oil must be cleaned by dedicated methods and with a complexity relevant to the fuel quality burnt and to the service pattern of the engine.

Generally, the cleaning treatment is performed by centrifugal purification. Filters for protection have to be located before the engine.

Engine designers are responsible for defining the level of cleanliness needed for their engine.

Details on the cleaning and maintenance processes required for today's engines are found in sections 3 and 4.

2. THE LUBRICANT

2.1 A User Language

Engines are evaluated on performance. Lubricants are an integral part of the engine and its systems and provide an essential contribution to the total systems' performance and reliability.

Undisputable performance criteria therefore must be agreed between all parties concerned to specify properly the lubricants' key jobs:

- To "protect" the engines' components and mechanisms which - without an appropriate lubricant - would fail.

- To ensure that the lubricated engine components remain in an acceptable condition for an acceptable period.

To comply with above no doubt the lubricant itself must be of acceptable performance and kept in acceptable condition for an acceptable period. Considering the latter, oil change intervals and engine overhaul intervals should be matched.

The lubricant must be designed, produced, applied and maintained to remain in a condition that allows for satisfactory operation including a safety margin, as agreed between user and supplier on terms of a "user language".
"Acceptable", therefore, 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 to avoid misunderstandings and resulting irritations this "user language" must be simple, clear, unequivocal, generally accepted and used.

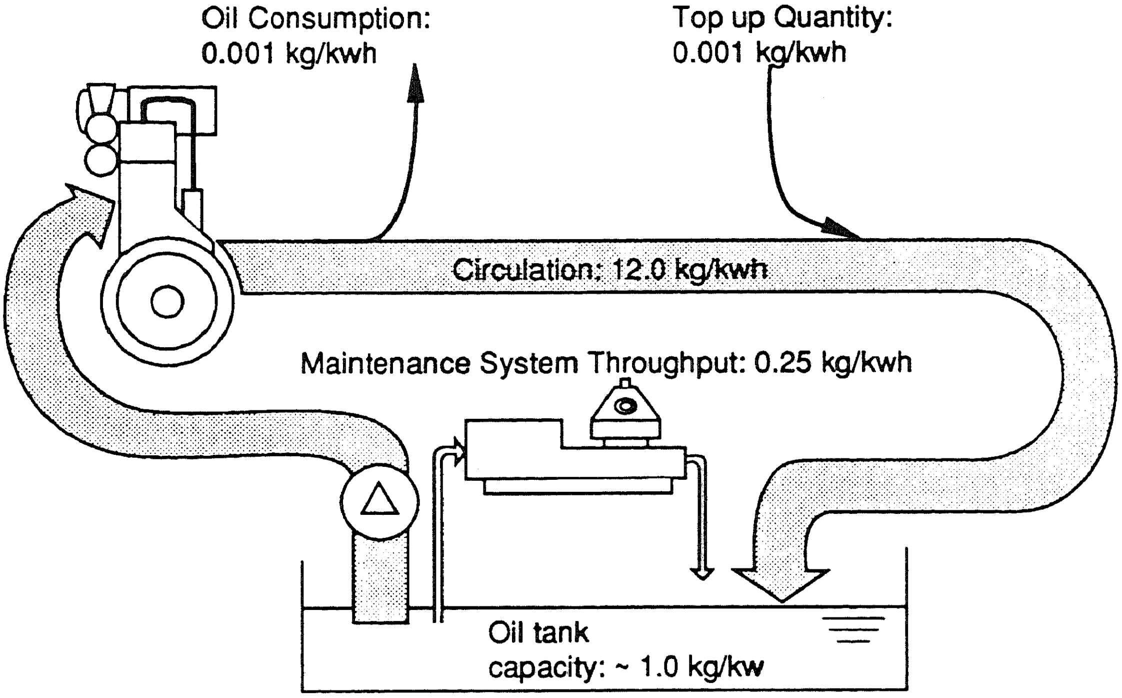
It is emphasised that this "user language" has the purpose of specifying performance and not composition.

2.2 Oil in Use

The engine hardly ever - apart from the first start up - enjoys unused - i.e., - "virgin" oil. The lubricant circulating in the system is used oil or, preferably referred to as "oil in use". Furthermore, it should be noted that for full effect the additive system of a "virgin" oil needs activation by thermal and other conditions in the engine.

With an oil consumption of approx. 1.0-1.3g/kWh and a systems' content of approx. 1.0-1.3 kg/kW the theoretical replacement time of the entire oil volume in the system is approx. 1.000 h (Figure No. 2).

Figure No. 2:
Oil Circulation and Replacement Speed



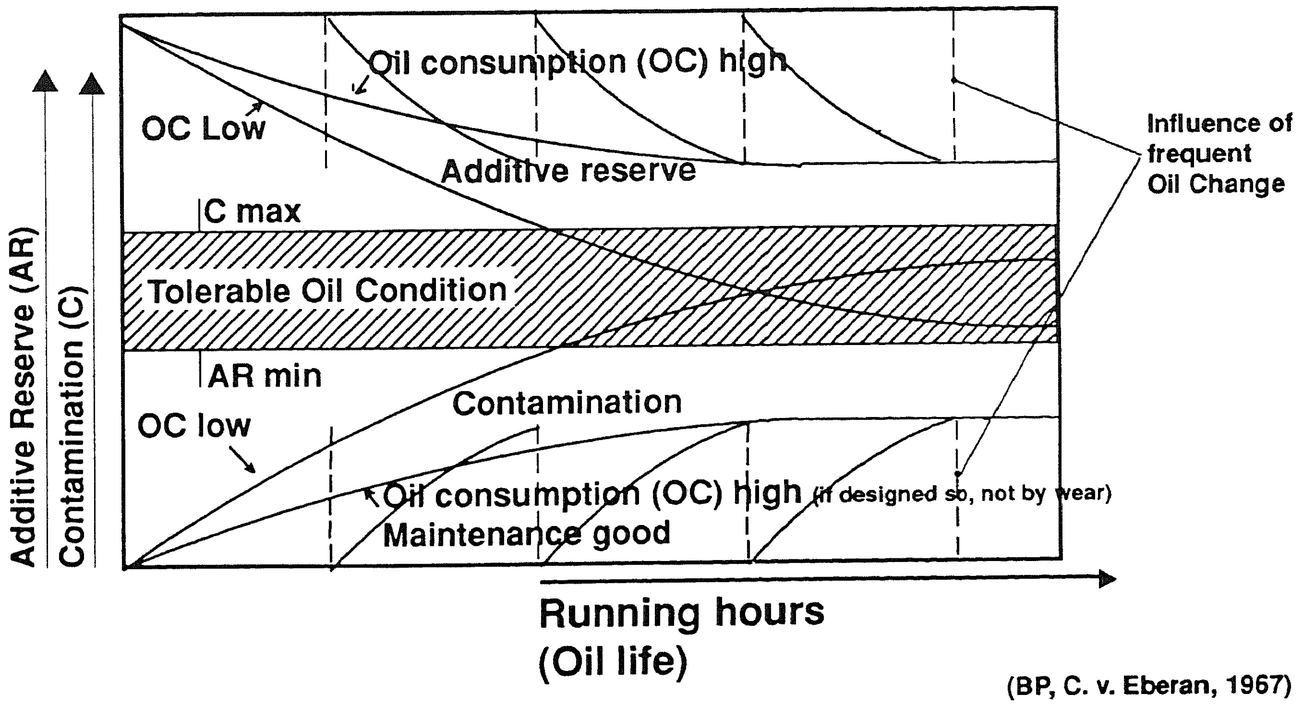
(BP, G.C. Fleischhack, '92)

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

So, with a given engine severity, - i.e., the total of all impacts the engine is charging the "oil in use" with, - it is a question of balance between the performance "reserve" of the virgin oil and the efficiency of the maintenance system whether the "oil in use" is maintaining a satisfactory performance level with an agreeable safety margin over the specified oil change period. Under practical conditions this often means that the oil is never changed but only refreshed by topping up. However, a more frequent oil change might be desired occasionally for a variety of reasons. [2]

In case above balance fails this may have unpleasant consequences: an increasing oil consumption, more frequent and mostly unplanned oil changes, poor performance of engine components or failure of the total system. See Figure No. 3.

Figure No. 3:
Med. Speed Diesel Engine Lubrication: Influence of Oil Consumption/Change



(BP, C. v. Eberan, 1967)

Aforementioned balance indicates how important, - apart from the lubricants performance, - the appropriate design, capacity and operation of the lubricants maintenance system is. This is detailed in sections 3 and 4. [3]

Knowledge on key data of 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 on what he has ordered, and that the product is meeting the engine manufacturers specification. They allow 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 above technical data sheet such a report should give clear evidence whether the lubricant, its additive reserves, and the engine's impacts together with the treatment by the maintenance system are well in balance as indicated in Figure 3 already. Selected metallic elements might also give additional information on the engine's wear behaviour.

2.3 Selection of the Oil Type

This is very much the job of the engine manufacturer, who in close cooperation with the oil formulator and - knowing his engines' requirements and the fuels to be used - must specify the preferred type and grade. A general picture of the available options is shown in Table No. 1. Individual deviations from this basic scheme appear less advisable due to the logistical problems to be envisaged when asking for a tailormade formulation in exotic ports.

TABLE 1

Scheme of Lubricants Theoretically Required

FUEL SULPHUR	FRESH OIL ALKALINITY	VISCOSITY	DISPERSANCY **)
HIGH > 2.5 %	BN 30 - 40 [mg KOH/g]	HIGH SAE 40	HIGHER
			LOWER
		LOW SAE 30	HIGHER
			LOWER
MEDIUM 1.5 - 2.5 %	BN 20 - 30 [mg KOH/g]	HIGH SAE 40	HIGHER
			LOWER
		LOW SAE 30	HIGHER
			LOWER
LOW < 1.5 %	BN below 20 [mg KOH/g] *)	HIGH SAE 40	HIGHER
			LOWER
		LOW SAE 30	HIGHER
			LOWER

*) Operation with gas or low sulphur gasoil 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 2.

Most sensitive is the decision between higher or lower dispersancy:

- High dispersancy means a clean system but a lubricant loaded with insolubles. The efficiency of the oil cleaning system must be low due to the effect of the dispersants. A change of the complete system content is inevitable when the insolubles content of the oil in use exceeds the tolerable limit.

  This concept appears advisable in first line for high output, low weight, low room installations that have to operate with short maintenance periods (e.g. naval vessels).

- Low dispersancy results in systems often appearing less clean together with a relatively clean lubricant. The efficiency of the oil cleaning system is high. It depends, however, very much on the adequate dimensioning and a professional operation of the cleaning system to keep engine and lubricant in satisfactory clean condition for a sufficient long period.

  This is the preferred approach for installations who have to operate for several years before an oil change is even considered.

Most middle alkaline lubricants today are of moderate dispersancy, with the aim to provide an acceptable compromise between above 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 fall out in the presence of water.

2.4 Oil Solutions for Engine Requirements

Tables No. 2 and 3 summarise engine requirements using the terminology developed in section 1.

These tables appear to suggest that a limited number of oil and additive properties are sufficient to overcome most problems. However, things are not that simple. The impacts of the engine on the lubricant are more complex. They form an interactive matrix and so is the response of the lubricants' components. Trigger conditions and reaction speeds of individual additives can vary significantly. Most additive ingredients have interactions with others and the base oil. And there are also interactions between surface active additives. High detergent contents, for example, make it more difficult to position anti wear additives on endangered metallic surfaces.

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. And, as mentioned already, dispersants, whilst rather helpful in keeping surfaces and critical passages clean, make it difficult to remove insolubles in conventional centrifuges and filters.

TABLE 2

Engine Components, Stress/Risk Factors and Protective Properties Required

ENGINE COMPONENTS	DETAIL	CHARACTER OF ATTACK	LUBRICANT PROPERTY/ ADDITIVE REQUIRED
1. Piston Ring	face sides	wear, corrosive & abrasive	alkalinity, corrosion inhibitor, Anti Wear / EP., base oil viscosity
	back	deposits	detergency
2. Piston	exterior:		
	- lands	deposits	detergency
	- grooves	deposits & wear	detergency, alkalinity, Anti Wear / EP., base oil viscosity
	- skirt	deposits	detergency
	- crown	deposits	low sulphated ash level
	interior:	deposits	dispersancy / detergency
3. Liner	surface	wear, corrosive & abrasive	corrosion inhibitor alkalinity Anti Wear / EP., base oil viscosity
		deposits	oxidation inhibitors
4. Bearing	surface	wear, corrosive & abrasive	corrosion inhibitor base oil viscosity
		deposits	oxidation inhibitors
5. Crankcase	surface	deposits	dispersants/ detergents
6. Maintenance System	centrifuge, filter	fluid & solid contaminants	low dispersancy
	oil coolers		high dispersancy
7. Injection	plunger	deposits	compatibility fuel / lube oil

TABLE 3

Additives: Properties and Chemical Character

TYPE	DUTY	CHEMICAL COMPONENTS	REMARKS
Detergents	Cleanliness (corrosive wear), acid neutralisation rust protection	Ca Sulphonate Ca Phenate Ca Salicylate (Ca, O, H, S)	Neutralise acidic combustion products, keep hot surfaces clean
Dispersants	Cleanliness (stabilisers)	Poly-isobutylene Succinimides Ester Succinimides (N, O, H, C)	Suspend sludge, water and combustion byproducts
Anti Oxidants	Anti Oxidation	Aromatic Amines Hindered Phenols DioThioCarbamates ZDTP (Zn, CS, P, N, O, H)	Sludge prevention, stabilise viscosity
Anti Wear	Prevent abrasive + adhesive wear, improve load carrying	ZDTP (Zn, S, P, C, H)	EP-high load high temperature
Anti Foam	Reduces surface tension to prevent foaming	Silicone Polyacrylate	Antagonistic effects on air release properties
Rust Inhibitors	Prevention of attack by water on Fe	Neutral Ca Sulphonate N dispersants	
Demulsifiers	Water shedding	Ethoxylated Alcohols	
Corrosion Fix	Protection of yellow metals, eg. Cu	N dispersants S components	

And, again, it has to be considered how much of above is provided in the virgin oil so that a regular top up compensates for the consumption and decomposition of the ingredients during service and what has to be ensured by the maintenance system respectively.

Table No. 4 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 CEC IL 21 *). Limits to be met should be the affair of the individual engine manufacturer as they no doubt differ from engine type to engine type and from application to application.

2.5 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:

2.5.1 A qualified inspection of the engines components' reaction on lubricants performance. For this a checklist has been developed with topics to look at and how to report (see Appendix No. 2). The checklist was made up following a two tier scheme:

- Scheme 1 lists the essential information required and to be reported for a meaningful discussion on engine components' and lubricants performance. This information has to be collected under all circumstances.
- Scheme 2 lists additional information to be collected under test bed conditions and is enabling the expert to obtain additional insights.

2.5.2 A regular sampling of the crankcase charge and consequent investigation by used oil analysis. Recommendations for such work have been developed by CEC IL 21. See Appendix No. 3 (Recommended Standard Methods for Used Engine Oil Analysis).

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*) CEC = Coordinating European Council:
A scientific inter-industry institution developing and publishing performance test methods for fuels and lubricants.

IL 21 = Investigation Group Lubricants: Large Diesel Engines

TABLE 4

Lubricant Performance Criteria and Their Evaluation:

LUBRICANT PROPERTY	TYPE OF EVALUATION	REMARKS
A) Base Oil Influence		
- Base Oil Viscosity at high & low temperatures	Lab. test	Specified min. viscosity at high temperature (180°C) and max. visc. at low temp. seems more appr. than VI
- Evaporation characteristics	Lab. test	modified Noack Test or distillation curve
- Thermal and oxidation stability	Lab. test	-
B) Additive Influence		
- Alkalinity	Lab. test	ISO 3771
- Detergency	Engine test	Cat HF or equivalent
- Dispersancy	Lab. / Engine test	Coker tests (??) or rig/engine test
- Anti Wear / EP	Engine / Field test	Instrumented vessel? reference lube?
- Corrosion inhibition	Lab. test	-
- Thermal and oxidation stability	Lab. / Engine test	-
- Water rejection	Lab. test	Rig with reference lube?
- Anti foam	Lab. test	-
- Cleanliness	Lab. test	-
- Separability	Lab. test	Rig with reference lube?
- Filterability	Lab. test	-
- Compatibility with fuel	Lab. test	Coker test?

2.5.3 All this requires a disciplined approach towards how and in which position to take samples. Again CEC IL 21 have taken the job to formulate a method. See Appendix No. 4 (Representative Sampling in Service of Marine Crankcase Lubricants).

Furthermore sampling intervals need to be agreed. Sampling for routine jobs, like performance feedback on one side and development and approval test programmes on the other, must be considered separately.

The first job should be at the discretion of those concerned, i.e., keeping oil supplier and user in compliance with the engine manufacturer's recommendations. For the second category the following intervals are recommended:

TABLE 5 Sampling Intervals

Sample No.	to be taken after total running time (hours)
1.	50
2	100
3	250
4	500
5	1000
6	1500

Samples should be evaluated on agreed acceptance criteria.

3. THE LUBRICATION SYSTEM

The efficiency of the lube oil system is crucial for the engine's performance and lifetime and much attention, therefore, has to be paid to its design and construction.

3.1 System Design

In order to assure that his engine's requirements are met, the engine manufacturer must provide the following information:

- 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 size of 30-35 micron absolute appears to be a typical recommendation. It is, furthermore, recommended to dimension the main filter according to the nominal oil pump capacity (flow rate) or according to the design pressure drop (0.5 bar is typical). Provided cold conditions are considered whilst dimensioning, a margin is available at working temperatures.
  If, additionally, the filter is bypassed upstream at a pressure regulating valve, the margin of the filter would be equivalent to the by-pass capacity when cold, but even higher at working temperatures.

- The required flow rate.
  Lube oil pressure inlet engine.
  Inlet/outlet temperature max./normal/min.

- The max. pressure drop in lube oil coolers.
  Lube oil outlet temperature. (Alternatively lube oil outlet viscosity. Typical 65-85 mm^2/s)

- Heat dissipation requirements.

- A list of all alarms and shut downs should also be available.

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

3.2 Piping Design

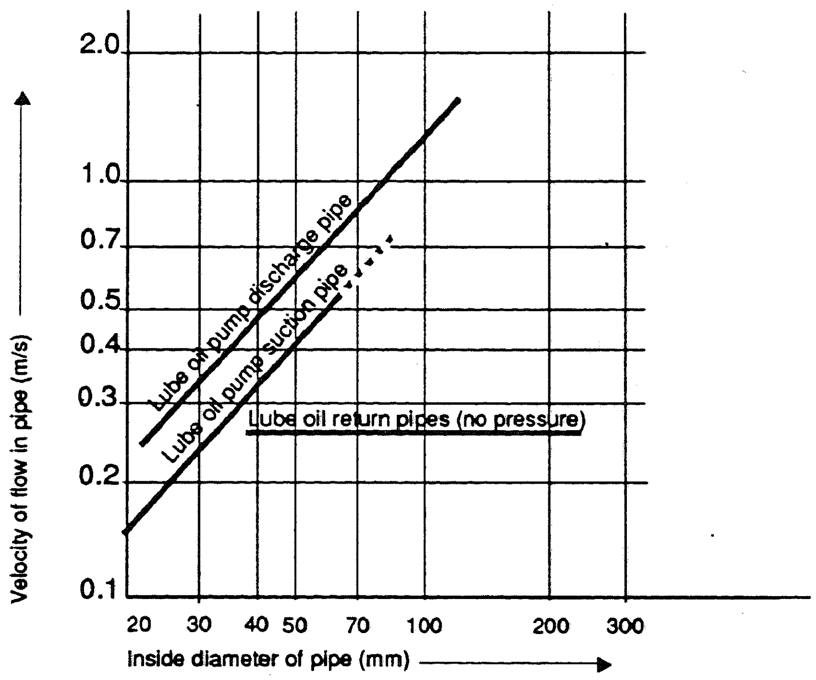
a) Pipe dimensions have to be in accordance with requirements of the classification society.
b) The shortest possible piping design with a minimum of bends.
c) Accessibility of all welds for mechanical cleaning (grinding).
d) Use of the minimum number of flanges, preferably of the spigot type. All flanged connections, flanges and valve lengths should comply with recognized international standards.
e) Clip fitting for prevention of vibration.
f) Piping layouts permitting absorption of expansion.
g) Preferential use of flexible fittings.
h) Piping in the neighbourhood of pumps and heat exchangers in general to be arranged permitting overhaul of the units with minimum dismantling of piping system.
i) Care to be taken to minimise number of pockets in pipe lines. Where pockets do occur, they must be fitted with drain cocks or valves.
j) Piping should be installed for stress-free mating with the flanges of the engine and all its auxiliaries (coolers, filters, heaters, thermostatic valves etc.)
k) Install sampling cock according to CEC M13 T92.

l) Flow velocities of oil shall be related to the inside diameters of the pipes as stated in Table No. 6 on standard velocity of flow.

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

V = Velocity		m/sec.
Q = Flow		m^3/hr
D = Inside pipe diameter		mm

Table No. 6:
Standard Flow Velocity in Oil Pipes



(Odense Steel Shipyard, J. Rassmussen'91)

3.3 Cooling Circuit

As it is essential that the lube oil inlet temperature is meeting the specification of the engine manufacturer (normally 40-50 °C), the lube oil cooler capacity must be adapted accordingly.

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

The following information is necessary for calculating the size of the cooler:

- heat dissipation,
- lube oil flow,
- maximum pressure drop oil side (0,5 bar typical),
- maximum pressure drop water side, (0,2 bar typical),
- lube oil outlet temperature (45 °C typical),
- sea water inlet temperature (32 °C typical) or
- fresh water inlet temperature (36 °C typical).

3.4 Acceptance

A lube oil circuit when designed and constructed according to above specification should be sent to the engine manufacturer for acceptance.

3.5 Lube Oil Storage and Handling

Because correct lubrication is vital to the operation of diesel engines, it is reasonable 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, 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 secure 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 micron max.) is highly recommended.

Deck filling connector caps and valves should be checked after filling the storage tank to be sure that they are closed.

Where only a small quantity of a particular grade is stocked in drums, these drums 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 lube oil purifier.
Not more than 10 %, preferably less than 5 % of the total system content should be added at a time if possible. Reasons for this are to keep an equilibrium and to avoid potential risks of sludge precipitation and difficulties in interpreting used oil analytical data when samples are taken.

Larger topping up amounts could also affect the balance of the used oil characteristics as shown in Figure No. 3.

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 oil before the engine is started up. Alternatively a small quantity of the new oil can be circulated and drained.

3.6 Preparation of the Lubrication System

When an engine, the systems or the connecting pipe system have been installed or opened for repair a certain amount of particles will inevitably find access.

It is essential for the engine's performance and life time, therefore, that such particles are fully removed.

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

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

3.6.1 Flushing the System

- Develop a flushing diagram and procedure.
- All flushing to be executed in one direction only.
- Pipe ends to be by-passed just before the engine.
- All tanks inspected before filling with oil.
- Oil into the system through a filter.
- Flow to be turbulent (Reynolds figure above 3000).
- Oil temperature to be 65 °C min.
- Pipe vibrators or shock facilities to be fitted.
- A flushing filter, with a mesh finer than the original system filter to be fitted during the flushing process.
- The purifier to be in service.

The flushing has to be continued until the predetermined cleanliness level is achieved (see paragraph 5.5.8). Normally the cleanliness level is specified by the engine manufacturer.

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

To fit running-in filters is a practice used occasionally and this can be done already before flushing starts.

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

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

3.7 Running-in

It is well known that many contamination products are released during the running-in period. It, therefore, is an advantage to remove such as soon as possible. This should be done as following:

- Keep the flushing filter in the system during the running in period.
- Establish an extra off-line filtration during the running in period.

3.8 In Service

When executing an overhaul or repair during later service there is always a risk that particles may enter the engine. It is therefore essential that a maximum of precaution is taken to keep these out from the engine and the lubricating system. To prevent external contamination all openings in the lubricant system should be blanked off during such periods.

4. THE LUBE OIL TREATMENT SYSTEM

As seen in Figure No. 4 for the system lay out, the lube oil treatment system consists of three major parts:

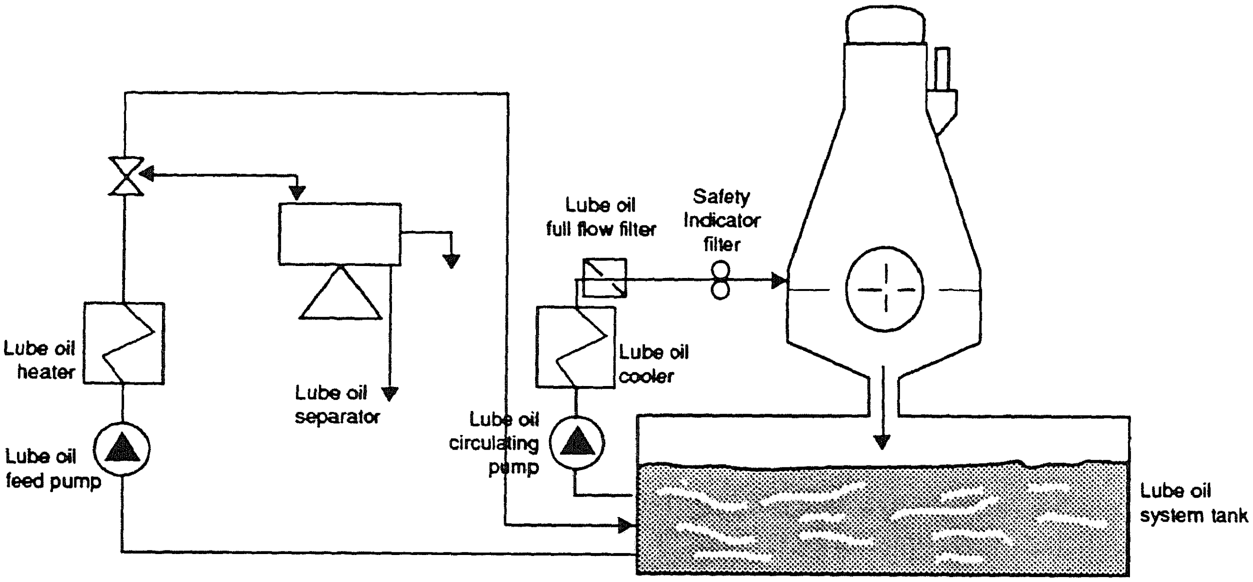
- The cleaning system which has to keep the impurities in the system at an acceptable low level.
- The protection system with the task to protect the engine from particles of harmful size, which have not yet been removed by the cleaning system.
- The cooling system which removes the excess of heat from the oil, as described in section 3.

4.1 The Need for Cleaning and Protection

To safeguard a good function of the engine the contamination of the lube oil must be kept at a low level.

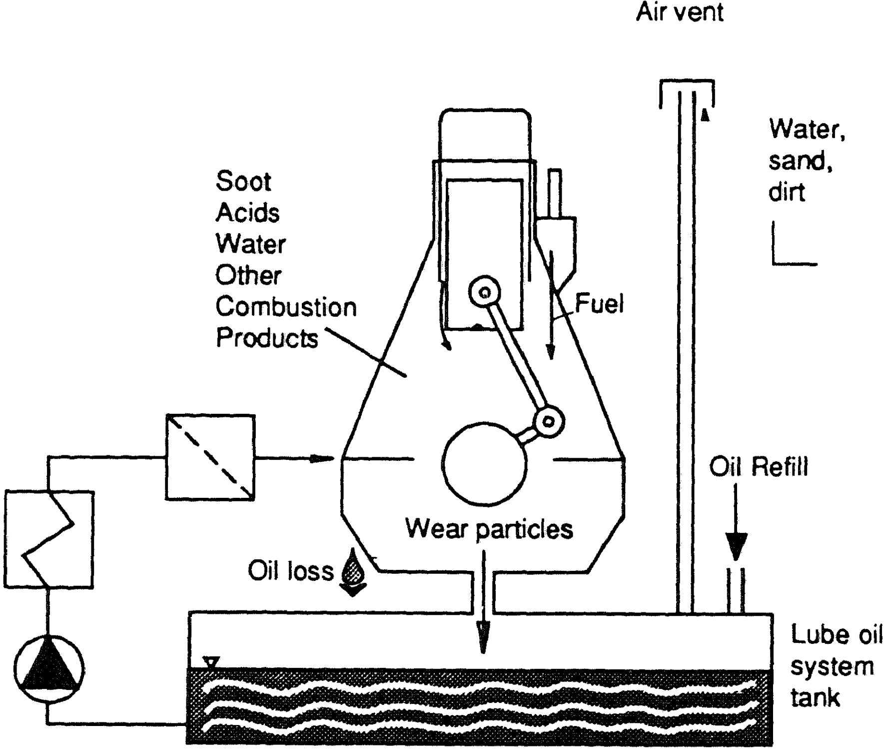
During the operation of the engine contaminants are entering the oil. Most are produced by the engine itself but some are also coming from different external sources. The contaminants consist for example of particles, wear debris, combustion products, decomposition products from the oil itself, water and raw fuel. See Figure No. 5.

Figure No. 4:
Principal layout of a lube oil system



(Alfa Laval, A. Pallmar, 1991)

Figure No. 5:
Contamination Sources



(Alfa Laval, A. Pallmar, 1991)

The main contamination source is the engine itself. The amount of the contamination ending up in the engine is depending on factors like

- Type of the engine
- Condition of the engine
- Engine output / load characteristics
- Type of fuel used
- Type of lubricant used
- Oil system content and design rate of oil consumption
- Oil maintenance system's capacity and efficiency
- Service conditions

In Figure No. 6 the effect of the fuel type on sludge production is shown. Here the contamination, defined as the amount of sludge removed from the system by a centrifugal separator, is plotted over the fuel viscosity. A typical sludge production by a trunk piston engine seems to be about 50 mg/kWh when using a heavy fuel oil such as ISO-F-RMG 35. That means that a 10.000 kW engine produces about 0.5 kilo of sludge per hour which must be removed from the system in order to safeguard a good function of the engine.

A typical particle distribution in a lube oil for trunk piston engines is presented in Figure No. 7. The vast majority of the particles are smaller than one micron.

A decreasing quality of the fuels and especially their combustion properties no doubt may increase the sludge load of the lube oil. Lube oils have, however, been developed to cope with such increasing demands. In order to keep the engine clean and to avoid agglomeration of sludge particles, more detergent and dispersant additives are used. This on the other hand makes the cleaning more delicate. Particles and water droplets are finely dispersed and thereby more difficult to remove. There is also an increasing risk that stable emulsions are formed which are difficult to separate.

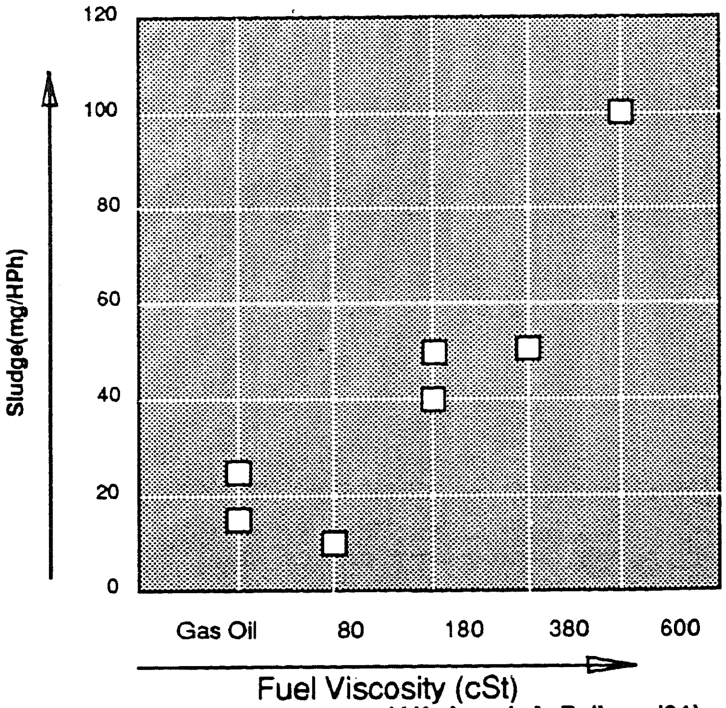
4.2 Cleaning and Protection Methods

In principle the removal of particles and sludge from the oil can be done by filters and/or by centrifugal separators.

The filter separates the particles from the oil by retaining particles bigger than the orifice in the filter mesh. Filters are, however, limited in their sludge and water handling capability. Filters can sometimes be justified for cleaning the lube oil in smaller engines operating on gas oil. But for larger engines operating on heavy fuel oil they are normally not sufficient.

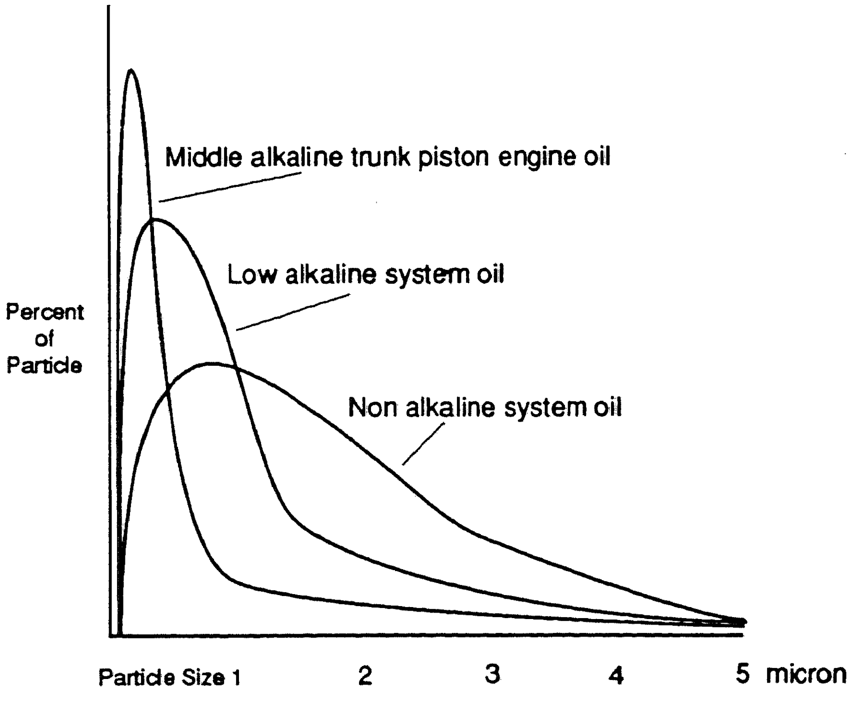
The centrifugal separator separates the particles according to the particle size and the density difference between particle and the oil. The separator has a large sludge handling capability and can remove particles down to one micron size. The separator also can remove large volumes of water from the oil. Normally both filters and separators are installed. The filter's main task is to protect the engine whereas the separator's main task is to keep the oil clean.

Figure No. 6:
Sludge amounts separated from system oils in trunk piston engines



(Alfa Laval, A. Pallmar '91)

Figure No. 7:
Sediment particle size distribution



(Mobil, Marine Diesel Engine Symposium, '81)

Whilst the filter for engine protection is installed as a full flow filter, the cleaning by separator is done in a by-pass circuit where only a small share of the oil is treated at a time. (If fine filters are used for the cleaning they also are used in by-pass.) A by-pass system is optimised to remove as much as possible of the contaminants per time unit rather than per pass over the separator.

Efficient cleaning of the oil with separators is important to support the function of the full flow filter in the protection system. If the level of contaminants is too high, this can lead to a higher load on the full flow filter and in the worst case clogging.

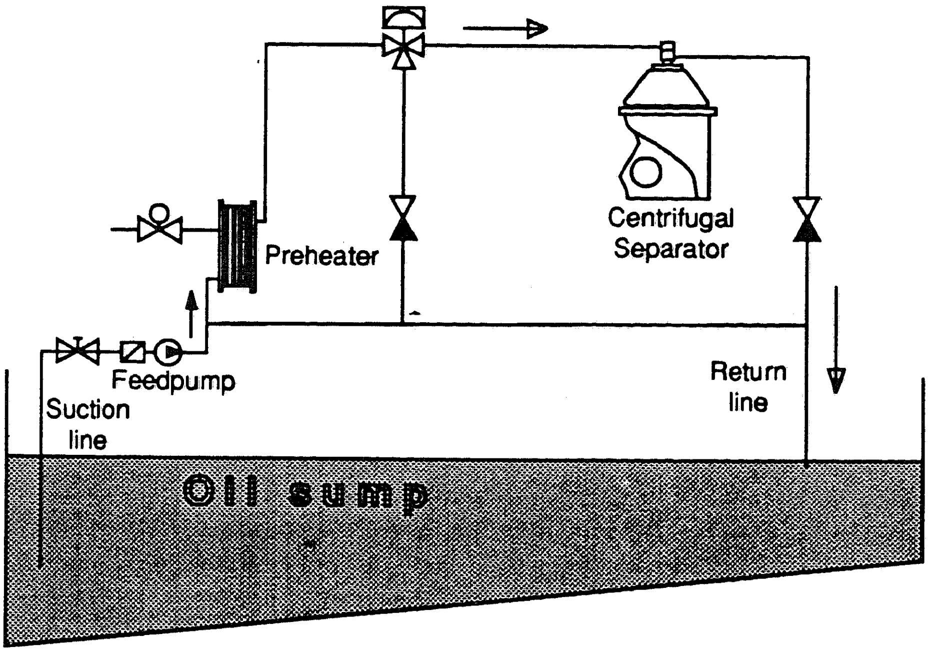
4.3 The Oil Cleaning System

Major components of the oil cleaning system are the feed pump, the preheater and the centrifugal separator. See Figure No. 8. The oil is pumped from the oil sump or tank, heated up to the appropriate separation temperature by the preheater and finally cleaned in the separator before being pumped back into the sump.

The orifice of the suction line for the feed pump should be installed in the lowest section of the lube oil tank.

The oil return line should lead into the tank opposite the oil suction point of the feed pump. This is to ensure proper oil circulation during cleaning when the engine is not in operation.

Figure No. 8:
By-pass lube oil cleaning system



(Alfa Laval, A. Pallmar, '91)

4.3.1 Components

Separator:

Today there are both conventional purifiers with gravity discs and modern purifiers without gravity discs available, the latter claimed as being less sensitive to external factors.

In case the engine is operating on Heavy Fuel Oil (HFO) self cleaning separators are recommended, because manually cleaned purifiers must be serviced frequently.

Feed Pump:

Separate, positive displacement type pumps, operating at constant capacity, should be installed in close proximity to the oil sump/tank so that suction lines can be as short as possible. By using this arrangement a constant feed rate is maintained, which is important to obtain good separation efficiency.

Oil Preheater:

Preheater dimensioning should not only take into account the temperature of the oil during engine operation but also the lower temperature of the oil in the sump when, for example, the engine is not in operation.

To avoid deposits and coking on the heating surfaces the following requirements should be considered for all types of heaters:

- Turbulent oil flow for optimum thermal efficiency and to avoid cooking
- No dead zones in which hot spots can occur
- The heater should be designed to exclude a potential "short circuit" of the oil flow
- Short retention time of the oil in the heater
- Low surface temperature
- The heater must always be started after and switched off before the feed pump to prevent blockages caused by coking

Keeping temperatures constant maintains separation efficiency and reduces the need of manual adjustments to the cleaning system.

Temperature variations influence the interface position in the separator which can result in a bad separation and/or broken waterseals. A collapse of the waterseal creates operational problems on which many react by selecting too small a gravity disc. This results in poor separation. The primary cause, however, can be too small a heater and/or inadequate temperature control.

The temperature control should therefore be of the "Proportional Integral" (PI) type in order to avoid such fluctuations (which should not exceed ± 2 °C).

4.3.2 Recommendations for Operation

The separator should be in continuous operation always when the engine is running in order to remove the contaminants as soon as possible. Also when the engine is shut off, separator operation should continue if possible to reduce contamination further.

The separator should always be operated as a purifier, e.g. being able to discharge separated water during operation.

The cleaning efficiency is mainly depending on:

- the interface position between oil and water in the separator,
- the throughput,
- the separation temperature,
- the "agitation" of the oil: extensive mechanical agitation, pumping and throttling in valves, etc., can cause emulsion and dispersion of fine particles,
- the lube oil properties like viscosity, density, etc.,
- detergent/dispersant properties of the lubricant.

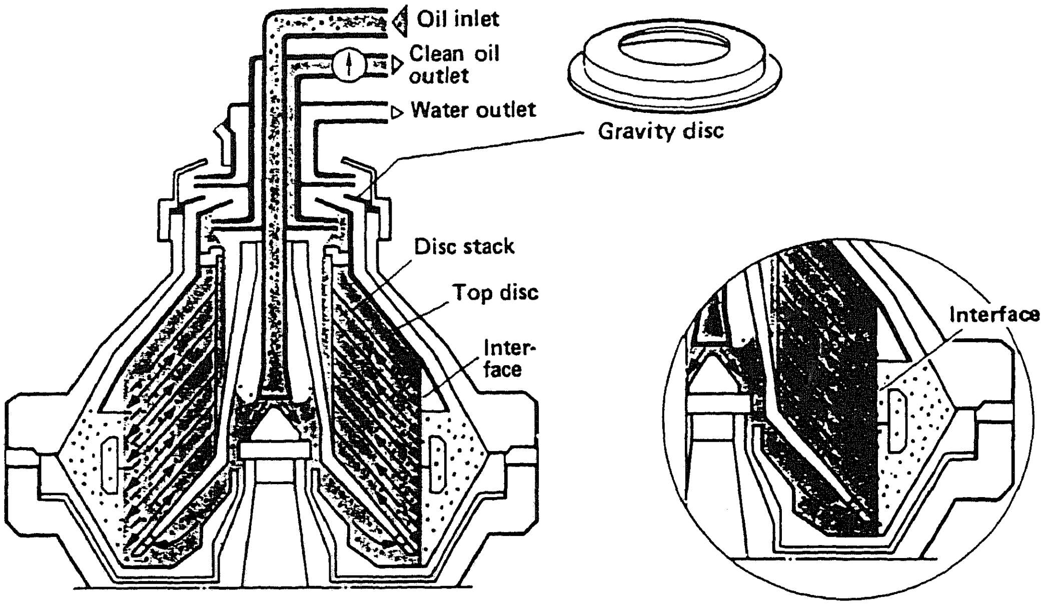
The correct interface position should be outside the distributing holes/disk stack but inside the top disc (see Figure No. 9). If the interface is allowed to go into the disc stack the separation efficiency will decrease. If it is allowed to go outside the top disc the waterseal will break and oil will flow into the water outlet.

In order to maintain the hydraulic balance between oil and water, the separator is equipped with a gravity disc. The gravity disc sets the position of the interface. During the operation the interface is inevitably affected by variations in flow and temperature. Therefore it is of utmost importance to ensure that these parameters are kept as stable as possible. [4]

4.3.3 Feed Pump Arrangement

All flow regulation by throttling of valves should be avoided as this can cause an emulsion whenever water is present. There is also a risk that sludge agglomerates are broken up and finely dispersed which reduces the cleaning efficiency.

Figure No. 9:
Correct Interface Position in a Purifier



Purifier - correct interface position.

Correct interface position. The oil is distributed to all channels in the disc stack.

4.3.4 Separation Temperature

Generally, the sedimentation rate is dependent on physical parameters; density, viscosity and particle size according to the following formula as derived from Stoke's Law:

$$Vg = \frac{d^2 (\rho_p - \rho_1)}{18 \eta} g$$

Vg = Sedimentation rate (m/s)
d = Particle diameter (m)
ρ_p = Particle density (kg/m^3)
ρ_1 = Density of the continuous phase (kg/m^3)
η = Viscosity of the continuous phase (kg/m,s)
g = Gravitational acceleration (9.81 m/s^2)

Both density and viscosity of the lube oil decrease when the temperature rises, thereby increasing the sedimentation rate and the separation efficiency of particles. The effect of temperature on viscosity (VI = Viscosity Index) is of special importance.

As said before, the higher the separation temperature the better the separation. A temperature reduction from 85 °C to 70 °C will result in a 40 % reduction in separation efficiency. Normally 85 °C to 90 °C give sufficient separation, but the temperature should be increased up to 95 °C if feasible and a further improved separation efficiency is needed.

4.3.5 Dimensioning of the Lube Oil Cleaning System

The required capacity of the lube oil cleaning system is depending on several factors such as

- engine output
- type of fuel
- type of lube oil
- type of service
- lube oil volume
- oil change intervals

The calculation should always be based on the size of the engine (MCR) and not on the actual sump volume.

Normally one separator per engine should be installed in order to ensure continuous cleaning. If this is not possible the dimensioning of the cleaning system should be based on the total installed output of all engines.

The required flow rate Q [l/h] of a lube oil cleaning system is to be calculated as follows:

$$Q = \frac{P \times z \times n}{t}$$

P = engine output MCR [HP or kW]
z = "conversion factor": 1 for l/HP or 1,36 for l/kW
n = number of turnovers per day of a theoretical oil volume corresponding to 1 l/HP.
Recommended are the following values:
n = 5 if the engine is operating on HFO (ISO-F-RMA...L)
(To be increased in case of very poor quality fuel)
= 4 if the engine is operating on MDO (ISO-F-DMB/C)
= 3 if the engine is operating on distillate (ISO-F-DMX/A)
t = actual operating time of separator per day

Hence, the appropriate separator is to be selected from the capacity tables issued by the separator manufacturers. In such tables the different dispersant levels of the lube oils normally are taken into consideration. In consequence, dispersant type lubricants for trunk piston engines are cleaned with a lower percentage of the nominal throughput than non dispersant crosshead engine system oils. In general it can be said that for oils in trunk piston engines running on heavy fuel oil not more than 20% of the nominal throughput is recommended.

4.4 The Engine Protection System

When the oil is pumped into the engine there is a need to stop abrasive particles from reaching it. These particles might have been picked up by the oil anywhere in the system. As the separator is treating the oil in a by-pass system with much lower throughput than the full flow there is always a risk that the particles are not removed immediately by the separator.

This protection of the engine is ensured by the full flow filter placed just before the engine, see Figure No. 4.

There are manually cleaned, automatic backflushing as well as disposable filters.

The filters must provide a good protection for the engine but this should not be done at the cost of spending excessive manhours on adjustment and maintenance.

For this the following is needed:

- a mechanically reliable construction of the filter element,
- a filter area large enough to handle the envisaged sludge amount (low specific filter load),
- a well functioning backflushing mechanism to limit sludge build up on the filter.

With the aim to reduce losses the backflushed oil should be returned to the system close to the suction pipe of the purifier. In some filter designs a filtration of the backflushed oil is provided.

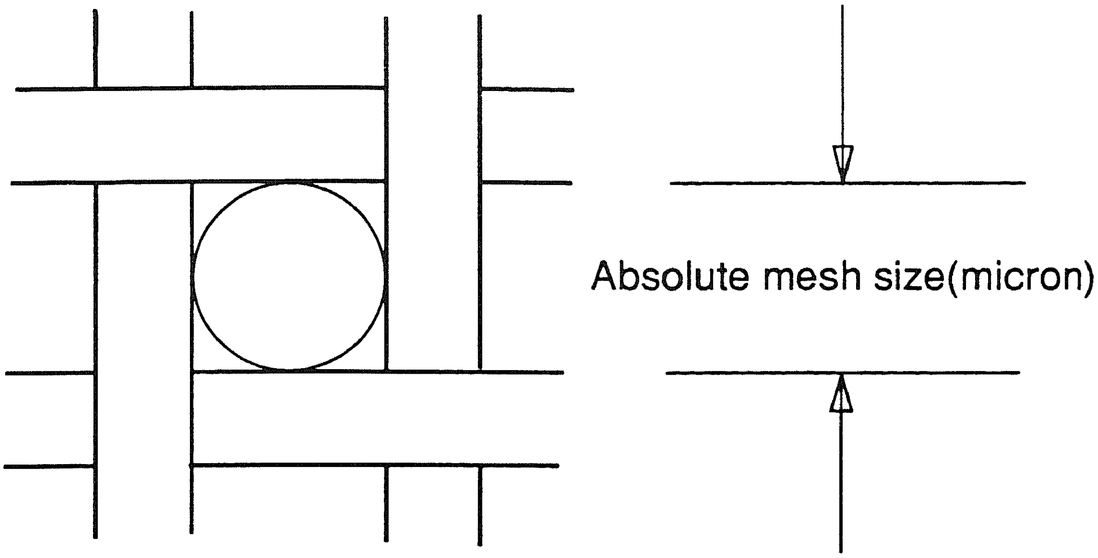
4.4.1 Filter Fineness

There are several definitions for filter fineness in use:

Surface Filters (manually cleaned or backflushing types):

- Absolute fineness (sphere passing mesh). One definition for absolute fineness mesh size is the square opening, as Figure No. 10 shows.
- Nominal fineness. The nominal fineness is a "practical" definition. It indicates that about 85 % - 90 % of the particles bigger than the nominal fineness are retained by the filters.

Figure No. 10:
Definition of "Absolute Mesh Size"



The diameter of the largest hard spherical particle that will pass through the filter under specified test conditions.
This is an indication of the largest opening in the filter element.

Experience shows that the nominal fineness figure is approximately 40 % smaller than the corresponding absolute fineness figure.

The removal characteristic of the surface filter is such that it removes particles bigger than the specified mesh with a high efficiency, but smaller particles with a lower efficiency.

Depth Filters

- For depth filters the removal efficiency of particles with a given size is sometimes specified. For example "15 micron/60 %", means that 60 % of particles bigger than 15 micron are removed. A specification regarding maximum particle size is not always given.

Comparing the removal characteristics of depth filters with those of surface filters shows that the removal efficiency of the depth filter may be somewhat lower for the biggest specified particle/filter opening. For particles smaller than the specified fineness size the removal is better.

In order to avoid misunderstandings it should always be defined whether "maximum sphere passing mesh" (absolute fineness) or "nominal fineness", together with filtration efficiency is meant.

4.4.2 Beta Value

The filter's removal efficiency is sometimes presented as the "Beta value" (ß). This Beta value is defined.as "number of particles bigger than a specified size before filter divided by the number of particles bigger than the specified size after filter". A dedicated filter test, namely the "Multi-Pass Test", is published as ISO 4572.

4.5 Installation

The filter should be placed as close as possible to the engine.

A typical filter installation for a trunk piston engine operating on heavy fuel as shown in Figure No. 4 consists of:

- One automatic backflushing filter as main filter. The filter size is typically 35 micron absolute.
- A manual duplex safety filter, installed after the main filter.

The safety filter size is usually 60-70 micron absolute. The purpose of this filter is to act as safety net in case the filter screen of the main filter is damaged. In this case the safety filter will be clogging rapidly thereby giving an indication to the operator.

A general guide line is that the safety filter should have double the filter fineness of the automatic main filter. Also, a filter with finer fineness should never be placed downstream a filter with a wider fineness. For lube. oils in service, the increase in the number of particles is enormous with a decrease in particle size. This means that the first filter would not be able to significantly reduce the load for the second filter and, therefore, reduce its function as "safety net".

The same recommendation is also valid for the installation of automatic filters in front of depth filters. The automatic filter would stop big particles including such that would perhaps not have been stopped by the depth filter. But then the depth filter would also stop small particles that pass the automatic filter. Again, as the amount of particles increases rapidly with decreasing particle size the automatic filter would not extend the service interval of the depth filter.

5. LUBRICATING OIL ANALYSIS AND ITS SIGNIFICANCE

5.1 The Purpose of the Oil Analysis

The main reasons for analysing used oils are as follows:

1) To determine the condition of the oil and to confirm whether or not it is fit for further service.

2) To detect and prevent trouble with lubricated parts if possible at an early stage.

3) To assist in investigating the cause of engine problems. [5]

5.2 Drawing of Samples

The results from any analysis, either in the laboratory or on site, will reflect the condition of the sample. Care must therefore be taken to ensure that meaningful samples are obtained. The details are described in paragraph 2.5.2 and also in Appendix No. 4 (CEC M-12-T-91 Code of Practice).

5.3 Sampling Intervals

Sampling intervals are recommended in paragraph 2.5.3 for approval purposes. 2000 or more hour intervals may be suitable for routine oil analysis.

5.4 Information Required for Oil Analysis

1) Name of vessel or plant
2) Owners
3) Date sample drawn
4) Date and port 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 drawn
9) Type of fuel used (including sulphur content)
10) Date previous sample from same source drawn
11) Quantity of lubricating oil in system and top up
12) Any special reasons for analysis being required (if non-routine samples).

For details see also 2.5.1 and Appendix 2.

5.5 Properties to be Tested

The significance of tests and their relevant information 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 mentioned in section 6.

5.5.1 Viscosity

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

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 and the calibration constant of the viscometer give the kinematic viscosity of the oil in use in mm^2/s. The viscosity of oil in use is generally determined at 100°C.

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

The viscosity of a lubricant in use may change in service mainly by contamination with soot from the combustion of fuel and lube components but also due to oxidation and thermal degradation and/or contamination with fuels, etc. An increase of pentane/heptane insolubles and oxidation will cause an increase in viscosity, while water contamination may cause either an increase or decrease. Accordingly, changes in viscosity should be considered in relation to other test data, such as T.A.N., pentane/heptane insolubles and water content for contamination, and flashpoint for dilution by fuels. If, however, these test data reveal nothing unusual, a change in viscosity may also indicate a mixture of different lubricating oils in the system.

Decreasing viscosity is obviously a greater risk than increasing viscosity, in fact a level may be reached where full-film lubrication is difficult to maintain, particularly in bearings. An increase of viscosity may be tolerated unless oil flow to the piston under crown is significantly reduced.

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

5.5.2 BN (Base Number)

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

There are two methods (ISO 3771 - perchloric acid and ISO 6619 - hydrochloric acid) for determining BN. Most engine manufacturers and oil suppliers recommend to measure BN by ISO 3771. Oils in use generally show higher BN figures when the alkalinity is evaluated by ISO 3771 than by ISO 6619.

The BN is a measure for the ability of an oil to neutralise strong acids caused by combustion products condensing on the cylinder walls and elsewhere. Sulphur in the fuel is converted to sulphur oxides during combustion and although the majority of these are expelled with the exhaust gases, a small proportion of SO_3 together with the water formed during the combustion 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 results in the formation of either calcium, barium or magnesium sulphates (depending on the additive in the oil) which become part of the insolubles burden carried by the oil returning to the crankcase.

Fuel sulphur content and temperature influence the dew point of sulphuric acid at the much higher combustion pressures inside diesel cylinders. This is difficult to measure in practice, but calculations on the basis of reasonable assumptions show, that elevated pressure has a very significant effect [6, 7]. (See Figure No. 11).

This figure gives no indication of the severity of corrosive wear which could occur in the absence of alkalinity in the lubricating oil, but for a fuel of a particular sulphur level it is quite clear that, the higher the pressure, the higher is the condensation temperature. Similarly, at any particular temperature, the higher the fuel sulphur content, the more acid is produced, provided this temperature is below the dew point.

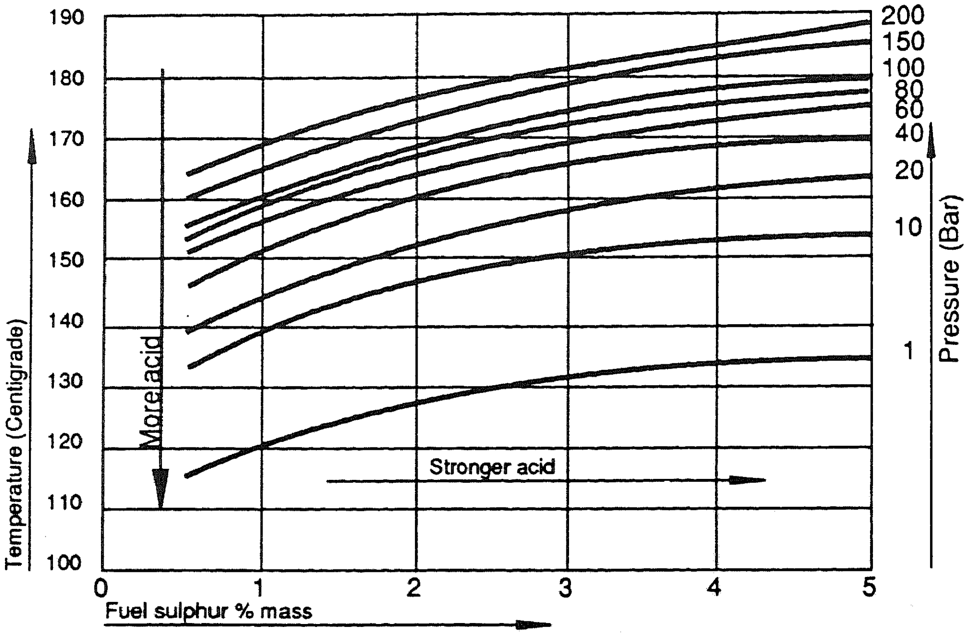
A further complication is the effect of temperature on the corrosion rate. This has been investigated at atmospheric pressure, but can be expected to apply similarly at higher pressures. It has been found that the rate of corrosion increases to a maximum when the temperature is about 30°C below the dew point. In case, however, the temperature is further reduced, the corrosion rate will fall sharply, as shown in Figure No. 12. [8]

In practice, both a temperature and a pressure gradient will be present along the cylinder bore during the power stroke. Whilst experience has shown that the majority of cylinder bore 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 about 150°C. Research has been demonstrating that corrosive wear in the upper and hotter part of a cylinder liner can be caused by condensed acid swept up from the lower cold part. [9] Therefore it is suggested to design engines in which temperatures are kept above the dew points on the entire cylinder liner between TDC and BDC. Formation of sulphuric acid also contributes to an increase of viscosity and pentane insolubles. Soots generally contain sulphuric acid. Thus good combustion is important, also in view of fighting corrosion.

In service, the BN normally falls initially quite steeply, but gradually levels to a steady equilibrium value (see Figure No. 3). This equilibrium will thereafter continue indefinitely, providing the sulphur content of the fuel and the lubricating oil consumption rates remain reasonably stable, and 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 walls. The "sulphur conversion" ratio of the engine, (i.e. the ratio of sulphur which is condensed as sulphuric acid to the total sulphur ingested with the fuel), can be determined at any time during the life of an oil charge. [10]

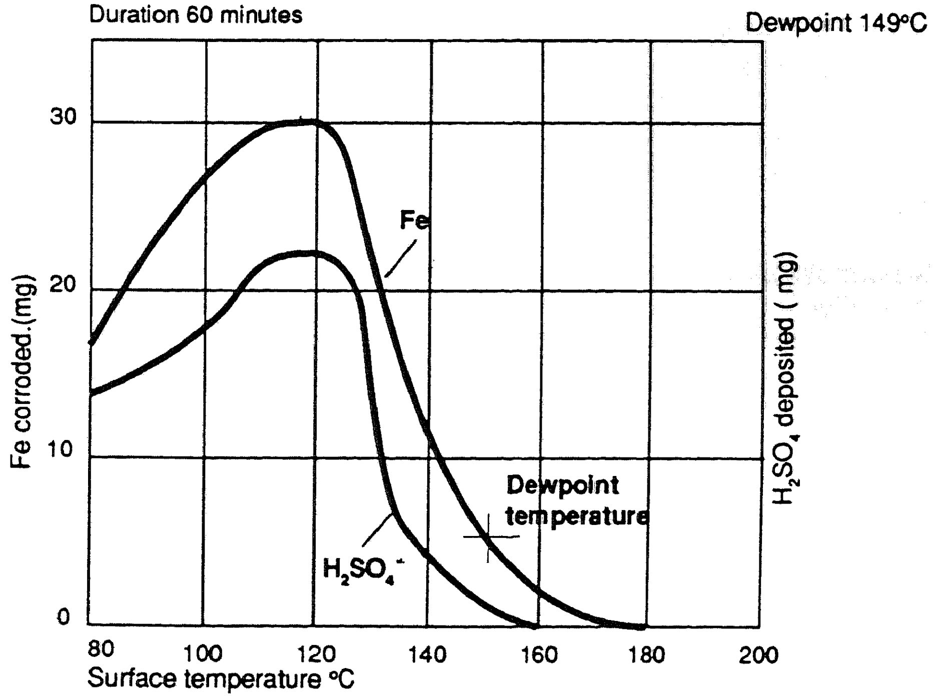
It should be stressed that this ratio is roughly constant for a particular design of engine with fixed operating conditions, independent from the sulphur level of the fuel. However, it is significantly influenced by cylinder wall temperature.

Figure No. 11:
The influence of fuel sulphur content and combustion pressure on the dew point of sulphuric acid.



(SHELL, D.W. Golothan, 1978)

Figure No. 12:
Effect of surface temperature on acid condensation and corrosion



(SHELL, P.R. Belcher, 1971)

The other factor influencing the level of the equilibrium BN in service, of course, is the lubricating oil consumption. In the unlikely event of no oil consumption, the BN of the crankcase oil would never stabilise but fall to zero in due course. Therefore, an appropriate oil consumption is very important and, in consequence, (see paragraph 2.2) equilibrium conditions are usually attained after a few thousand hours. **It is the task of the oil supplier to incorporate sufficient alkalinity into the oil so that the equilibrium BN is still adequate under the most adverse conditions of high fuel sulphur content and low lubricating oil consumption**, as shown in Figure No. 3. Hence, the apparent economy of designing engines for extreme low oil consumption may well be offset by the need for more frequent oil changes, or the use of a much higher BN for initial fill and top up.

The actual minimum equilibrium level of BN of the crankcase oil to be considered acceptable in a splash-lubricated engine operating on residual fuel of course must be sufficiently high.

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 also depends. Thus, while it may be acceptable for 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. Carbonaceous piston crown and land deposits, unless grossly excessive, generally have little effect upon engine operation. Deposits in piston ring grooves are, on the other hand, potentially harmful since lack of freedom of the rings leads to bore scuffing, blow-by and rapid engine deterioration.

Lubricants used in engines burning residual fuel therefore must be able to minimise such deposits, which can be achieved by adequate detergency of the oils.

Ring groove deposits originate mainly from unburnt or incombustible components in the fuel, the products of neutralisation of the sulphuric acid condensate, and potentially from the oxidation of the lubricant itself, which can result in insoluble resins. The higher the temperature of the piston ring grooves, the more deposits can be seen therein. The recommended maximum temperature in piston ring grooves also depends on residence time of the oil in the piston ring grooves [1]. In view of experience, it would be desirable to keep the temperature in piston ring grooves well below 220°C when conventional mineral oils are used.

Cleanliness of the piston undercrown is also important. The surface temperature of the piston undercrown should, if possible, be controlled to below 250°C.

In humid climates there is a risk of excessive quantities of condensed water entering the cylinder with the scavenge air. This problem is likely to be more acute in modern highly rated engines having rather high scavenge air pressures. If the temperature of the air cooler tubes is low, moisture can condense on them, and the resulting droplets are carried over into the cylinder with the scavenge air.

This water may be very harmful because it tends to wash the oil film from the cylinder walls and, furthermore, can contribute to corrosion or rusting by reacting with the sulphuric acid derived from combustion of the fuel sulphur. Heavy wear or scuffing can thus occur on the cylinder and piston rings during the period when the engine is operated under the mentioned humidity and temperature conditions.

In some instances, the quantity of condensed water passing into the cylinder can be very large - up to several tonnes per day have been recorded on occasions. Much work has been done by engine manufacturers to design devices for removing the water from the scavenge air, but this equipment, although very effective, is expensive and often difficult to install and has so far been used only on few installations. [5]

To avoid water condensation as far as possible, the cooling water inlet temperature to the air coolers should be controlled according to the humidity and the temperature of the inlet air. It has been found that controlling air temperature alone does not necessarily prevent water entering the cylinder. In case the air cooler tubes are too cold, relatively large drops of water will condense and subsequently reach the cylinder walls before given sufficient time to evaporate.

5.5.3 Insolubles

Currently two methods (centrifuging - ASTM D 893 - and membrane filtration - ASTM D 4055) are popular for the determination of insolubles in used lubricating oils.

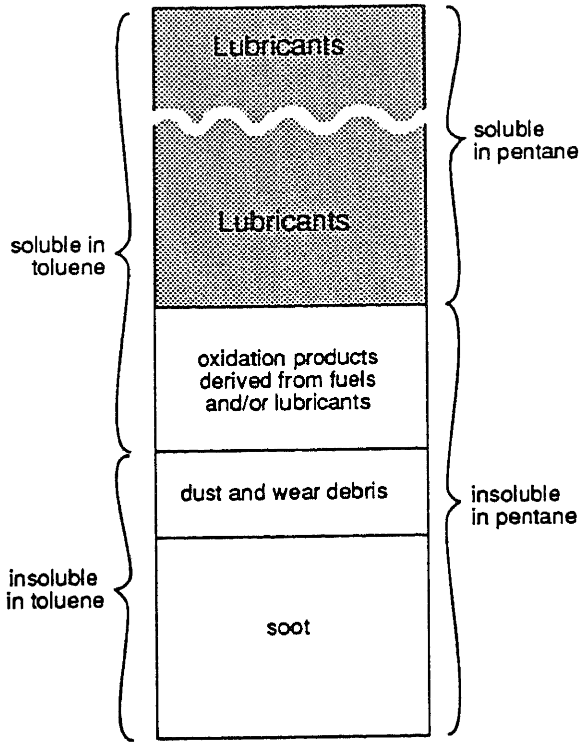
ASTM D 893

1) Procedure A:
   A sample of used lubricating oil is mixed with pentane and centrifuged. The oil solution is decanted and the precipitate 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 then 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 coagulated toluene insolubles.

The difference between pentane and toluene insolubles is shown in Figure No. 13.

Figure No. 13:
Pentane and Toluene Insolubles



ASTM D 4055

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

The pentane insoluble-method B (ASTM-D-893) is widely applied on oils in use for routine oil analysis purposes.

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

The accumulation of insolubles can be minimised by suitable purification and operating conditions (see section 4).

Occasionally hard deposits are formed on piston crowns and lands and, where such hard deposits are removed from the pistons by mechanical force, they may cause premature damage of bearings. Such hard deposits on pistons are believed to be caused by abnormal high temperatures due to long exposure to the combustion flame. Formation of such hard deposits cannot be cured by the selection of the oil brand or the type of oil, but should be reduced by the improvement of combustion and maintenance (particularly avoid clogging of air coolers and exhaust economisers).

5.5.4 Water Content

The test method is described in ISO 3733 (ASTM D 95)

> 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.

In the past non-additive oils as used in the systems of low-speed engines were water-washed in the course of the centrifuging treatment to remove traces of strong acid 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 lubricants for medium speed engines.

Middle alkaline oils can form water-in-oil emulsions which can hardly be broken in the centrifuging operation. Such emulsions, if circulated, will reduce the load carrying capacity of the oil in bearings which may lead to failures. Therefore such oil should be exchanged as soon as possible.

As mentioned already in paragraph 1.2.3, the alkaline and other additives are sensitive to depletion by water, forming insoluble sludges which are deposited in the centrifuge. It has been found that the water tolerance of a used oil is worse compared to the same oil when new.

Little damage will be caused in most cases by accidental water contamination to new oils in storage. However, if an oil is confronted with continuous water leakage in service, some additive depletion is inevitable. Even if the water can be removed successfully by centrifuging, the charge should be analysed as soon as possible to confirm that it is still in acceptable condition. The deliberate introduction of water washing is not only unnecessary but also detrimental to additive content and efficiency.

Traces of water in the lubricating oil are inevitable as mentioned above - for example, salt water from leaking oil coolers, fresh water from coolers and cylinder cooling jackets, and 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 to a minimum by centrifuging. If it exceeds 0.2% volume, operation of the centrifuge should be carefully checked and adjusted to ensure optimum oil/water separation. The running time of separators should be increased, if necessary to continuous operation. The cause of water contamination should always be investigated and immediate action taken to remedy.

5.5.5 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 sample is extracted with water in the presence of a solvent and a demulsifying agent in a TEL extraction apparatus (IP 248-ASTM D2547). The halides in the extract are determined volumetrically after the removal of sulphide. The result is recorded as sodium chloride.

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

Highly additivated oils normally provide reasonable protection against salt water corrosion. Therefore a small salt content is tolerable. "Water washing" of the oil can reduce the concentration of salt in the oil as salt is more readily soluble in water than in oil and therefore would be removed with the water effluent from the centrifuge. Because of the risk of a stable emulsion forming, however, (particularly if insolubles are high) "water washing" of such oils is not recommended. Therefore only dry centrifuging is recommended when salt is detected in the oil in use.

Regardless of the type of oil in use, if the salt content reaches 0.005% mass (50 ppm), the source of contamination should be traced and remedial measures taken.

Salt contents are reported as a percentage of the oil sample, not of the water present in the sample.

5.5.6 Flash Point

The test method is described in ISO 2719 (ASTM D 93).

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

A drop in closed flash point indicates contamination of the lubricant by fuel, although with heavy fuels no significant change may be apparent. As a very general guide it is advisable to check for fuel leaks when the closed flash point drops by 30C or more.

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

5.5.7 Metal Content

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

Two techniques are commonly 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 lubricating 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 oil sample is burnt in the flame of an AA spectrometer. The absorbance characteristic of each element is measured and compared with the standard.

The ASTM Method D 5185-91 is recommended for the determination of additive elements, wear elements and contaminant elements in used oils. An inductively coupled plasma atomic emission spectroscopy (ICP-PES) technique is employed for the analyses. In Appendix 3 the CEC document M-13-T-92, reproduced by permission, includes a summary of the method together with the repeatability and reproducibility values for numerous 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 Atomic Absorption using D4628.

Whatever the method, particles greater than 5 microns are not completely 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.

One must realise that - according to the type of apparatus, sample preparation, standards used, plasma used, 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 also provides data on the concentration of metallic salts in the additives, the content of metals originating from the wear of engine components and/or by contamination.

Additive elements (% m): - Ca, Ba, Mg, P, Zn, N - their concentration can serve for identification of the lubricant in use, or as an indication of addition or contamination by other grades.

Wear (ppm): - Fe, Cr, Al, Mo, Pb, Sn, Cu may indicate wear of bearings, piston rings, cylinder liners and so on.

Contamination (ppm): - Na, V, Al, Si contaminants from the fuel oil and Mg, B and Na from water. Si also from dust.

Control limits cannot be generalised for metals, at least not until sufficient data and experience have been accumulated. Results therefore will have to be assessed by comparison with previous analytical history.

5.5.8 Particle Counts

For hydraulic oils particulate counting under a microscope has been common practice for years, and for evaluation purposes ISO (and other) methods have been developed. These methods cannot be applied to engine oils in use, because the particulate contents in a used oil, even under normal conditions, far exceed any range covered by the hydraulic oil methods. They can, however, be a useful tool to check the cleanliness of fresh oils and the effect of flushing as described in section 3.
Typical acceptance criteria for such can well be ISO 19/16.

6. QUALITY LIMITS OF OIL IN USE

TABLE 7

Limits for Precautionary and Mandatory Action

PROPERTY	METHOD [2]	UNIT	PRECAUTIONARY ACTION [3]	MANDATORY ACTION	REMARKS
Viscosity [1]	ISO 3104	mm^2s^{-1}	-2.95 / +3.00	-3.45 / +3.50	for SAE 30
			-3.00 / +4.20	-3.50 / +4.70	for SAE 40
BN [1]	ISO 3771	mgKOH/g	-	5 min	for ISO-F-DMX/A
			-	7 min	for ISO-F-DMB/C
			-	15 min	for ISO-F-RMA...L [4]
			-	20 min	for ISO-F-RMA...L [5]
Water content	ISO 3733	% vol	0.2 - 0.49	0.5 max	
Flashpoint	ISO 2719	° Celsius	-	180 min	
Insolubles	ASTM D-893/B	% mass	1.5 - 2.49	2.5 max	

1) The "mandatory action" limits apply only in cases where there are no specific recommendations from the engine manufacturer.

2) Alternative test methods can be used on condition that results of such demonstrably correlate with methods listed.

3) Precautionary limits are for guidance only.

4) With separate cylinder lubrication.

5) Without separate cylinder lubrication.

<u>Additional tests</u>:

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

7. TROUBLE SHOOTING LIST

Below operating troubles are listed which are frequently associated with lubrication. Although often claimed different, serious operating difficulties resulting from lubrication are not very common in marine diesels. It may be of value, however, to consider briefly some of the problems that might occur. [11]

1) <u>Ring Sticking</u>

1. Continuous overload operation
2. Distorted piston or cylinders
3. High or low jacket water temperatures
4. Worn pistons
5. Worn rings or such that lost tension
6. Insufficient ring side clearance
7. High oil consumption
8. Bad combustion
9. Excessive blow-by
10. Low oil consumption and in consequence, additive depletion
11. Use of piston ring of wrong dimensions
12. Insufficient detergency of oils, oxidation and thermal degradation.

2) <u>Ring and Cylinder Wear</u>

1. Improper filtration of air, fuel or oil resulting in presence of particles.
2. Water in oil
3. Corrosive fuel
4. Low oil viscosity
5. Insufficient oil feed/ distribution to cylinders
6. Low jacket water temperature
7. Access of drain water condensed at air inter cooler
8. Excessive blow-by
9. Pistons or cylinders distorted by mechanical force and/or thermal expansion
10. Frequent cold starts
11. Excessive piston clearance
12. Improper running-in
13. Inadequate surface finish condition
14. Unsuitable cylinder liner material
15. Overloading of the engine
16. Adverse combustion properties (long combustion time) of fuel
17. Excessive high content of carbon residue in fuel
18. Excessive temperature due to insufficient air by blockage of air cooler/exhaust gas economiser
19. Heavy deposit on piston undercrown

3) Combustion Chamber Deposits

1. Improper air filtration
2. Wet or corrosive gas in gas or dual fuel engines
3. Improper diesel fuel filtration
4. Improper combustion
5. High cylinder oil feed rate
6. Worn rings or such that lost tension
7. Low jacket water temperature
8. Continuous overload operation
9. Excessive vanadium and/or sodium content in fuels

4) Crankcase Deposits

1. Insufficient dispersancy of oils
2. Improper oil filtration/purification (insufficient capacity/operation of the purifier or neglected replacement of filter element)
3. Improper combustion (high insolubles content in oil)
4. High oil temperature
5. Low oil temperature
6. Excessive blow-by
7. Condensation
8. Leaking water jacket
9. Excessive or too low oil consumption
10. Clogged crankcase breather or vent
11. Inadequate piston cooling
12. High insolubles content

5) Bearing Wear or Failure

1. Excessive bearing clearance
2. Insufficient bearing clearance
3. Misaligned bearings
4. Distorted crankshaft
5. Insufficient oil feed to bearings
6. Oil viscosity too low
7. Contaminated oil
8. Corrosive oil (high T.A.N. or presence of S.A.N.)
9. Water in oil
10. Defective bearing construction
11. Improper combustion (many large insolubles in oil)
12. Insufficient removal of sooty contaminants in oil by purifier/filter
13. Vibration of engine (when not running) caused by external source.
14. Hard deposits, based on calcium ashes, removed from piston crown and lands (Hard deposits are believed to be formed by too high temperatures under the presence of sodium and/or vanadium with calcium from additives.)
15. No nickel barrier to prevent diffusion of tin below lead overlay on bearings
16. Insufficient oil feed into bearings before engine is started

17. Insufficient length/diameter of bearings to support combustion pressure and/or centrifugal force
18. Inadequate oil groove design on bearings (insufficient minimum oil film thickness in bearings)

6) Wear of Crank-shaft

1. Refer to "5) Bearing Wear or Failure"
2. Wear due to migrating electric currents

7) High Oil Consumption

1. High cylinder oil feed rate/splash
2. Leakage
3. Worn or stuck rings
4. Ineffective oil control ring
5. Worn pistons or cylinders
6. Excessive bearing clearance
7. High oil pressure
8. Low oil viscosity
9. Piston design fault, particularly faulty design of oil distribution holes in piston ring grooves
10. Piston ring design fault
11. Wrong fitting of the oil scraper ring (e.g. upside down)
12. Excessive deposit formation on piston top lands
13. Frequent discharge of sludge accumulated in centrifuge due to bad combustion
14. Improper cylinder liner surface finish (too much oil retention)
15. High oil temperature at outlet of oil cooler
16. Oil consumption via valve guide/stem
17. High volatility of lubricant
18. Excessive foaming of oil
19. Liner surface too smooth due to lacquer formation
20. Liner surface too smooth due to bore polishing

8) High Oil Temperature

1. Clogged oil cooler
2. Clogged oil lines
3. Sludged crankcase
4. Continuous overload operation
5. Insufficient jacket water cooling
6. Overheated bearing
7. Incorrect oil viscosity
8. Insufficient oil in sump or crankcase
9. Insufficient oil circulation
10. Improper injection timing

9) Lack of Power

1. Improper combustion
2. Insufficient air
3. High back pressure
4. Low fuel energy content
5. Low compression pressure
6. Leaking exhaust valves
7. Improper lubrication
8. Leaking injectors
9. Late injection timing

10) Improper/Bad Combustion

1. Unbalanced cylinder load
2. Sticking, leaking or plugging injectors
3. Unsuitable fuel (due to improper fuel heating temperature and bad combustion properties of fuel)
4. Low injection pressure
5. Incorrect injection timing
6. Insufficient air (due to blockage of air cooler/ exhaust gas economiser)
7. Low compression pressure
8. Leaking or sticking intake or exhaust valves
9. Low load
10. Low jacket temperature

11) Premature Loss of Alkalinity (BN) of Lubricants

1. High sulphur content of fuel
2. Oil consumption too low
3. Cylinder liner temperature too low
   (low cooling water temperature)
4. Access of drain water condensed at air inter cooler
5. Access of splashed sea water due to improper design of intake air vent
6. Low load operation
7. Bad combustion (soots generally contain sulphuric acid)
8. Wet centrifuging
9. Neglect of fresh oil top-up (Reduction of oil quantity.)
10. Top-up with lower alkalinity oil
11. Excess blow-by into crankcase
12. Raw residual fuel contamination of lube oil

12) Premature Increase of Viscosity

1. Increase of insolubles in used oils due to bad combustion
2. Insufficient capacity of purifier
3. High carbon residue of fuel
4. Low oil consumption

5. Higher viscosity oil used for cylinder lubrication (Engine with cylinder lubricators.)
6. High volatility of lubricant
7. Faulty operation of purifier
8. Filter element not replaced
9. Insufficient capacity of filter
10. Ingress of sulphuric acid into oil due to low cylinder liner temperature
11. Oxidation due to contamination of lube oil by fuel, probably from leaking fuel pumps

13) Foaming of Lubricant

1. Faulty design of lubricating system
2. Inhalation of air into lubricating system
3. Insufficient anti-foaming performance of oil (should meet anti-foaming requirements of MIL-L-2104D.)
4. Anti-foam additive removed by fine filter
5. Contamination with grease and/or rust preventives (Complete replacement of oil recommended.)
6. Air release properties of lubricant

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APPENDIX 1

Membership

The following companies, institutions and associations have cooperated with the CIMAC Working Group "Lubricants":

- Alfa Laval
- BP Marine
- Castrol
- Chevron Chemical Co.
- CNIDI
- Elf
- Exxon
- Germanischer Lloyd
- Guiterrez Ascunce
- Istituto Motori CNR
- KHD / Deutz MWM
- Krakow Technical University
- Loyds Register of Shipping
- Lubrizol
- MAN - B&W Diesel
- Marine Engineering Society in Japan
- Mobil
- Det Norske Veritas
- Odense Steel Shipyard
- Ricardo Consulting Engineers
- S.E.M.T. Pielstick
- Shell
- New Sulzer Diesel
- Texaco
- Technical University Hannover
- Wärtsilä

APPENDIX 2

CIMAC Checklist

for Information on

Lubricant and Deposit Samples

TEXT AFTER

CONTRIBUTIONS AND DISCUSSION

AT

October 1, 1990

MEETING IN NAPLES

THE **CIMAC CHECKLIST** IS INTENDED AS A GUIDELINE FOR THE RETRIEVAL OF INFORMATION RELEVANT TO TRUNK PISTON DIESEL ENGINE OPERATION AND THE RELATED DIESEL LUBRICANT PERFORMANCE. THE LIST IDENTIFIES THE INFORMATION REQUIRED AS **BASIC** AND **ADDITIONAL**. THIS DIFFERENTIATION RECOGNISES THAT THERE MAY BE PRACTICAL DIFFICULTIES WITH RETRIEVING AS MUCH DETAILED INFORMATION IN THE FIELD AS GENERALLY POSSIBLE UNDER TEST BED CONDITIONS. WHATEVER THE AMOUNT OF INFORMATION EVENTUALLY GATHERED, IT IS OF PARAMOUNT IMPORTANCE THAT THIS BE **ACCURATE** AND **RELIABLE**.

CIMAC CHECKLIST FOR INFORMATION ON LUBRICANT AND DEPOSIT SAMPLES

FIELD TEST REPORT

BASIC INFORMATION REQUIREMENTS

ENGINE TEST BED REPORT

ADDITIONAL INFORMATION REQUIRED

1. ENGINE

1.1 Make : ______
Type : ______
Engine No : ______
Year Built : ______
MCR : ______
RPM : ______
Total Hours : ______
Cylinder Lubrication : SPLASH, SEPARATE, OTHER: ______
Modifications : ______

			Fitted at M.E. Hours
1.2 Piston Type	:	______	______
Piston Ring Type	:	TOP	______
		2nd	______
		3rd	______
		______	______
		______	______

Piston Temperature, °C : Cooling IN/OUT ______
1st Groove ______
2nd Groove ______
Undercrown ______

Piston Clearance, mm : CROWN LAND - LINER (a) ______
GROOVE - RING (b) ______

2. OPERATION

2.1 Test Hours : ______
% MCR (approx. over period) : ______
Type of Operation : ______
Number of START/STOP : ______
Oil Sump Volume : ______
Average Oil Consumption (Over 24 hrs): ______
(in g/bhp-hr on average LOAD over period)

2.2 Notification of Any Abnormal Behaviour
(to include adverse weather conditions): ______

2.3 Details of daily log records to be attached

CIMAC CHECKLIST FOR INFORMATION ON LUBRICANT AND DEPOSIT SAMPLES

FIELD TEST REPORT

BASIC INFORMATION REQUIREMENTS

3\. FUEL

3.1 For each Supply over Period provide:

(a) grade (CIMAC)	(b) QUANTITY

(c) Also supply:

- copies of analysis (DnV, FOBAS..) if available
- sealed retained sample
- sample after treatment (Before Engine)

ENGINE TEST BED REPORT

ADDITIONAL INFORMATION REQUIRED

3.2 Actual Inspections (CIMAC) for Fuel Before Engine:
[Test Methods as per CIMAC recommendation, otherwise indicate alternative]

Batch ________ ________ ________

Density, 15°C g/ml : ____________
Viscosity, 100°C, cSt : ____________
Flash Point, °C : ____________
Pour Point, °C : ____________
Conradson Carbon, % mass : ____________
Asphaltenes % mass : ____________
Ash, % mass : ____________
Water Content, % vol : ____________
Sulphur, % mass : ____________
Vanadium, ppM : ____________
Aluminium, ppM : ____________
Silicon, ppM : ____________
Sediment Hot Filtration : ____________

4\. LUBRICANT (Provide samples for laboratory testing)

4.1 Physical Characteristics

	FRESH OIL	LUBRICANT IN SERVICE			
		50h	100h	250h	500h
Viscosity, 40°C					
Viscosity, 100°C					
Viscosity Index					
TBN, (D-2896)					
Water Content					
Insolubles(D-893"B")					
Flash Pt. Closed Cup					
Elements (ES) ppM					
(18 elements, min)					

4.2 In addition to the analysis listed for the field test report, provide details in tabular or graphical form of analyses of lubricant in service for a minimum of four samples (in addition to fresh oil) or at intervals of 100 hours (in case of an extended test bed run).

MEMO ITEMS

- o Take samples before topping up with fresh oil
- o Indicate lubricant treatment applied
- o Indicate rate and timing of topping up with fresh oil.

CIMAC CHECKLIST FOR INFORMATION ON LUBRICANT AND DEPOSIT SAMPLES

5\. DEPOSITS

(A) ENGINE TEST BED REPORT

PISTON RATING (clockwise from thrust) ENGINE TEST BED		(1) Crown Land	(2) 1st L.	(3) 2nd L.	(4) Top Groove G.BTTM/R.BACK	(5) 2nd G. G.BTTM/R.BACK	(6) 3rd G. G.BTTM/R.BACK	(7) Scraper Ring SLOT FILL %	(8) Undercrown
Appearance (WET-DRY)	Thrust								
	+90°								
	+180°								
	+270°								
Thickness (MIN-MAX),mm	Thrust								
	+90°								
	+180°								
	+270°								
Hardness (MIN-MAX), "pencil" method	Thrust								
	+90°								
	+180°								
	+270°								

(B) FIELD TEST REPORT (If time available does not allow rating as per ENGINE TEST BED)

Appearance (WET-DRY)								
Thickness (MIN-MAX),mm								
Hardness (MIN-MAX), "pencil" method								

Note: Indicate location of MIN and MAX thickness and hardness

SAMPLES OF DEPOSITS FOR LABORATORY ANALYSIS (sample size : as much as possible)
To be obtained from locations (1) through (5) whereever deposits exhibit MAXIMUM HARDNESS and/or MAXIMUM THICKNESS

SUPPLY IF POSSIBLE, PHOTOGRAPHS OF PISTON WITHOUT RINGS

PISTON RINGS CONDITIONS (sliding face and sides)

TOP : FREE/STUCK (Cold-Hot)* 2ND : FREE/STUCK (Cold-Hot)* 3RD : FREE/STUCK(Cold-Hot)* SCRAPER : FREE/STUCK (Cold-Hot)*

* Delete as applicable

APPENDIX 3

RECOMMENDED STANDARD METHODS FOR USED ENGINE OIL ANALYSES.

1. Introduction

A survey by the CEC IL-21 Investigation Group for Large Diesel Engine Lubrication showed that there is a growing tendency to apply proprietary test methods for routine used oil analysis. These methods are more cost effective and often provide additional information compared with standard methods. However, the application of these non-standard methods leads to problems of interpretation by shipowners and engine manufacturers and creates difficulties in comparing test results from different laboratories.

2. Scope

The purpose of this document is to recommend a number of standard methods with established repeatability and reproducibility, which are widely recognized and applied for used engine oil analysis and which should be used in the event of dispute on the oil condition. It is not the intention to promote these standard methods for routine analysis as they are often too elaborate, not automated and sometimes provide less information in comparison to some proprietary methods. This would lead to an uneconomic burden on industry and would be restrictive.

3. Selection of Test Methods

The selection of tests is based on the CEC IL-21 survey.of the methods for used oil analysis. Preference has been given to internationally acknowledged ISO methods. If no suitable ISO method exists, ASTM methods have been preferred, as they are the most widely used and accepted methods in the petroleum industry. The methods considered are summarised in Appendix 1 and the preferred choice of methods follows.

Using the above criteria the following tests methods are selected and data should be used in the resolution of disputes.

Test	**Method**(1)(2)	**Year** (3)
Density at 15°C, g/ml	ISO 3675	1976
Density at 15°C, g/ml	ASTM D4052	1986
Water, % vol (4)	ISO 3733	1989
Flash Point,Closed Cup, Pensky-Martens,°C	ISO 2719	1986
Diesel Fuel Dilution, % m (5)	ASTM D3524	1986
Pentane Insolubles, % m (A/B)	ASTM D893	1985
Toluene Insolubles, % m (A/B)	ASTM D893	1985
Kin. Viscosity at 100°C, mm²/s	ISO 3104	1976
Kin. Viscosity at 40°C, mm²/s	ISO 3104	1976
Base Number, mg KOH/g	ASTM D2896	1988
Additive element Analysis by Atomic Absorption	ASTM D4628	1986
Inorganic chlorine content	no standard method	
Wear Metals Analysis	no standard method (6)	

For references see page 4

(1) For information a complete list of test methods, which are equivalent or which show only minor differences, is given in Appendix 1.

(2) A short description of the test methods including the scope, a summary, the significance and the precision is shown in Appendix 2.

(3) The most recent issue is shown, but it is recommended that the latest published issue be used.

(4) No standard method is available to differentiate between fresh or seawater. A non-standard method, which could be used to establish the nature of the water contamination is described in Appendix 2.7.

(5) Distilled fuel only.
The problem of heavy fuel determination is presently under study by the CEC IL-21 group.

(6) The test results can differ by applied method, by apparatus and by laboratory. It is therefore recommended to compare only figures obtained by the same method and originating from the same laboratory. The use of trend analysis will minimize the effect of these differences. A discussion and a recommended procedure is shown in Appendix 2.10.

4. Discussion

The test scheme has been selected to provide reliable information on the physical properties, elemental composition and type of contamination of the lubricant. To obtain valid test results on a used oil, it is essential that the analysis be done on a truly representative sample of the oil charge. To obtain such a sample, a good sampling practice is necessary.

The CEC IL-21 group has recommended a code of practice for lubricant sampling on board ship, which also applies to stationary installations. This code of practice, **CEC M-12-T-91**, is included for reference as Appendix 3.

It is fully realised that the tests shown do not provide complete information on the oil composition and properties. Additional information to assist in the identification and causes of field problems can be obtained by applying more extensive testing by either standard or non-standard analytical methods to representative oil samples.

5. Precision

The precision data shown in the following individual method summaries are derived from the methods published by ISO, ASTM et al and have not been independently established by CEC.

6. Acknowledgements: CEC has been granted permission to summarise the ISO and ASTM methods shown in appendices 2.1 to 2.8. These methods are subject to change and the enclosed summaries should not be used as procedures for laboratory use. In all cases, the complete and latest edition of each method should be followed and may be obtained from either:

1. ISO: via National Standards Organisations
2. ASTM: ASTM European Office - 27/29 Knowl Piece - Wilbury Way
   Hitchin - Herts SG4 0SX - UK
   Tel. 44 462 437 933 - Fax: 44 462 433 678

APPENDIX 1

Test methods equivalent or similar to the recommended reference method

TEST	Standard	Equivalent or similar methods				
PROPERTY	ISO	ASTM	I.P.	D.I.N.	AFNOR	JIS
Density at 15°C, g/ml	3675	D1298 D4502	160	51757	1298	
Water, % vol	3733	D95	74	3733	T60113	K2275
Flash Point Pensky-Martens, °C	2719	D93	34	51758	MO7919	K2265
Diesel Fuel Dilution, % m		D3524				
Pentane Insolubles, % m (A/B)		D893		51365	T60157	
Toluene Insolubles, % m (A/B)		D893		51365	T60157	
Kin. Viscosity, mm^2/s	3104	D445	71	51550	T60100	K2283
TBN, mg KOH/g	3771	D2896	276	3771		K2501
Additive Element (1) by Atomic Absorption by Emission Spectro.		D4628 D4951	187			
Wear Metals by Plasma Optical Emission Spectrometry ICP-AES		(2)		(2)		

(1) Applies only for unused oils.

(2) For additional information on these proposed methods refer to Appendix 1.10.

I.S.O	The International Organization for Standardization
A.S.T.M.	American Society for Testing and Materials
I.P.	The Institute of Petroleum
D.I.N.	Deutsches Institut fur Normung
A.F.N.O.R.	Association Francaise de Normalisation
J.I.S.	Japan Industry Specification

APPENDIX 2

Short Description of the Test Methods

2.1 Flash point - Pensky-Martens Closed Cup - IS0 2719

Test:	Flash Point , Pensky-Martens Closed Cup.
Scope:	The method determines the flash point of lubricating oils in a closed cup apparatus.
Summary of Method:	The test portion is heated at a slow constant rate with continual stirring in a cup closed by a cover. A small flame is directed through an opening (kept closed at other times) into the cup at regular temperature intervals with simultaneous interruption of stirring. The flash point is the lowest temperature at which application of the test flame causes the vapour above the test portion to ignite.
Significance:	The method indicates the contamination of lubricating oils with minor amounts of volatile material.

Precision :

Flash Point Range,°C	Repeatability,°C	Reproducibility,°C
104 and under	2	4
above 104	6	8

APPENDIX 2

2.2 Test Method for Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration - ASTM D 2896

Test: Base Number.

Scope: This test method covers the determination of basic constituents in petroleum products by titration with perchloric acid.

Summary of Method: The sample is dissolved in an essentially anhydrous mixture of chlorobenzene and glacial acetic acid and titrated with a solution of perchloric acid in glacial acetic acid with a potentiometric titrimeter.

A glass indicating electrode and a calomel reference electrode are used, the latter being connected with the sample solution by means of a salt bridge.

The meter readings are plotted against the respective volumes of titrating solution, and the end point is taken at the inflection in the resulting curve.

Significance: The method determines the alkaline reserve of the oil.

Precision :

	Repeatability	Reproducibility
All oils with forward titration	3 %	7 %
Used oils requiring back titration	24 %	32 %

2.3 Kinematic Viscosity - ISO 3104

Test:	Kinematic Viscosity
Scope:	The method specifies a procedure for the determination of the kinematic viscosity of liquid petroleum products, both transparent and opaque, by measuring the time for a volume of liquid to flow under gravity through a calibrated glass capillary viscometer.
Summary of Method:	The time is measured, in seconds, for a fixed volume of liquid to flow under gravity through the capillary of a calibrated viscometer under a reproducible driving head and at a closely controlled temperature. The kinematic viscosity is the product of the measured flow time and the calibration constant of the viscometer derived by direct or step-up calibration with distilled water, which is the primary kinematic viscosity standard.
Significance:	The test determines the kinematic viscosity of the used oil.
Precision:	No precision values have been determined for used oils. The values for clean, transparent liquids tested between 15 and 100 °C are:

Repeatability	Reproducibility
0.35 % of the mean (1)	0.7 % of the mean (1)

APPENDIX 2

2.4 Density - ISO 3675

Test: Density

Scope: The method determines, using a glass hydrometer, the density of liquid petroleum products or mixtures of petroleum and non-petroleum products, having a Read vapour pressure of 180 kPa (1.8 bar) or less.

Summary of Method: The sample and a hydrometer cylinder are brought within a prescribed temperature range and a test portion is transferred to the cylinder at approximately the same temperature.

The appropriate hydrometer is lowered into the test portion and allowed to settle. After temperature equilibrium has been reached, the hydrometer scale is read, and the temperature of the test portion is noted.

If necessary the cylinder and its contents are placed in a constant-temperature bath to avoid excessive temperature variation during the test.

Significance: The test determines the density of the used oil.

Precision:

Product	Temperature range	Repeatability	Reproducibility
Transparent low viscosity	-2 to + 24.5°C 29 to 76°F	0.0005 0.0005 g/ml	0.0012 g/ml 0.0012
Opaque	-2 to + 24.5°C 29 to 76°F	0.0006 g/ml 0.0006	0.0015 g/ml 0.0015

APPENDIX 2

2.5 Test Method for Density and Relative Density of Liquids by Digital Density Meter - ASTM D4052

Test:	Density
Scope:	The method determines, using a Mettler/Paar digital density meter, the density or relative density of petroleum distillates and viscous oils at temperatures between 15 and 35 °C with vapour pressures below 80 kPa and viscosities below about 15 000 mm2/s.
Summary of method:	Approximately 0.7 ml of liquid sample is introduced into an oscillating sample tube and the change in oscillation frequency caused by the change in mass of the tube is used in conjunction with calibration data to determine the density of the sample.
Significance:	Density is a fundamental physical property that can be used in conjunction with other properties to characterize the sample.

Precision:

Range g/ml	Repeatability	Reproducibility
0.68 - 0.97	0.0001	0.0005

2.6 Test Method for Insolubles in Used Lubricating Oils - ASTM D893

Test: Insolubles in used lubricating oils

Scope : This test method covers the determination of pentane and toluene insolubles in used lubricating oils.

PROCEDURE A: Covers the determination of insolubles without the use of coagulant.

PROCEDURE B: Covers the determination of insolubles in oils containing detergents and employs a coagulant for both the pentane and toluene insolubles.

Summary of Method:

PROCEDURE A: A sample of used lubricating oil is mixed with pentane and centrifuged.
The oil solution is decanted and the precipitate 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 toluene alcohol solution and once with toluene.
The insoluble material is then dried and weighed to give the insolubles.

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 coagulated toluene insolubles.

Significance : Pentane insolubles indicate the level of used oil contaminants which are not soluble in pentane, such as fuel carbon, salts, resinous matter originating from oil contamination or degradation.
Toluene insolubles indicate the level of used oil contaminants which are not soluble in toluene such as fuel carbon, highly carbonized materials from oil or fuel degradation, inorganic contaminants, salts, wear particles etc.
Resinous matter such as oxidation and nitration products are normally soluble in toluene.

Precision :

PRECISION	INSOLS %m	UNCOAGULATED (PR.A)		COAGULATED (PROC.B)	
		PENTANE	TOLUENE	PENTANE	TOLUENE
REPEATABILITY					
	<1.0	0.7	-	0.7	-
	>1.0	10% of mean	-	10% of mean	-
	0.1	-	0.068	-	0.068
	0.2	-	0.097	-	0.097
	0.3	-	0.12	-	0.12
	0.4	-	0.14	-	0.14
	0.5	-	0.15	-	0.15
	0.6	-	0.17	-	0.17
	0.7	-	0.18	-	0.18
	0.8	-	0.19	-	0.19
REPRODUCIBILITY					
	<1.0	0.10	-	0.10	-
	>1.0	15% of mean	-	15% of mean	-
	0.1	-	0.14	-	0.30
	0.2	-	0.20	-	0.43
	0.3	-	0.24	-	0.53
	0.4	-	0.28	-	0.60
	0.5	-	0.31	-	0.68
	0.6	-	0.34	-	0.74
	0.7	-	0.37	-	0.80
	0.8	-	0.39	-	0.86
	0.9	-	0.42	-	0.91
	1.0	-	0.44	-	0.96
	1.1	-	0.46	-	1.00

2.7 Water content - ISO 3733

Test : Water

Scope: This test method covers the determination of water in petroleum products by the distillation method.

Summary of Method: The material to be tested is heated under reflux with a water-immiscible solvent, which co-distills with the water in the sample.

Condensed solvent and water are continuously separated in a trap, the water settling in the graduated section of the trap and the solvent returning to the still.

Significance: The test method determines the extent of water contamination in the oil sample.

Precision :

	Repeatability	Reproducibility
Water Collected, ml	Difference, ml	Difference, ml
0.0 - 1.0	0.1	0.2
1.1 - 25	0.1 or 2 % of mean, whichever is greater	0.2 or 10 % of mean, whichever is greater

APPENDIX 2

2.8 Test Method for Diesel Fuel Diluent in Used Diesel Engine Oils by Gas Chromatography - ASTM D3524

Test:	Diesel Fuel Diluent in Used Diesel Engine Oils by Gas Chromatography
Scope:	This test method covers the determination of diesel fuel as a contaminant in used lubricating oil.
Summary of Method:	A mixture of n-decane and used lubricating oil is introduced into a gas chromatographic column which separates hydrocarbons in boiling point order. The column temperature is raised at a reproducible rate and the resulting chromatogram is interpreted for diesel fuel dilution. There is some overlap of the boiling ranges of diesel fuel and SAE 30 engine oils, lower viscosity oils and multigrade oils. Moreover the boiling range of SAE 30 oils from various sources can vary appreciably. As a result, the calibration can be altered by as much as 2 %, in terms of fuel dilution. When testing unknown or mixed brands of used engine oil, it should be realized that the precision of the method may be poorer than obtained when calibrating with a new oil representative of the used oil being tested.
Significance:	The method permits the determination of the diesel oil and other low boiling material, which may be indicative for an equivalent problem.
Precision:	The precision was determined for used SAE 30 oils.

Repeatability	Reproducibility
0.3 % m	1.6 % m

2.9 Inorganic Chlorine Content

Discussion:

Presently there is no standard method to differentiate between fresh or seawater contamination.

This information is often essential to establish the origin of the water contamination.

The ASTM D 878 test method for inorganic chlorides and sulfonates in insulating oils is often used. This test method indicates only the presence of inorganic chlorine. It is not quantitative.

There are non-standard methods available which more accurately determine the amount of inorganic chlorine present in used oils.

A distinction between fresh and seawater can be made if the inorganic chlorine content of the used oil sample is known.

We have included an example of a non-standard method which could be applied for this purpose.

Method:

Determination of the inorganic chlorides by use of test kit " Aquaquant 14401 Chloride", available from E. Merck, Darmstadt, Germany.

The method gives a semi-quantitative indication of the water soluble chlorine in the oil.

5 ml of oil sample is mixed with 5 ml of distilled water. The water is separated. A few drops of mercuric thiocyanate and an iron salt are added to 1 ml water. A reaction with the chlorine ions forms chloromercurate (II) anions and ferric thiocyanate.

The red-orange color of the water solution is compared against a color scale indicating a chlorine content graduation of 0-5-10-20-40-75-150-300 ppm.

Provided all inorganic chlorides are originating from the water contamination and no water is evaporated, the inorganic chlorine content of the water can be calculated as follows.

$$\frac{\text{ppm chlorine} \times 100}{\text{\% water in the oil sample}}$$

This semi-quantitative determination of the inorganic chlorine concentration in the water implies a differentiation between fresh and sea water.

APPENDIX 2

2.10 Wear Metal Analysis

There is no standard method to determine the wear metal content of lubricating oils, despite the fact that this information is considered by shipowners, engine manufacturers and oil companies as indicative of wear of different components of the engine.

However, there is extensive literature on various methods one can use.

Two methods are most commonly used:

the first one is based on ATOMIC ABSORPTION (A.A) and

the second one PLASMA EMISSION SPECTROMETRY (P.E.S).

In the first method, a diluted sample of the lubricating oil to be analyzed is burnt in the flame of an A.A. spectrometer. The absorbance corresponding to each element is measured and compared with a standard.

In the second method, a diluted sample of the lubricating oil is injected by a nebulizer into a plasma where the atoms are excited. The specific emission intensity for each element is compared with standards similarly prepared.

The P.E.S. method is more often used for the advantages it provides, for example :

- Capacity to determine as many as 20 elements at the same time.
- Easy automation.
- Increased sensitivity and reduced chemical interferences.

Whatever the method, the particles greater than 5 microns are not completely detected i.e. wear element concentration may be under estimated.

It should be emphasized that, according to the type of apparatus, sample preparation, standards used, plasma used, selected wave lengths, results obtained can be very different. It is most important for comparisons and for plotting for trend analysis, that the data are generated by the same laboratory, the same apparatus and by the same methods.

Information added at drafting date :

The ASTM Committee D2 (Petroleum Products and Lubricants) has been considering a proposed ICP-AES method for wear, contaminant and additive elements/metals. An extensive round robin was held 1.5 years ago and balloted with two negatives concerning oils with particulate matter. The method was withdrawn pending resolution of those negative votes. The method was subsequently re-balloted in Autumn 1990 with no negatives and will be forwarded for D2 ballot in June 1991. It is proposed that the draft method become a full method in the 1992 ASTM books.

EG and G AR have conducted an independent round robin on used oil analysis by ICP-AES. Their data will be made available to the ASTM Study Group.

As soon as the ICP-AES method receives approved status the ASTM number should be added to the list of recommended standard test methods for used oil analyses, footnotes removed or modified accordingly, and the method summary included in Appendix 1.2.

CODE OF PRACTICE

REPRESENTATIVE SAMPLING OF ENGINE LUBRICANTS ON BOARD SHIP

(CEC M-12-T-90)

1. *Introduction*

In assessing the significance of the results of the analysis of any used engine oil, it must be assumed that the sample of lubricant provided is truly representative of the complete oil charge from which it was taken. The responsibility for securing a valid sample must rest with the ship's engineer for whom this Code of Practice for proper sampling has been prepared.

There are three basic requirements for preparing a sample for analysis.

1. The sample must be representative of the total oil charge within the engine system.
2. The sample taken must not become contaminated after collection.
3. The sample must be fully identified and correctly packaged before despatch to the laboratory.

The following guidance is given to ensure that the small oil sample despatched for analysis is fully representative of the condition of the complete oil charge, which in practice may be of several tonnes.

2. *Recommended sampling procedure*

2.1 The same sampling location must be used each time that a sample is taken.

2.2 Samples should be drawn from a sampling cock which has been specially fitted for this purpose.

2.3 The preferred location for the sampling cock is in the main oil supply line into the engine and after the full flow filter.
Figure 1 indicates this location (and alternative good sampling points) which will depend upon the precise layout of each installation.

2.4 Ensure that the total quantity of oil in circulation is approximately the same immediately prior to drawing each sample.

2.5 Draw samples only when the engine is running and the oil has reached its normal operating temperature.

2.6 Thoroughly purge the sampling cock and associated connections until all cold stagnant oil has been completely cleared and hot oil is flowing steadily from the outlet point.

2.7 Draw oil samples directly into clean, dry containers of one litre capacity.

2.8 Draw samples during a period of about ten minutes for larger engines (> 2MW) or five minutes for smaller engines (< 2 MW).

2.9 After drawing the sample, mix it thoroughly before decanting into the sample bottle provided for the purpose; it should not be filled to more than 90% of its capacity.

3. *Unacceptable sampling*

Unsatisfactory sample will result if used oil is drawn from areas of stagnation or where little flow is occurring. These include:

- Sumps
- Auxiliary/smaller pipelines
- Purifier suction lines or discharge lines
- Drain cocks of filters, coolers etc.

Samples drawn from such points will not be representative of the bulk of the oil in active circulation.

4. *Safety*

The compilers and publisher of this document have assumed that persons implementing its recommendations ensure their compliance with employer standards and/or local or national legislation regulating the handling of and exposure to used engine oils. For additional information please refer to, for example, Concawe Report 3/82 *"Precautionary advice on the handling of used engine oils"* and Concawe Report 5/87 *"Health aspects of lubricants"*.

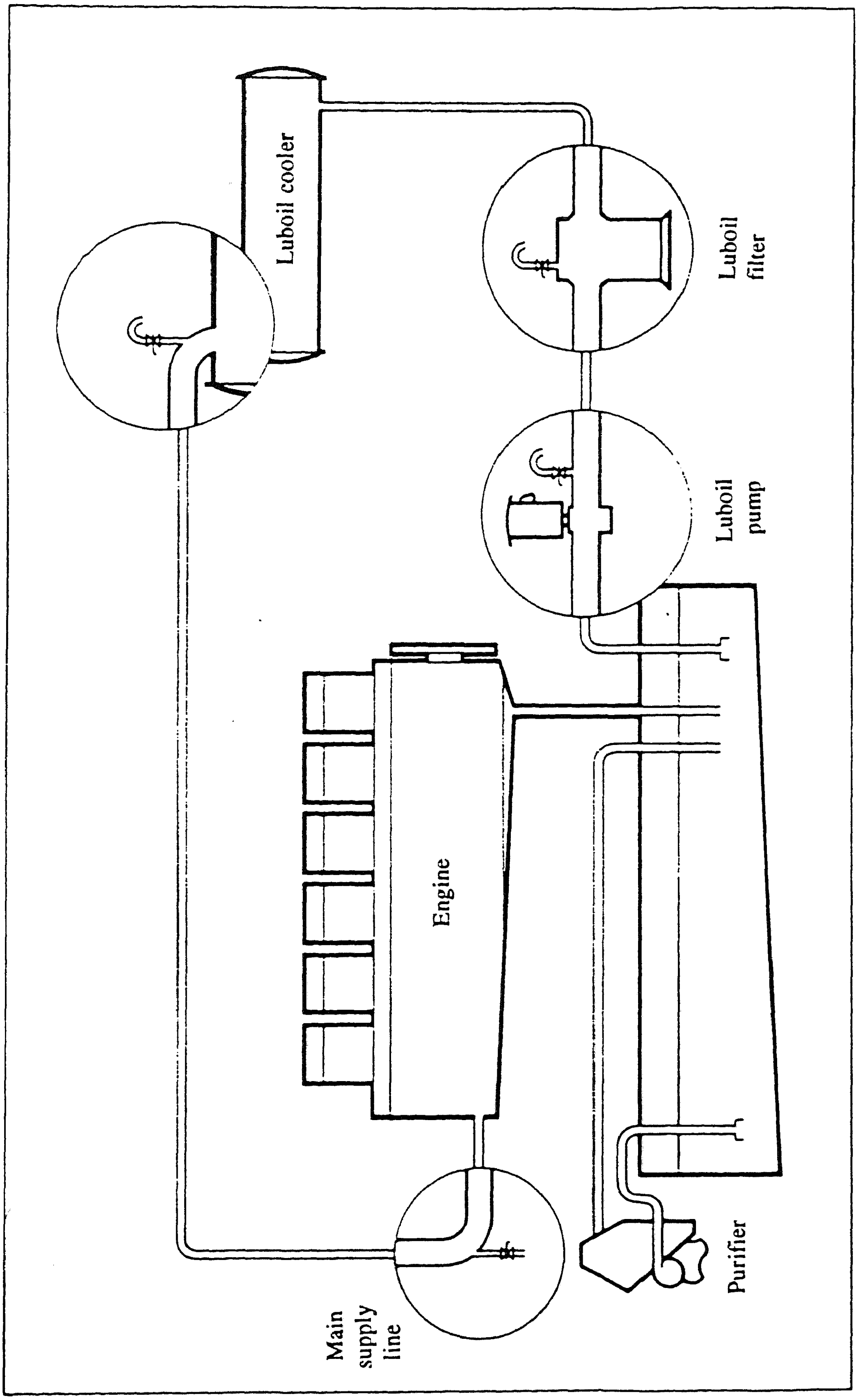

Figure 1 Good sampling locations

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