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CIMAC

GUIDELINES FOR DIESEL ENGINES LUBRICATION

OIL CONSUMPTION OF MEDIUM SPEED DIESEL ENGINES

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 and previous CIMAC Recommendations still available are listed in the back of this publication.

This document has been elaborated by the CIMAC Working Group „Marine Lubricants“ and approved by CIMAC in May, 1999.

FOREWORD BY THE PRESIDENT

The consumption of lubricating oil by an engine has been considered by many as an unnecessary waste and something which should be eliminated. This document shows that this is not the case and explains clearly why lubricating oil consumption is essential to maintain the quality of the lubricant in the engine whether it be by steady consumption during operation or by charge replacement. Lubricating oil is a highly engineered and fundamental part of the engine operating system, designed and blended to meet many differing requirements. It is therefore essential that the quality of the lubricating oil be maintained.

This will be the 17th in the series of CIMAC recommendations which was started back in 1968. Since CIMAC is an international organization composed of representatives from the engine manufacturers, engine users, universities, research institutes, components suppliers, fuel and lubricating oil suppliers and other interested parties it can be seen as being truly independent. I am therefore sure that this present document will be very effective in passing on the message about lubricating oil consumption which has often been given by individual companies or sections of the industry, but which has seldom been seen as a message which is truly independent and free of any commercial interest.

Future publications from this very active Working Group are expected to include:
- The impact of fuels on lubrication – 4 & 2 stroke
- Lubrication of large high speed engine
- Oil degradation
- Gas engine lubrication

When these are available announcements will be made in the Press and on the Internet at www.cimac.com.

Our thanks go to all those members of the working group who put in so much effort and to their respective organizations for their support.

Stephen. G. Dexter, President
July 1999

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PREFACE

This document addresses oil consumption defined as the combined amounts of oil make-up and system charge renewal that are required: (i) to keep the engine operating satisfactorily and: (ii) to control the oil quality reserve within the limits prescribed by the engine builder or suggested by the oil supplier, if no specific limits are indicated by the engine builder. Major factors impacting on oil consumption are summarised together with the consequence of inadequate make-up quantity/quality and some advice to cope with such situations.

1. INTRODUCTION

All medium speed engines in service have an oil consumption which is usually expressed in g/kWh and depends on the engine design, operation and system losses, *(Reference (1)).* In order to maintain the system level, make-up oil is added to compensate for the oil consumed. The quantity of this make-up oil is a major factor in determining the suitability of the lubricant for further service.

2. FACTORS IMPACTING ON OIL CONSUMPTION

There are a number of factors that have an impact on the oil consumption of the engine. These can be grouped under the following headings:

- engine design and condition;
- oil quality;
- fuel quality;
- oil system capacity;
- operating conditions;
- service effect on BN depletion;
- system losses;
- system maintenance.

2.1 Engine Design and Condition

Oil consumption is affected by the design and condition of the piston ring pack and of the cylinder liner, specifically:

- number of rings fitted and their profile;

- number of oil control ("scraper") rings;
- tolerance and clearance of the ring in the piston groove;
- running-in;
- method of lubrication, splash or forced;
- condition of cylinder liner, honed/run-in/oval/worn;
- presence of an anti-polishing ring in the cylinder liner, or equivalent arrangement.

2.2 Oil Quality

In service the lubricant is subject to degradation, the key factors causing it being:

- oxidative and thermal stresses of the oil;
- products of combustion;
- metallic particles as a result of controlled wear at the ring / liner interface;
- any debris left in the engine following maintenance.

Some oil parameters define the suitability of the oil for further use by meeting specific engine builders' limits. These parameters include alkalinity reserve, viscosity, flash point, insolubles and water content, *(Reference (2))*. It should be noted that alkalinity reserve is expressed as Base Number (BN), mgKOH/g. In the past alkalinity reserve was known as Total Base Number (TBN).

A particularly harmful source of oil degradation is raw residual fuel that may generate substantial sludging of the engine, *(Reference (3)).* If the fuel is a distillate, the contamination will depress the flash point of the lubricant with safety implications.

2.3 Fuel Quality

2.3.1 Residual Fuel Oil

The quality of residual fuel oil has a great impact on the quality of lubricant in service and is often the reason for renewal (partial or complete) of the oil charge, as/when make-up volumes are inadequate to maintain the required oil quality reserve. The residual fuel oil quality parameter most commonly influencing oil consumption is SULPHUR CONTENT. The higher its value is, the greater is the rate of Base Number (BN) depletion, hence generally the reduction of the detergency / dispersancy reserve of the oil. A typical sulphur level is about 3% and the limit in ISO 8217:1996 is 5% m/m, *(Reference (4)).*

Other residual fuel oil quality parameters to affect oil consumption are COMBUSTIBILITY and COMPATIBILITY with the lubricating oil in the system. Poor combustibility is likely to result in higher insolubles content and viscosity of the oil as well as increased piston deposits. Poor compatibility leads to sludge formation and generally dirtier engines.

2.3.2 Distillate Fuel

Operation with distillate fuel is generally less severe than with residual fuel oil. Typically distillate fuel has a significantly lower sulphur content, less than 1% although ISO 8217:1996 permits up to 2% m/m. Its combustion quality is better and there are no distillate-residue compatibility problems with the lubricating oil. However, occasionally liner lacquering and/or bore polishing occur which may result in higher oil consumption. Distillate fuel dilution may result in lower oil viscosity.

2.3.3 Natural Gas

In general, the nature of gas (mainly used in power plant applications) does not give operational problems.

2.4 Oil System Capacity

The oil system capacity and related oil quality in circulation, have an impact on the rate of BN depletion and of deterioration of oil quality reserve in general. The greater the oil "working volume" is, the more likely that routine oil make-up will suffice to provide good engine performance and that the oil will remain within the quality limits set by the engine manufacturer.

2.5 Operating Conditions

Oil consumption is affected by anyone or a combination of the following factors:

- engine load, the higher the load, the greater the oil consumption;
- mode of operation, typically stop-go, manoeuvring;
- engine components maintenance, such as fuel injectors (for proper combustion), fuel pumps (for raw residual fuel leakages into the oil), piston overhaul interval (for preventing blow-by gases that affect oil quality).

In recent years the development of medium speed engines has put particular emphasis on reduction in specific fuel consumption. This has been achieved, in the main, by the general increase in pressure and temperature in the operating cycle, so making greater demands upon the ring pack. Also other trends have taken place which have an effect upon the lubricant. These are a reduction of the oil charge in some designs, when expressed on a kg/kW basis and a reduction of the lubricating oil make-up by attention to the ring pack design and liner surface. These trends have a significant effect on the oil in circulation both with respect to alkalinity reserve and contaminants management, the latter demanding the application of efficient centrifuging practices. These matters are discussed in greater details later on in this document.

2.6 Operational Effects on Oil BN Depletion

The purpose of the alkalinity reserve, incorporated in all medium speed engine oils, is to protect the engine from acid attack caused by the sulphur content of the fuel. In service the alkalinity reserve is depleted and this can be expressed as below, *(Reference (5)).*

$$BN_t = BN_0 - A\,(1 - e^{-rt})$$

BN_t = BN of the oil after t running hours
BN_0 = BN of the new oil
A = Neutralization effect = 0.3 yfs
r = Ratio of oil consumption / oil charge

t = Running hours
y = Sulphur conversion factor
f = Ratio of fuel consumption/oil consumption
s = Fuel sulphur content in % m/m

Figure 1 shows the general trend of alkalinity depletion, as expressed by BN, for three different engine designs. Curve 1 shows the trend for an engine with a high lubricating oil consumption and large system capacity in relation to the power of the engine. Curve 2 illustrates an engine with a slightly lower consumption, but with a system capacity similar to the engine in example 1. Curve 3 represents an engine with a low lubricant consumption and small system capacity. Whilst curves 1 and 2 have reached a stable state, the BN represented by curve 3 is continuing to fall.

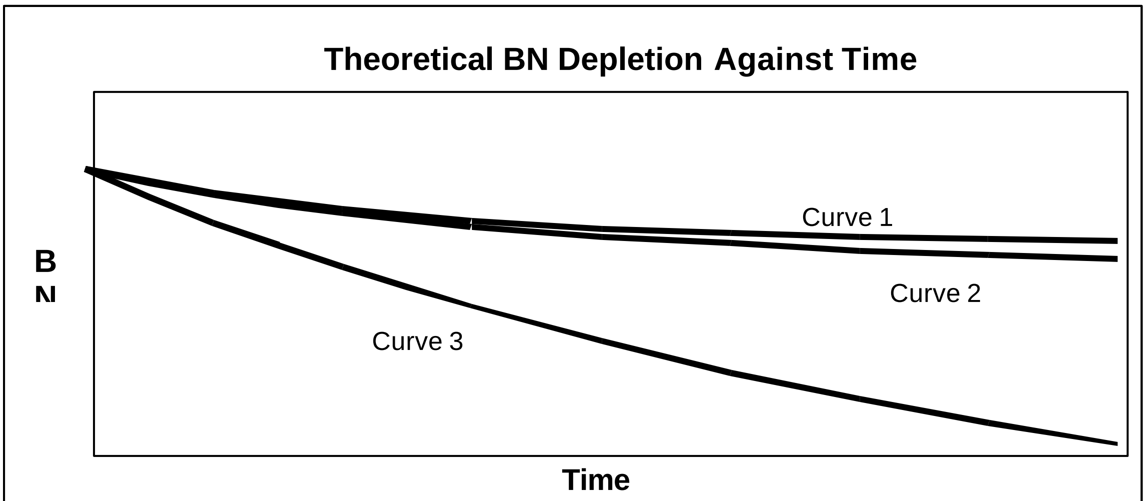

Figure 1

All engine builders have a limit for alkalinity depletion, that is sometimes expressed as a percentage of the initial BN, or as a numerical value. If this limit is approached in service, corrective action has to be taken. One approach is to use an oil with a higher initial BN. The effect of this is shown in Figure 2.

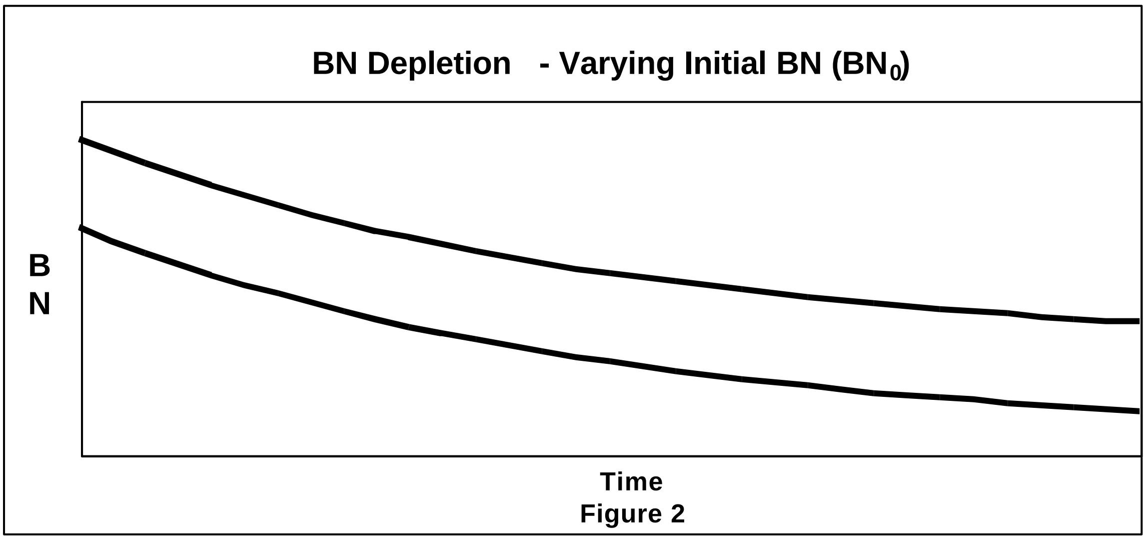

Figure 2

Increase of the initial BN has a purely linear effect and may raise the stable state to above that of the engine builders limit. An alternative approach is to renew the sump charge and the economic consequences of this are considered in a later section.

For engines with a low lubricant consumption and small service charge, the use of a high initial BN oil may permit the engine builders limit for alkaline reserve to be met. Then the limiting factor on the life of the lubricant becomes the level of insolubles and increase in viscosity of the oil. Higher BN levels do not necessarily help control quality properties such as insolubles and viscosity.

2.7 System Losses

System losses have some impact on oil consumption, the greater the losses, the larger the make-up volume, hence the renewal of quality reserve. Ironically an inefficient system may benefit the operation of the engine. As a broad indication, system losses can account for about 0.1-0.2 g/kWh of fresh oil make-up, under normal conditions.

System losses may arise from leakage from the engine in the form of leaking glands / joints / crankcase doors and/or from the operation of some centrifuges through sludge discharges and breaking of the water seal. Another source of losses is the desludging of back-flush filters. Additionally, severe water contamination and/or fuel dilution may require replacement of the working volume.

2.8 System Maintenance

Maintenance of the oil system aims at keeping the oil quality reserve at satisfactory level at all times, hence it does contribute to oil consumption. A maintenance procedure and schedule is usually in place and covers:

- topping-up intervals: the shorter it is, the more effective it will be in maintaining the oil at best possible conditions;
- system working volume: the greater the oil volume in circulation, the better its condition, also influenced by regular and frequent topping-up, *(Reference(1));*
- condition of oil heaters: where fouling can result in overheating of the oil and bring about some unwarranted oxidative/thermal deterioration of it;
- use of renovating tanks: where the oil in service is allowed some time to decant at least part of its carbonaceous products of combustion which are seen and measured in the oil as insoluble matter;
- operation of centrifuges: this being a particularly important factor in disposing of contaminants.

Of course, the accumulation of contaminants in the oil depends on a number of factors such as the design of the engine, the quality of the fuel burnt and the operational characteristics of the lubricating oil. But it is up to the arrangement of the on-board lubricant treatment system, notably centrifuging, to ensure that the actual level of contaminants is kept as low as possible.

The centrifuge is operated, almost without exception as a purifier, ie able to discharge the separated water, on a system by-pass arrangement. With the centrifuge set correctly, purification of the lubricant will remove most of the water which may be present and the level of contaminants will be reduced. The extent of the contaminant removal is a function of the size of the insoluble material in the lubricant, the size of the centrifuge in relation to the engine output, the flow through the centrifuge and the lubricant temperature into the purifier.

The size of the centrifuge in relation to the engine output is given by the engine designer's recommendation that takes into account the type of fuel, namely distillate or residual, and the designer's operational experience. In selecting a centrifuge for this application, notice has to be taken also of its manufacturer's recommended maximum through-put capacity.

3. TECHNICAL CONSEQUENCES OF INADEQUATE RENEWAL OF OIL QUALITY

Inadequate make-up combined with reluctance to implement some system charge renewal, will most likely result in significant operational problems, which can be expensive to rectify and may even jeopardize the overall safety of the installation. Specifically, the main issues are:

- reduced oil quality reserve in terms of basicity (BN), detergency and dispersancy. Also the oil condition may no longer be within the specified limits of the engine builders;
- loss of control of deposit formation on piston lands, grooves and undercrown, possibly conducive to increased wear of rings and liners. Also the engine spaces may become dirtier;

- increased possibility of overloading of centrifuges and filters, thus reduced efficiency of purification of the oil;
- reduced resistance of oil to water contamination, bringing about additional depletion of oil quality reserve;
- reduced efficiency of oil heaters through fouling, and increased oxidative / thermal stress of the oil.

4. ECONOMIC CONSEQUENCES OF DIFFERENT LUBRICATION REGIMES

For many large medium speed engines, ship owners have come to expect that periodic renewal of the lubricant charge is not necessary. Under normal operating conditions this view has been correct as the lubricant received periodic replenishment by the addition of make-up oil sufficient to stabilise the oil at levels within the designer's recommendations, with respect to BN, insolubles and viscosity.

A low oil make-up invariably leads to partial or complete renewal of the charge. This poses the question whether a low make-up rate is economical. The answer lies in the complex interaction of make-up and renewal charge volumes, running hours between renewals and any additional maintenance cost that may be related to low consumption. In comparing the whole life cost of different lubrication regimes, account must be taken of the possible differential lubricant cost and also the cost of disposal of used oil.

5. SUMMING-UP

- **Keep abreast of the operational requirements of the installation by regular oil analysis and engine inspections.**

- **Ensure proper and safe operation of the installation at all times.**

- **Carefully assess the economics of lower make-ups versus the need for oil changes, partial or complete, to maintain the necessary oil quality reserve.**

6. REFERENCES

(1) "Guidelines for the Lubrication of Medium Speed Diesel Engines" CIMAC Publication No. 13, London 1994

(2) CEC L-47-M-97 "Recommended Standard Methods Analysis of Used Oil from Large Diesel Engines, Brussels 1997"

(3) CEC 97-EL08 "Effects and Determination of Raw Fuel Dilution in Marine Crankcase Lubricants"

(4) ISO 8217:1996 Petroleum Products - Fuels (class F) - Specifications of Marine Fuels

(5) Diesel Engine Lubricants. Their Selection and Utilisation with Particular Reference to Oil Alkalinity. Dyson, A., Richards, L.J., Williams, K.R. Proc. Inst. Mech Engr., No 23, 171,1957.

7. ACKNOWLEDGEMENT

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

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Other CIMAC Recommendations (Prices exclude packaging and postage!)

No. 1	Recommendations for Diesel Engine Acceptance Tests, 1968	Out of Print
No. 2	Recommendations for Gas Turbine Acceptance Test, 1968	Out of Print
No. 3	Recommendations of Measurement for the Overall Noise of Reciprocating Engines, 1970	Out of Print
No. 4	Recommendations for SI Units for Diesel Engines and Gas Turbines, 1975	Out of Print
No. 5	Recommendations for Supercharged Diesel Engines, 1971 Part I: Engine De-rating on Account of Ambient Conditions Part II: Engine Acceptance Tests	Out of Print
No. 6	Lexicon on Combustion Engines, Technical Terms of the IC Engine and Gas Turbine Industries, 1977	Out of Print
No. 7	Recommendations regarding Liability - Assured Properties, Publications and Fuels for Diesel Engines, 1985	DM25.00
No. 8	Recommendations regarding Requirements for Heavy Fuels for Diesel Engines, 1986 (superseded by No. 11)	DM25.00
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No. 10	Recommendations regarding Liability - Assured Properties, Publications and Fuels for Gas Turbines, 1985	DM36.00
No. 11	Recommendations regarding Fuel Requirements for Diesel Engines, 1990	DM08.00
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No. 13	Guidelines for the Lubrication of Medium Speed Diesel Engines, 1994	DM10.00
No. 14	Standard Method for the Determination of Structure Borne Noise from Engines, 1994	DM08.00
No. 15	Guidelines for the Lubrication of two-stroke Crosshead Diesel Engines, 1997	DM10.00
No.16	Guidelines for operation and/or maintenance contracts, 1999	DM 10.00

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