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TREATMENT OF THE SYSTEM OIL IN MEDIUM SPEED AND CROSSHEAD DIESEL ENGINE INSTALLATIONS

The International Council on Combustion Engines

Conseil International des Machines à Combustion

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

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

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

This document has been elaborated by the CIMAC Working Group “Marine Lubricants“
and approved by CIMAC in September 2005.

CIMAC Central Secretariat
c/o VDMA e.V.
Lyoner Str. 18
60528 Frankfurt/Main
Germany

Phone: +49 69 6603-1355
Fax: +49 69 5503-2355
E-mail: cimac@vdma.org
Web: http://www.cimac.com

FOREWORD BY THE PRESIDENT

Contamination of the system lubricant must be maintained to safeguard the reliable operation of diesel engines. Reciprocating engines benefit from operation with good quality lubricants that are designed for particular applications and operational conditions.

The present Recommendation on “Treatment of the System Oil in Medium Speed and Crosshead Diesel Engine Installations” was prepared by the CIMAC Working Group “Marine Lubricants”.

This Recommendation describes the treatment technology of system lubricant. It clarifies why treatment is necessary and what consequences can result from insufficient treatment of lubricant. The various types of contaminants have been handled and the components of the system are described.

Anyone with an interest in engine lubrication should find this paper informative and useful. My sincere thanks to the authors and to all those members of the Working Group who put efforts into elaborating this CIMAC Recommendation.

Matti Kleimola, President
September 2005

CONSEIL INTERNATIONAL DES MACHINES A COMBUSTION

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INTERNATIONAL COUNCIL ON COMBUSTION ENGINES

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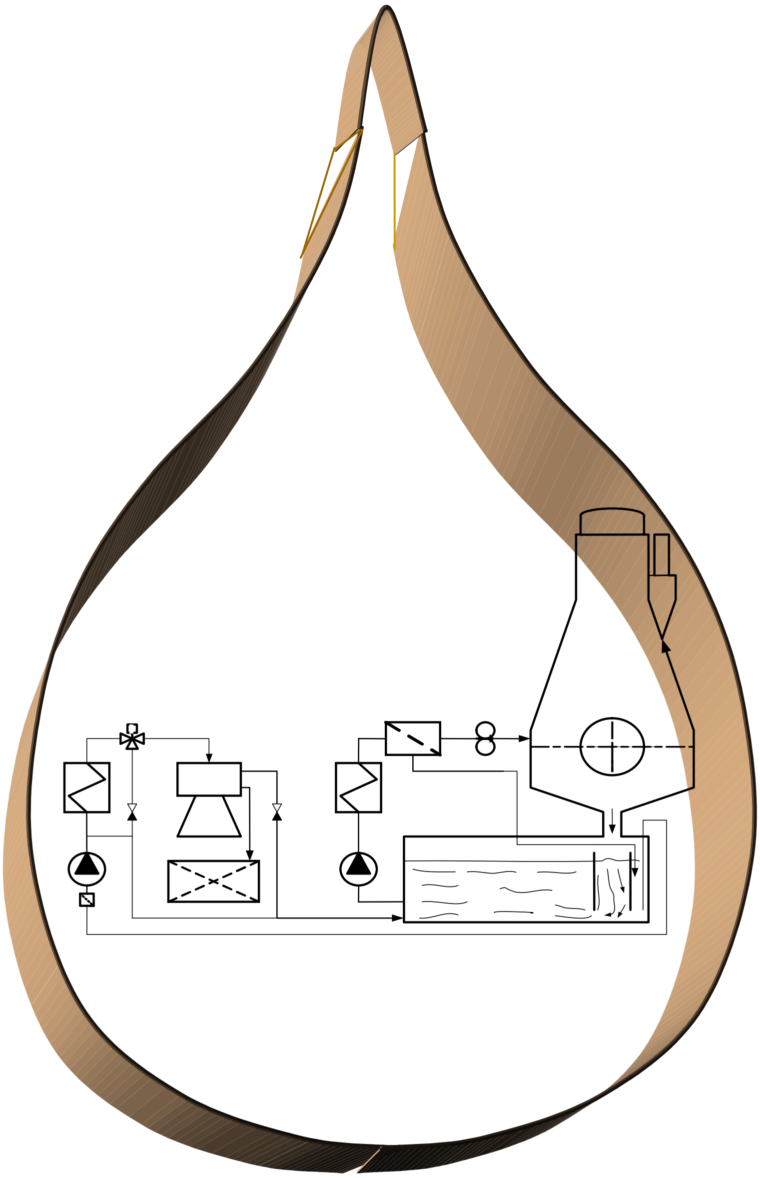

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PREFACE

This document describes the system to treat the system lubricant of medium speed and crosshead diesel engines. It explains why treatment is necessary and what the consequences are of inadequate treatment of the lubricant. The various types of contaminants in the lube oil are discussed and the components of the system are described. Recommendations on how to operate the system are also given.

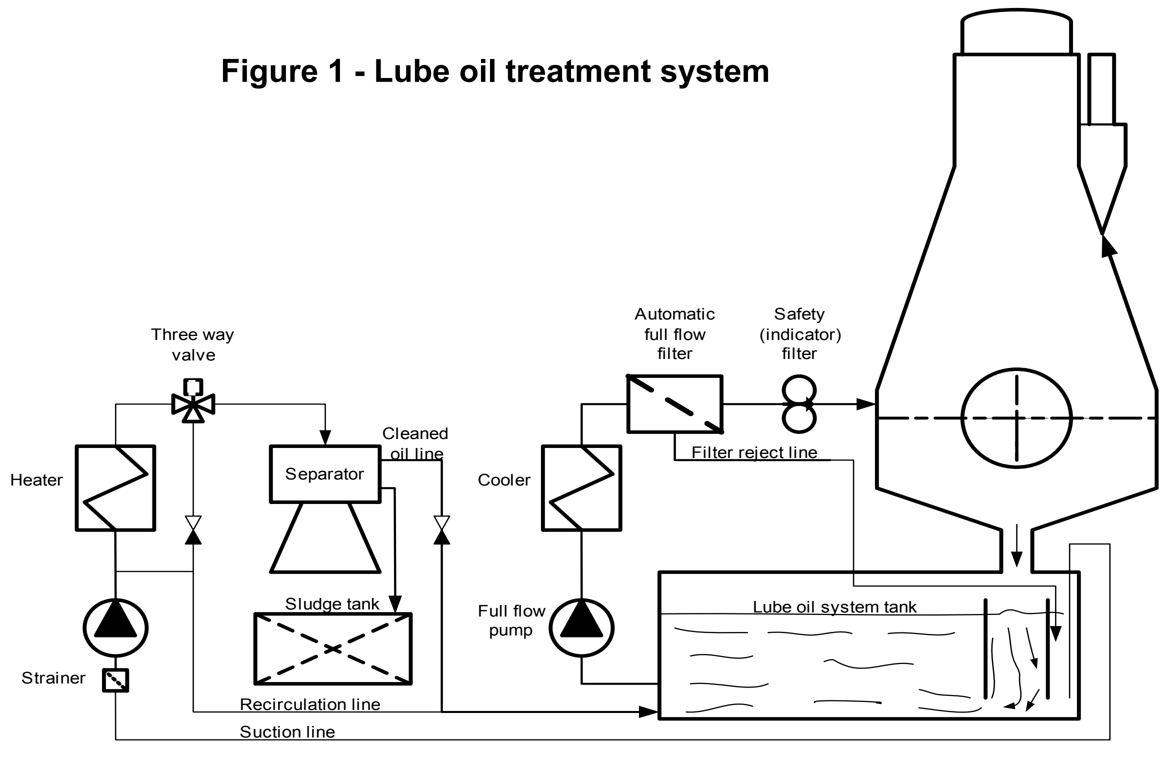
1. INTRODUCTION

Modern diesel engines benefit from operation with good quality lubricants that are appropriate for the application, as recommended by the engine manufacturer. Such lubricants are a complex and delicately balanced mixture of base oil (refined crude oil) and chemicals known as additives, designed to enhance base oil properties. During engine operation the oil becomes contaminated, additives become depleted, and the lubricant degrades. Consequently, treatment is required to restore the lubricant so that it retains the required properties and can therefore perform its functions adequately. Hence, the engines are equipped with a treatment system comprised of a full-flow filter, a centrifugal separator (operated in by-pass to the full-flow system), and in some engines a centrifugal by-pass filter.

2. LUBE OIL TREATMENT SYSTEM

Figure 1 shows the typical layout of a lube oil treatment system of a medium speed or crosshead diesel engine.

Figure 1 - Lube oil treatment system



The lube oil treatment system consists of two major parts:

- The cleaning system: to keep the level of contaminants in the lubricant at an acceptable low level.

- The protection system: to protect the engine from harmful particles not removed by the cleaning system.

3. THE NEED FOR CLEANING AND PROTECTION

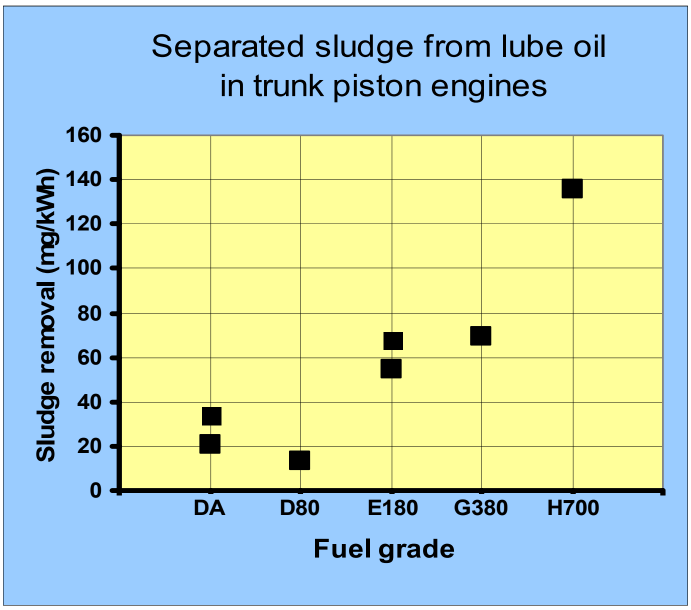
Contamination of the system lubricant must be kept at a low level to safeguard the good and safe operation of diesel engines.

During the operation of the engine, a variety of contaminants are formed, which end up dispersed in the lube oil or deposited on the internal surfaces of the engine. Most of the impurities are produced by the engine itself but some can come from different external sources, e.g. the oil refill and the vent pipe.

The contaminants consist of wear debris, combustion products, partly-burned or raw fuel, water and decomposition products from the additives or the lube oil itself. The actual contaminants and level of contamination will depend on the type of engine, medium speed or crosshead, engine operation, and the fuel used.

Figure 2 (data from Alfa-Laval from field tests onboard ships and power stations) gives an indication of the amount of sludge (lube oil contaminants) that is removed from the lubricant by the centrifugal separator. A typical sludge production rate is approximately 70 mg/kWh when burning HFO 380 (HFO = Heavy Fuel Oil). This means that a 10 000 kW engine produces about 0.7 kg sludge per hour. This sludge must be removed from the oil system in order to safeguard a good function of the engine.

Figure 2 – Amount of Sludge Removed from Lube Oil



3.1 Differences between Medium Speed and Crosshead Diesel Engines

In crosshead engines, a piston rod stuffing box separates the combustion chamber and the scavenge air space from the crankcase. The cylinder is lubricated by a high BN SAE 50 cylinder lubricant and the crankcase is lubricated by a low BN SAE 30 system oil, which is also used to cool the piston (except for some older designs which use water for piston cooling). The system oil is treated and re-used whereas the cylinder lubricating oil is a once-through product.

In medium speed engines, the combustion chamber and the crankcase are not totally separated and the lubricant is treated and re-used for both the cylinder and the crankcase. A few older medium speed engines are designed with a separate cylinder lubrication with fresh oil.

The oil in medium speed engines is contaminated with combustion products in the combustion chamber or via blow-by, and with fuel through the injection system; the crosshead engine system oil is contaminated through the piston rod stuffing box.

As a result, the lubricant of medium speed engines is contaminated to a much larger extent with combustion products and fuel than the system oil of crosshead engines.

In crosshead engines, a mixture of (used) cylinder lubricant, wear debris and to a lesser extent also partly burned fuel is formed in the scavenge air space above the stuffing box. In the event that such mixture should enter the crankcase through the piston rod stuffing box and contaminate the lubricant, the viscosity and BN of the system oil will increase.

The Table below summarizes contamination in the two engine types.

Table 1 – System Oil Contaminants and Their Origin

Contaminant	Origin	
	Trunk Piston Engine	Crosshead Engine
Used cylinder lubricant (BN)	-	Through stuffing box
Used cylinder lubricant ($CaSO_4$)	Combustion chamber	
Combustion products	Combustion chamber and/or blow-by	Through stuffing box (minor amount)
Unburned or partly burned fuel	Combustion chamber and/or blow-by and leakages	Through stuffing box (minor amount)
Wear debris	Engine and/or lubrication system components	
	-	Through stuffing box (minor amount)
Water	Combustion chamber and crankcase. Leakage from coolers, cooling jacket and separator. Condensation	Scavenge air (through stuffing box). Leakage from coolers cooling jacket and separator. Condensation
Additive decomposition	Lube oil	

The principles and risks of contamination with the different components are explained in more detail below.

3.2 Combustion Products and BN Depletion

During the combustion process sulphur present in the fuel is converted into sulphur oxides. A minor part of the sulphur oxides reacts with water to form sulphuric acid.

In medium speed engines, sulphuric acid entering the lube oil (either in the cylinder or in the crankcase via blow-by) is neutralized by the over-based additives with formation of calcium sulphate. As a result, the BN of the system oil is reduced.

In crosshead engines, the system oil is contaminated through the stuffing box with waste cylinder lubricant containing both used (calcium sulphate) and unused (BN) additive. The waste cylinder lubricant contaminant is often higher BN than the system oil, and this will result in the increase of system oil BN.

When the engine is running on heavy fuel oil (HFO) with a high sulphur content, calcium sulphate often becomes one of the major contaminants in the lube oil.

The other solid contaminants from combustion are soot and ash particles.

3.3 Fuel

Contamination of the lube oil with HFO is a well-known problem in medium speed engines.

There are different sources to this contamination:-

- fuel leakage, especially in fuel pumps,
- unburned or partially burned fuel components in the blow-by. The latter is key to the heavier residual fraction contamination.

The ingress of fuel into the lube oil may lead to the formation of sludge by precipitation of asphaltenes and other products that co-precipitate.

It is not easy to remove fuel or fuel components from the lube oil. The reason is that although fuel and lube oil possess different properties they do share some chemical compositional characteristics [1]. To a certain extent it is possible to remove heavy components (mainly asphaltenes) from the lube oil in the centrifugal separator. Investigations however, have shown that the efficiency of the centrifugal separator in removing asphaltenes from the lube oil is very low; and this can also be influenced by the disersancy of the lubricant.

The dispersancy of modern lubricants can improve the compatibility with HFO. This helps to preserve the engine from problems, such as black sludge, piston undercrown deposits or fuel pump sticking. However, a side effect of this improved compatibility could be some loss in the centrifugal separation efficiency.

3.4 <u>Water</u>

Water in the system oil is undesirable as it can interfere with lubrication and there is the risk of corrosion. The lube oil can be contaminated with fresh water and/or sea water.

Fresh water can enter the lube oil by leakage from:-

- coolers
- cylinder cooling jackets
- by poorly set or optimised centrifugal separators
- by condensation, e.g. after the engine is stopped, some of the water vapour, present in blow-by gases, condenses to water droplets and becomes dispersed in the lube oil,

High water content can lead to the overbased additive precipitated as insoluble calcium carbonate.

In crosshead engines, the system oil can be contaminated with water entering the crankcase through the stuffing box. This may happen when water in the scavenge air is not removed sufficiently in the charge air cooler.

Salt water in the system oil originates from leakages of coolers that are using seawater.

The centrifugal separator should be able to remove the water from the system oil. However, sometimes water contamination leads to the formation of a stable emulsion which will not settle or centrifuge out. Water and emulsion are harmful since it reduces the load-carrying capacity of the oil. In such a case the oil will have to be renewed.

Alkaline detergents and other additives are sensitive to depletion by water forming sludge that is deposited in the centrifugal separator.

Seawater is corrosive and therefore potentially harmful. When the oil is contaminated with seawater, the lube oil supplier should be contacted.

4. CLEANING AND PROTECTION METHODS

The removal of particles and water from the lube oil is done by centrifugal separators. Additionally filters also help to protect the engine against the larger harmful particles.

The filter separates particles from the oil by retaining particles bigger than the mesh size of the filter media. Filters are, however, limited in their sludge and water handling capability.

Filters can only be justified as the sole cleaning equipment for small engines operating on gas oil. Filters only are **not** sufficient for large engines or engines operating on heavy fuel oil.

The separation of particles and water droplets in a centrifugal separator is dependent of the particle size and the density difference between the particle and the oil. The oil viscosity at the separation temperature has a strong influence on the particle removal. The centrifugal separator has a large sludge handling capability and can remove theoretically particles down to a size of one micron. The centrifugal separator can also remove large volumes of water from the oil.

Normally both a filter and a centrifugal separator are installed. The main task of the **filter** is to **protect** the engine from harmful particles. The filters are therefore typically placed in the full flow system. The **centrifugal separator** task is to keep the oil **clean** from particles and water. This is done by removal of particles and water from the oil with intermittent discharge of separated sludge to a separate sludge tank.

5. THE LUBE OIL CLEANING SYSTEM

5.1 Task

The task of the lube oil cleaning system is to remove particles and water from the lube oil and to keep the level of contaminants at an acceptable level.

5.2 Design

The major components of the lube oil cleaning system are:

- Centrifugal separator feed pump
- Lube oil pre-heater
- Three-way-valve for re-circulation of the oil during start up and in alarm situations
- Centrifugal separator
- Centrifugal separator sludge tank

5.3 Centrifugal Separator Feed Pump

A positive displacement pump operated at constant capacity should be installed close to the lube oil sump/tank with a strainer on the suction side of the pump to protect the pump from coarse solids in the oil.

The flow rate to the centrifugal separator should be constant to maintain good separation. Preferably the pump motor should be of low speed to minimize agitation of the oil and avoid emulsification if water is present.

In order to increase the dwell time in the tank and minimise foaming, the suction pipe of the pump should be fitted close to the bottom of the lube oil sump/tank and sufficiently far from the lube oil return line of the crankcase.

In many typically installations, the back-flushed oil from the full flow filter is returned to the sump tank. Ideally this return line should be at a location close to the centrifugal separator suction.

5.4 Oil Pre-Heater

The recommended processing temperature for a lube oil cleaning system is 95 ± 2ºC. The maximum temperature should not exceed 100°C in order to prevent any water that may be present from boiling. The temperature control is of utmost importance for the centrifugal separator in order to operate at the highest possible efficiency (see the remark in bold under 5.5.3).

Preheating of lube oil before separation is done in heaters which are carefully designed and controlled in order to avoid operational problems and minimise energy consumption.

The most common heaters on board ships are steam heaters.

Other fluid heat sources are hot water and thermal oil.

A large proportion of the smaller tonnage ships and the power industry use electric heaters.

Some of the most common sources of problems with lube oil cleaning systems are undersized heaters, heaters that have very poor temperature control and components that are not adapted to each other (to form a well operating control system).

In case steam is used as heat source it is very important that the steam valve is of the correct size. A valve with *"equal percentage characteristics"* is recommended [2].

When the system is operating at the recommended flow rate, the steam valve should have a flow margin of 25 to 50% to ensure good control.

In case of electric heating, the heating elements should be specially designed for lube oil pre-heating. Local overheating may lead to depletion of the additives and to deposits on the heating surface. To avoid this, the electric load on the heater element should be less than 2.0 W/cm^2, depending on the type of heater.

In order to avoid temperature fluctuations the temperature control should be of the Proportional Integral type (PI-type). A Proportional-Controller (P-type) always has a built-in temperature offset and is therefore not preferred

There can be several reasons why the temperature cannot be kept constant:

- The temperature controller is of the Proportional-Controller type
- The heater is undersized
- The heater is dirty

There is an important difference between electric heaters and those operating on steam, hot water or thermal oil. The fluid operating heaters, are by design safe in that the temperature in the heater will never exceed the temperature of the heating medium. In such heaters, the **heat transfer** is the dependent parameter adapting to prevailing temperature, flow conditions and the degree of fouling on the heating surface.

Electric heaters, on the other hand, have a constant heat transfer with the **temperature** as the dependent parameter. The temperature is not limited by the heating process itself and will rise very high if not regulated by the control system. Such heaters should always be equipped with a mechanical temperature guard.

When selecting heaters for preheating of the lube oil, the following factors should be considered (especially for heaters with high surface load such as electric heaters):

- The oil flow through the heater should be turbulent in order to have optimum thermal efficiency and to avoid deposits on the heating surfaces.
- The temperature on the surface of the heating elements should not be too high.
- The heater must not have “dead” zones where the oil flow is zero or close to zero. This could lead to hot spots with fouling as a consequence.
- There should be no “short cuts” of oil flow in the heater.
- The contact time between the oil and the heating surface should not be longer than necessary. A short retention time also gives a system with a fast response to changes in the process parameters ensuring fast and accurate control of the lube oil temperature. A short retention time should not lead to an undersized heater.

Steam / Hot Water / Thermal Oil Heaters

The most common lube oil pre-heater is of the shell-and-tube design. The design is simple and it is easy to inspect, clean and repair the heating surface. The shell can be with or without baffles inside. Heaters without baffles may suffer from irregular flow conditions, which can result in poor heat transfer.

There are certain disadvantages connected with shell-and-tube heaters:

- The size is large and much space is needed for dismantling the tubes.
- Slow temperature control due to large oil volume
- Poor turbulence or even laminar flow leading to fouling and slow temperature control.
- Complete cleaning is very difficult, especially for fin-type tubes.

Plate Heat Exchangers

Plate-heat-exchangers (PHE) are frequently used as lube oil pre-heaters. The PHE provides both a short retention time and a highly turbulent flow. The size is much smaller than that of a shell-and-tube heater. The PHE is easy to disassembly, maintain and repair. Single plates can be replaced if necessary.

A special type of PHE is the braised PHE with the corrugated steel plates braised together.

5.5 Centrifugal Separator

5.5.1 Matching of Centrifugal Separator Size to Operation Requirement

The following parameters should be taken into account when selecting a centrifugal separator:

- Type of engine (trunk or crosshead)
- Type of fuel (GO, MDO, HFO)
- Engine output
- Number of lube oil passes per 24h (engine manufacturers specification)

With respect to the size and flow rate of a lube oil cleaning plant, the recommendation from the centrifugal separator manufacturer (or engine maker) should be followed. In general, the flow rate should be proportional to the power output of the engine:

$$\mathbf{Q = k \cdot P}$$

Q = flow rate
k = sizing factor (to be obtained from the centrifugal separator manufacturer or engine maker)
P = engine output at MCR

5.5.2 Recommendations for Centrifugal Separator Operation

The centrifugal separator should be in continuous operation as the engine is running in order to ensure removal of contaminants as quickly as possible. If possible, the centrifugal separator should be in operation also when the engine is shut down to further reduce the level of contaminants. In the latter case, oil temperature for efficiency separation needs to be maintained through heaters. Those installations with their separation plant shut down during engine stop, should consider re-starting the separator prior to engine start-up because contamination (engine leaks, condensation) could have occurred during engine stop.

The cleaning systems of auxiliary engines are often designed such that the centrifugal separator intermittently serves one engine at a time. Depending upon the operating time between two periods of oil cleaning the discharge time may have to be shortened during the first couple of hours. In this way the centrifugal separator will be able to cope with the high level of contaminants at the beginning of the cleaning phase. The appropriate discharge interval has to be found by trial and error.

It is important that maintenance and operation of the centrifugal separator is done according to the recommendations of the manufacturer.

5.5.3 Importance of Correct Separation Temperature

During separation the oil temperature is of utmost importance. The settling velocity of particles and water in a centrifugal separator follows the (law of nature known as) Stoke´s Law:

$$\mathbf{V_p = \frac{D^2 \cdot (\rho_p - \rho_0)}{18 \cdot v \cdot \rho_0} \cdot g_c}$$

V_p = settling velocity of particles
D = particle diameter
ρ_p = particle density
ρ_o = oil density
v = kinematic viscosity of the oil
g_c = centrifugal acceleration

The higher the temperature the better the separation efficiency. Both density and viscosity of the oil decrease when the temperature rises, thereby increasing the settling velocity.

If the separation temperature is lowered from 95ºC to 90ºC the centrifugal separator throughput has to be reduced by 22% to maintain the same separation efficiency!!

5.5.4 Types of Centrifugal Separators

For cleaning of the lube oil there are two types of centrifugal separator systems available on the market: the purifier system and the clarifier system.

The purifier is a centrifugal separator with continuous water outlet which depends on a water seal that is controlled by a gravity disc. The choice of the gravity disc depends on the oil density, the oil viscosity, the separation temperature, and the flow rate. All purifiers have a paring disc for discharge of cleaned oil. Certain types have also a pumping device in the water outlet.

The clarifier does not have a water seal and gravity disc. Consequently there is no continuous water outlet. All clarifiers have a paring disc for discharge of cleaned oil. Separated water accumulates together with separated solid material at the periphery of the bowl. To protect the centrifugal separator from being overfilled with water the clarifier system has a water-monitoring device to ensure that no water enters the cleaned oil outlet. Discharge of solid material and water is done intermittently and controlled by a timer or water-sensing device. It is important to know that after discharge the bowl has to be primed with a small amount of water before the oil feed is started again. This is to give the sludge a consistency to ensure ease of discharge.

5.5.5 Centrifugal Separator Waste

During operation of the centrifugal separator solid material and water are transported by centrifugal force to the periphery of the centrifugal separator bowl. The material with the higher density settles at the bowl wall and water accumulates between this material and the oil.

In case of a highly detergent lube oil the water layer may consist of an oil in water emulsion as the continuous phase with gradually increasing concentration of emulsified oil towards the oil phase.

When a purifier is used, the water is continuously discharged through the heavy phase outlet. Only solid material accumulates at the periphery with the water seal between the solid material and the oil.

When the separated solid material and water is discharged, the oil in the centrifugal separator bowl is first displaced by water in order to minimise the loss of lube oil. The water fills the centrifugal separator bowl pushing the lube oil out through the cleaned oil outlet. This displacement can be more or less complete depending on the type of centrifugal separator. In the case of partial discharge centrifugal separators, the displacement by water will only comprise that part of the total bowl volume being discharged. In centrifugal separators with total discharge of the bowl volume the displacement has to be as complete as possible without overfilling the bowl as this will result in water ingress into the cleaned oil. The centrifugal separator bowl volume is partially or totally discharged into the centrifugal separator sludge tank normally situated underneath the centrifugal separator.

The water necessary for the operation of the centrifugal separator maneuvering system also ends up in the centrifugal separator sludge tank

A typical composition of the material in the centrifugal separator sludge tank is shown below:

Table 2 - Composition of Centrifugal Separator Waste

Type of separator	Water %	Oil %	Solid Material %
Total discharge purifier	80 - 90	9 - 17	1 - 3
Partial discharge clarifier and purifier	93 - 97	1 - 4	2 - 3
Modern total discharge clarifier	90 - 93	3 - 5	4 - 5

The content in the centrifugal separator sludge tanks is transferred to a common sludge tank where different waste streams are collected; these include, the settling and day tank drainage, centrifugal separator waste, and waste from fuel (back-flush) filters. The composition of the content in the common sludge tank may differ substantially from that in the centrifugal separator sludge tank. For instance, drainage from the settling and day tank and reject material from back-flushing filters may increase the oil content.

Normally the waste material in the common sludge tank is landed for disposal at a substantial cost per ton.

There are systems on the market designed to reduce the landed volume to a minimum. These include the separation of water and oil for further treatment in the bilge system or by use of the waste as burner or incinerator fuel.

Sometimes specially designed centrifugal separators are used that separate the water and oil from the sludge tank. The water quality obtained is such that it can be transferred to the bilge system for further treatment and the cleaned oil contains in the order of 1 to 15 % water.

There are chemical demulsifiers available on the market that can be helpful when there are high levels of emulsion in the sludge tank. Correct dosing of such a demulsifier can drastically improve the degree of separation.

Separation of water and oil can reduce the initial sludge volume by 80 % or more.

5.5.6 Effect of Separation on Lube Oil Analysis

The efficiency of the centrifugal separator is generally not reflected in the routine lube oil analysis (viscosity, BN, etc.). For instance, the comparison of the analysis results of lube oil samples drawn before and after the centrifugal separator, may reveal no differences. **This can lead to the wrong interpretation and conclusion that the centrifugal separator is not working correctly.**

Routine lube oil analysis usually includes viscosity, BN, water, insolubles, oxidation and inorganic constituents. These may be analysed using standard industry methods, but some laboratories also use in-house methods for expediency (when catering for large number of samples) or for additional proprietary information.

Viscosity is mainly influenced by contaminants that cannot be fully removed by separation.

BN is normally not influenced by separation.

Reduction of water can only be observed when the water content in the lube oil is above approx. 0.2%.

"Insolubles" test methods measure the amount of contaminants that precipitate from the lube oil after the addition of a solvent eg pentane, heptane etc. Only a small portion of these "insolubles" were insoluble in the lube oil before addition of the solvent and therefore only this small portion belongs to the contaminants that could be removed by separation. The main fraction of the so called "insolubles" is not affected by the separation process. The pentane insolubles are usually in the order of 0.05-2.0% whereas the separable sludge is in the order of 0.005-0.05% by weight.

Oxidation products are dissolved or dispersed in the oil and therefore cannot be removed by the separation process.

Inorganic constituents are normally measured by ASTM D5185-02. However, this method can only measure particles smaller than 5–10 µm. Bigger particles can be measured if the oil sample is ashed but this is not done in routine analysis.

One method to demonstrate that the centrifugal separator is cleaning the oil effectively is to measure the number of particles in relation to the particle size. Usually, large particles (> 5 µm) are removed very effectively. This is important because bigger particles are more harmful. The efficiency of the removal of smaller particles is quite low. However, the method is only available in a limited number of laboratories.

5.6 Crosshead Engine Stuffing Box Leakage Oil

In crosshead engines, the cylinder is separated from the crankcase by a seal arrangement on the piston connecting rod known as the stuffing box.

In the scavenge space above the stuffing box, a viscous mixture is formed. It consists mostly of cylinder oil with used and unused additives, system oil, water, and combustion residues. A part of this viscous liquid continuously drains through the stuffing box contaminating the system oil.

The stuffing box has a drain pipe and the oil removed through this consists mainly of system oil and to a lesser extent, scavenge space oil.

The amount of stuffing box leakage oil depends on the engine type and can vary from cylinder to cylinder. The average value in older engines is about 20 l/day/cylinder. Technical development of stuffing box and connecting rod ((eg harness) in newer engines has reduced the stuffing box leakage oil amount to 0 - 10 l/day/cylinder.

As the stuffing box leak oil consists of up to 80% system oil, a considerable amount of system oil might be lost this way. Therefore, some installations are equipped with a unit to clean the drain oil.

The stuffing box cleaning unit consists of a tank and a fine filter. The drained oil is pumped through the fine filter of only a few microns mesh and then returned to the system oil sump.

The fine filter will clean the drain oil of combustion residues and wear particles. **However, used additives will remain in the oil, i.e. a stuffing box cleaning unit will not prevent increase in the BN and viscosity of the system oil. It is for this reason that engine builders are not in favour of this practice.**

6. THE ENGINE PROTECTION SYSTEM

The engine protection system normally consists of the following components:

- Full flow filter, which can be a surface filter or a depth filter
- Safety indicator filter

6.1 Task of Full Flow Filter

The task of the engine protection system is to protect the engine from abrasive particles. Therefore, a filter is installed in the full flow oil circuit just before the engine. As the centrifugal separator operates in parallel to the full flow circuit and only at a flow rate typically in the order of 1% of the full flow, there is always the risk that solid contaminants have not (yet) been removed by the centrifugal separator.

The function of the full-flow filter is to protect the engine from harmful larger particles rather than to remove sludge.

6.2 Filter Types

Surface filters are normally used to protect large diesel engines burning heavy fuel oil. They operate with filter media made of wire mesh. When the pressure drop over the filter indicates the presence of a sludge layer, the filter elements have to be cleaned by back flushing; this is done automatically or by manually operation. Normally the filter mesh is clean or almost clean.

The main parameter of a filter is the mesh size, which is the size of the openings in the filter.

Absolute mesh size is defined as the size of the biggest spherical particle that will pass through the mesh (larger particles may pass if they are elongated). This definition gives a virtual understanding of the mesh openings.

Nominal mesh size, is defined as the size of particles of which 85 to 90% are retained in practical use. This definition, which is purely empirical, is dependent on the particle shapes. It does not give a clear understanding of the filter mesh geometry but gives flexibility to the filter manufacturers.

The nominal mesh size is always smaller than the absolute mesh size. The ratio between the two depends on the wire structure, the mesh size and on the particle shape and size distribution. For particles in the range of 5 to 50 microns the ratio of the absolute to nominal mesh size is of the order of 1.5:1.0.

The selected mesh size depends on the requirements of the engine supplier. The absolute mesh size of the full flow filter is typically 35 microns (20 microns in terms of nominal size).

In most cases filters are cleaned by automatic back-flushing. There are two different systems for automatic back-flushing. In one system the cleaning depends on the differential pressure across the filter elements. At a pre-set pressure difference back-flushing is achieved through one or more filter elements in a cyclic sequence. A cleaning cycle counter warns when the frequency exceeds a pre-set value.

The other type of automatic back-flush filter uses disc-shaped filter elements divided in a number of sectors. The elements are back-flushed one at a time while the remainder of the filter sectors are in operation.

The material from filter back-flushing consists mainly of oil which is returned to the oil sump.

In small diesel engines operating on distillate fuel depth filters are used for both cleaning and protection. Depth filters operate with filter elements made of thick material such as felt, cellulose or synthetic fibres. In these filters the sludge is deposited throughout the entire thickness of the filter element, not only on the surface.

6.3 Safety Indicator Filter

In addition to the full-flow filter mentioned above, a manual duplex safety filter is usually installed just before the engine. 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 clog rapidly thereby giving an indication to the operator of a problem with the main filter.

A general guideline is that the safety filter should have a mesh size of twice that of the automatic main filter.

A filter with smaller mesh size should never be placed downstream of a filter with larger mesh size. When looking at the size distribution of particles in lube oil in service, it appears that the number of particles increases rapidly with decreasing particle size. The effect of this is that the load on the finer filter is always higher which reduces its “safety net” capability.

Exceptions to this are strainers that protect pumps and other sensitive components in the system from harmful solids. In such cases the largest possible mesh size whilst still fulfilling its duty should be the choice.

6.4 Centrifugal By-Pass Filter

The centrifugal by-pass filter or “Glacier type filter” is an optional device for medium speed engine installations.

6.4.1 Tasks of Centrifugal By-Pass Filter

The task of the by-pass filter is to contribute to the sludge removal from the lube oil. In reality the amount of sludge removed by this type of filter is small compared to what is removed by the centrifugal separator. Therefore, the centrifugal by-pass filter can only be used in place of a centrifugal separator in applications where the amount of sludge in the oil is small (e.g. gas or gasoil operation).

Another possible application of the by-pass filter in some engines is that it can act as an indicator filter. When the lube oil is heavily contaminated, this will be noticed from the shorter time to fill the sludge space. The by-pass filter is easy to open for visual inspection.

In some applications the centrifugal filter may be used for treatment of the back-flush oil from the full-flow filter.

6.4.2 Design of Centrifugal By-Pass Filter

The centrifugal by-pass filter has an oil-driven turbine connected to the centrifuge shaft. The oil is fed from the circulation pump with a typical pressure of 2–7 bar and the speed of the centrifuge is 4000 to 7000 rpm. The unit works in a by-pass circuit to the full flow circuit, and the cleaned oil is returned to the oil sump/tank. The flow rate is in the order of 10% of the circulation pump capacity.

The sludge is collected in the centrifuge basket. This sludge may become very dry because of its long residence time in the unit. It has to be manually removed from the basket at regular intervals. The sludge separation/removal capability is far below that of a disc-stack centrifugal separator. For engines running on heavy fuel oil the centrifugal by-pass filter is not an alternative option to the typical centrifugal separator.

6.5 Fine Filter for Camless Crosshead Engines

In camless crosshead engines the system oil is used for the hydraulic system controlling the engine. In order to protect the hydraulic system, an automatic back-flushing fine filter is installed after the standard full flow filter and at just before the high pressure pump on the engine.

The back-flushed material consists primarily of system oil and is therefore cleaned and re-used. Cleaning of the back-flush oil is done in the centrifugal separator or by filtration.

7. RISKS OF INADEQUATE TREATMENT

As explained above, treatment of the lubricant is necessary to keep the level of contaminants at an acceptable level so that the lubricant retains its essential properties and can perform its functions adequately. Another function of the treatment system is to protect the engine from harmful particles. If the treatment of the lubricant is not adequate there is the risk of engine malfunction.

For instance, if abrasive particles are not removed adequately the result can be bearing damage, and/or for medium speed engines it can lead to increased wear of the piston rings, piston grooves, and cylinder liners. A high amount of contaminants (sludge, insolubles, soot) can lead to deposits on internal surfaces, increased load on the filters and eventually in filter clogging.

A high amount of water can result in emulsification of the lube oil, destabilization of the lube oil, and corrosion. Emulsification changes the lubricant properties, especially in its viscosity, resulting in ineffective lubrication. Water can destabilise the oil by washing out (some of the) additives.

For medium speed engines, insufficient lube oil replenishment or lube oil batch renewal can lead to the oil base number (BN) becoming too low and/or the oil viscosity too high or too low. A low base number can result in increased corrosive wear because the acids (mainly sulphuric acid) formed during the combustion are not sufficiently neutralized. Contamination with HFO can lead to an increase in lube oil viscosity, and contamination with distillate fuel can result in a viscosity decrease. A too high or too low viscosity can lead to ineffective lubrication and eventually in engine damage.

There is a risk of shortened service life of the lubricant when the amount of contaminants increased and/or when there is not enough oil replenishment/refreshment. In such cases the oil analysis may show that the oil no longer meets OEM specifications.

The table below summarises the various risks.

Table 3 – Risks of Inadequate Treatment

<table>
<tr><th rowspan="2">Inadequate Treatment</th><th colspan="2">Risks</th></tr>
<tr><th>Trunk Piston Engine</th><th>Crosshead Engine</th></tr>
<tr><td rowspan="6">Inadequate centrifugation and/or inadequate filtration</td><td colspan="2">Bearing damage and high wear, when abrasive particles are not removed</td></tr>
<tr><td colspan="2">Restriction of oil flow through oil passages due to deposits and poor heat ransfer</td></tr>
<tr><td colspan="2">Filter clogging</td></tr>
<tr><td colspan="2">High water content leading to 1) emulsification of the lube oil, 2) destabilization of the lube oil, and 3) increased corrosion</td></tr>
<tr><td colspan="2">Decreased lubricant service life</td></tr>
<tr><td colspan="2">More frequent engine maintenance</td></tr>
<tr><td rowspan="3">Inadequate oil replenishment and/or oil batch renewal</td><td colspan="2">Ineffective lubrication and eventually engine damage when viscosity becomes too high</td></tr>
<tr><td>Ineffective lubrication and eventually engine damage when viscosity becomes too low</td><td>-</td></tr>
<tr><td>Corrosion, when BN has depleted too much</td><td>-</td></tr>
</table>

8. REFERENCES

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9. ACKNOWLEDGEMENT

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