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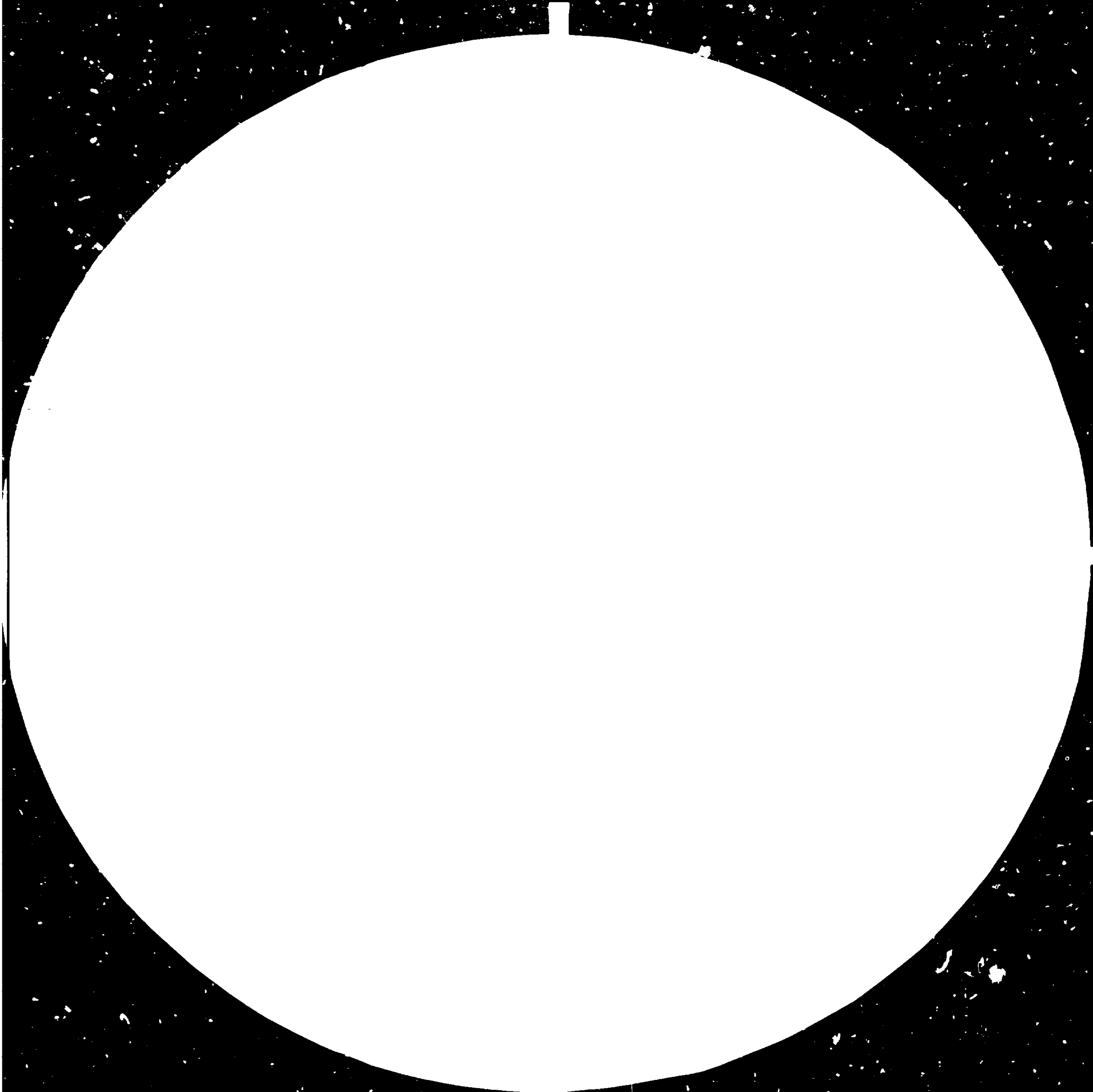

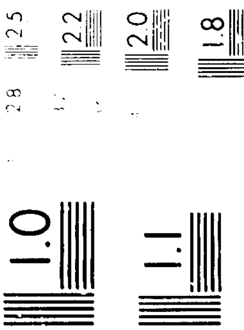

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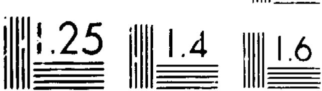
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LUBRICANTS FOR EXTENDED ENGINE LIFE*

prepared by

Hugh D. Smith**

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** Technical Co-ordinator, CASTROL.

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LUBRICANTS FOR EXTENDED ENGINE LIFE

By taking the popular analogy of a ship as being a "she" we can consider the engine as the heart, the fuel as the food and the lubricating oil as the life blood. Indeed this human analogy is remarkably apt. Just as today's un-natural foods are tending to have a detrimental effect on heart and blood so are today's highly processed fuels having an equally bad effect on engines and lubricating oils.

We shall discuss these effects in relation to the lubrication of medium to high speed diesel engines in marine applications and show that the correct lubrication of such engines depends on the quality of the lubricant, the design of the engine, the quality of the fuel and the design of the lubrication system.

Engine Design Influences

There has been a progressive increase in engine power output over the last ten years and this trend is likely to continue through this decade. This power uprating, achieved by the use of efficient turbochargers, is accompanied by higher firing pressures which increase the loads on piston rings, cylinder liners and bearings. Ring, liner and bearing materials together with surface finishes have become more critical and the lubricant needs to have sufficient film strength to avoid metal to metal contact.

More serious than the high pressure effects is the fact that engines with higher specific power outputs burn a greater amount of fuel per unit area. This means that more heat has to be dissipated and an increased amount of combustion acids have to be neutralised.

A further significant influence in modern diesel engines is the tendency of engine designers to strive for, and achieve, very low lube oil consumption rates. While very high lube oil consumption rates must be deplored, consideration should be given to the beneficial effect of new oil make-up, without which the life of the lube oil charge has to be shortened. The object should therefore be to aim for a reasonable quantity of lube oil make-up to give an extended life to the complete charge. We think that a lube oil consumption figure of 1 g/bhp/hour should be considered as a minimum with 1.5 g/bhp/hour being a good average figure.

Lube Oil System Design Influences

Although design details will differ, all diesel engine lube oil systems are basically designed around the wet or dry sump principle as shown in figures 1 and 2. In spite of the straightforward simplicity of these systems, basic design faults can be encountered, the most common being the fact that it may be virtually impossible to drain all the oil satisfactorily from the engine even when the oil is hot. In many cases sample analysis carried out a few hours after an oil change show considerable contamination from the un-drained used oil, thus making oil changing a very inefficient operation.

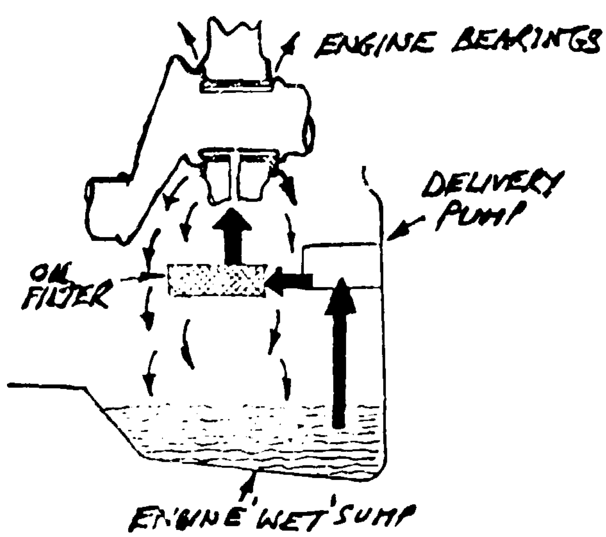


Figure 1 - Wet Sump System

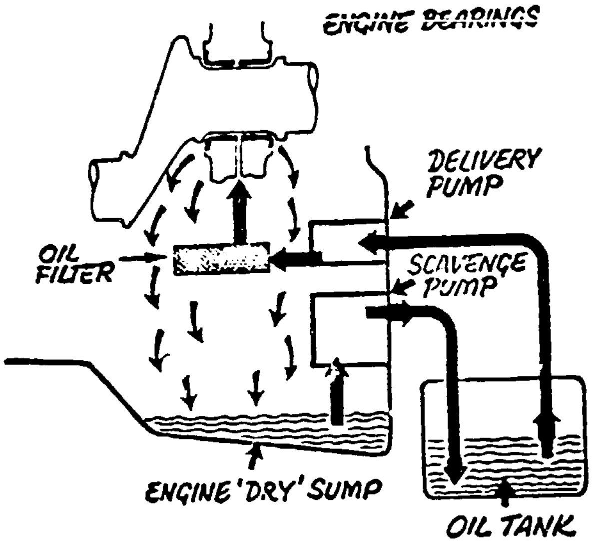


Figure 2 - Dry Sump System

With larger engines the dry sump principle is normally employed and larger quantities of oil are usually in circulation. For these it is sound economic sense to fit some form of lube oil treatment, either back-flushing self cleaning filters or better still, a centrifugal purifier. Here again care should be taken to obtain the optimum position for siting lube oil suction and return pipes so that there are no dead spaces in the sump tank where dust and debris may accumulate. As shown in figure 3, the purifier should have its own suction pipe to draw from the lowest part of the sump tank.

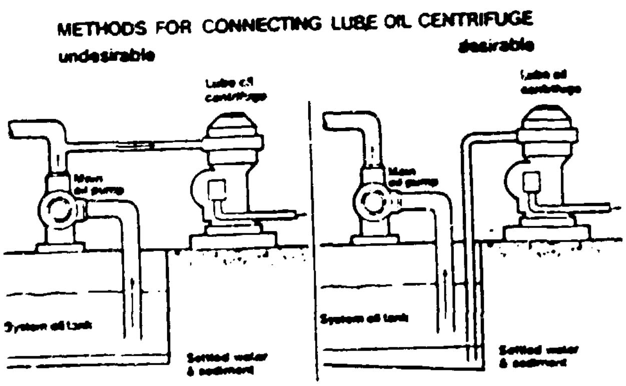


Figure 3

Water is one of the most damaging contaminants in any engine lube oil system because it reduces the load carrying ability of the lube oil and increases the danger of rusting and other forms of corrosion. For this reason most engine-builders restrict the permissible water contamination level to 0.2% and this figure can easily be reached by simple condensation. Indeed, very large quantities of water can accumulate in engines operating under humid conditions which makes it essential that close attention should be given to sump breathing arrangements. Particular attention should be paid to vent pipes and figure 4 shows how easily a vent pipe can be rendered ineffective by trapped water due to incorrectly sited pipes.

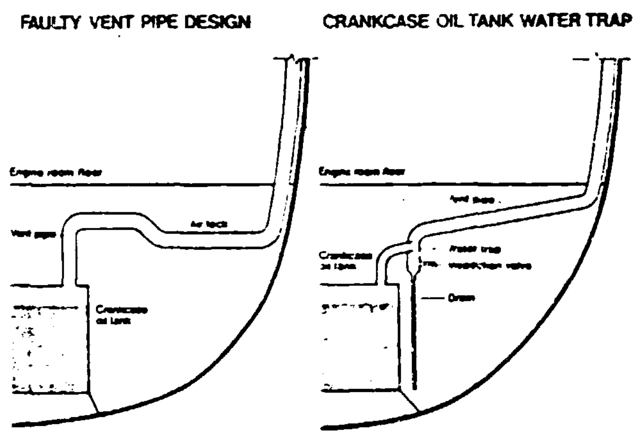


Figure 4

All lubrication systems are fitted with some type of filtration either full-flow as shown in figure 5 or bye-pass as in figure 6. In the full-flow system all of the oil is filtered on its way from the lube oil pump to the bearings whereas on the bye-pass system only a certain amount, usually about ten percent, is directed to the filter. It is obvious that full flow filtration should be the preferred system and engine tests have confirmed its advantage.

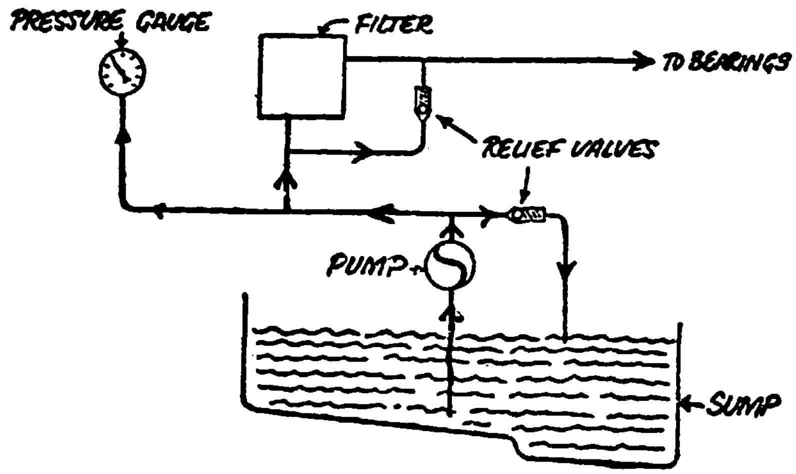


Figure 5 - Full Flow System

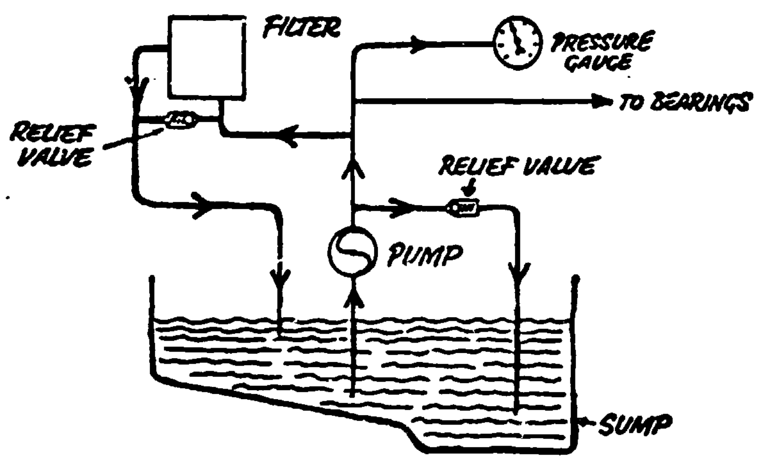
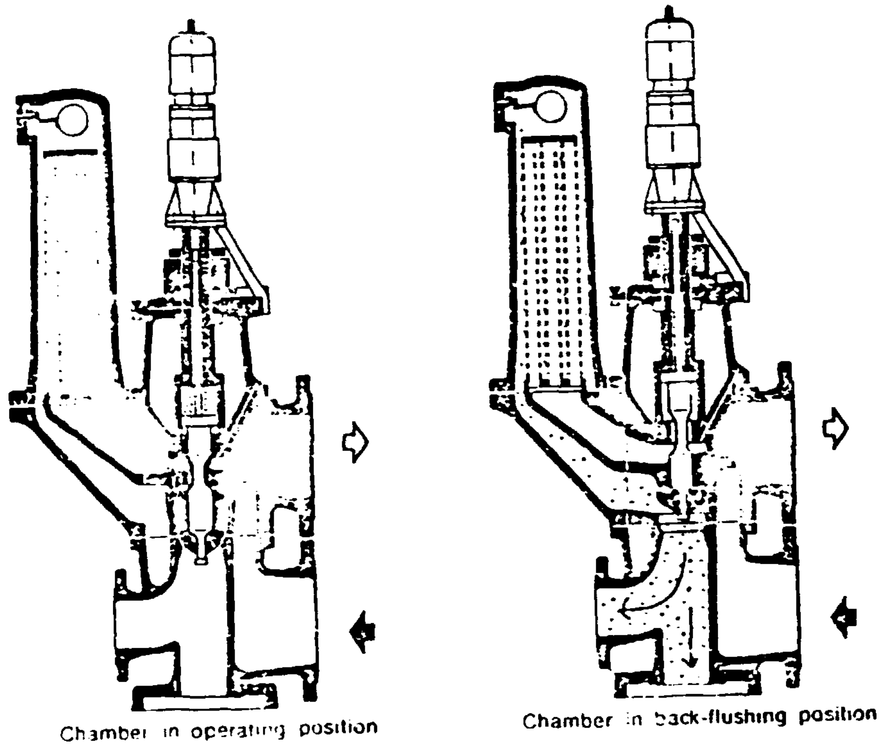


Figure 6 - Ey-Pass System

Considering normal cylinder and bearing wear on an engine without filtration as 100% then a bye-pass filter will on average reduce this by 50% while a full-flow filter should reduce it to around 15% or less. Full flow filters are normally of the back flushing self cleaning type, figure 7, while bye-pass filters are normally of the disposable cartridge type as shown in figure 9.



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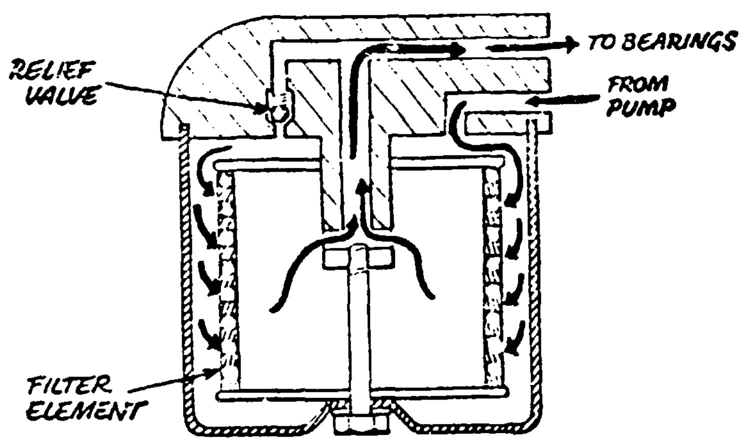


Figure 8 - Oil Filter

Fuel Influences

In the marine industry today, we are well aware of the marked deterioration in the quality of the residual fuels which are burned in the larger diesel engines, but there has also been an insiduous decrease in the quality of some of the distillates. The main parameter affected is sulphur content and sulphur levels in distillate fuels has generally increased over the last few years as shown in table 1:

Date	7/79	6/80	6/81	2/82	3/82
Density at 15°C	0.85	0.848	0.87	0.87	0.87
Viscosity cSt at 50°C	2.55	2.9	3.09	3.4	3.8
Closed Flashpoint °C	84	84	86	104	77
Calculated Cetane Index	55	53	53	45	50
Sulphur content % wt	0.48	0.61	1.28	1.57	1.63

Table 1: Various analyses of diesel distillate fuels.

As is well known, during combustion the sulphur in the fuels forms sulphur oxides which combine with the moisture in the intake air to produce sulphuric acid. This acid can accumulate in the lubricating oil and chemically attack cylinder liners, piston rings, exhaust valvestems and guides and other components, thus producing a high level of corrosive wear. Since condensation is invlolved and marine engines are likely to always have a high moisture content in the intake air, it follows that they are more liable to suffer from this problem than certain land based installations. Unfortunately, the symptons of fuel sulphur wear only appear after the damage is done and they are common to normal engine wear. However fuel sulphur wear will occur much earlier than normal wear and the following early wear indications should alert you to the possibility of fuel sulphur wear:

INCREASED OIL CONSUMPTION
INCREASED CRANKCASE BLOW-BY
VAPOUR VISIBLE IN THE CRANKCASE BLOW-BY
BLUE EXHAUST SMOKE
OIL ANALYSIS SHOWING DECREASE IN ALKALINITY OF ACIDITY
OIL ANALYSIS SHOWING HIGH IRON LEVELS

The best safeguard against fuel sulphur wear lies with the lubricating oil and only a high performance product to API-CD level with an adequate reserve of alkalinity should be used. Most engine manufacturers specify either a minimum oil alkalinity as measured by TBN or a reduction in oil chage periods to counteract fuel sulphur levels. Some manufacturers, have taken rather drastic steps such as recommending one fourth normal oil change periods for sulphur contents 1% and above and another recommends that the lubricating oil should have an initial TBN number which is 20 times the sulphur content of the fuel see figure 9.

Certainly the danger is real and every effort should be made to establish the actual sulphur content of any fuel used.

Lubricating Oils

To be able to give a long and economical life in highly rated diesel engines a modern high performance lubricant has to be formulated from good quality base oils incorporating a balanced blend of additives which will include:

DETERGENTS
DISPERSANTS
ACID NUETRALISING ADDITIVES
ANTI-OXIDANTS
ANTI-RUST ADDITIVES
ANTI-WEAR ADDITIVES
ANTI-FOAM ADDITIVES
POUR POINT DEPRESSANTS

GRAPH FOR DETERMINATION OF NECESSARY TBN.

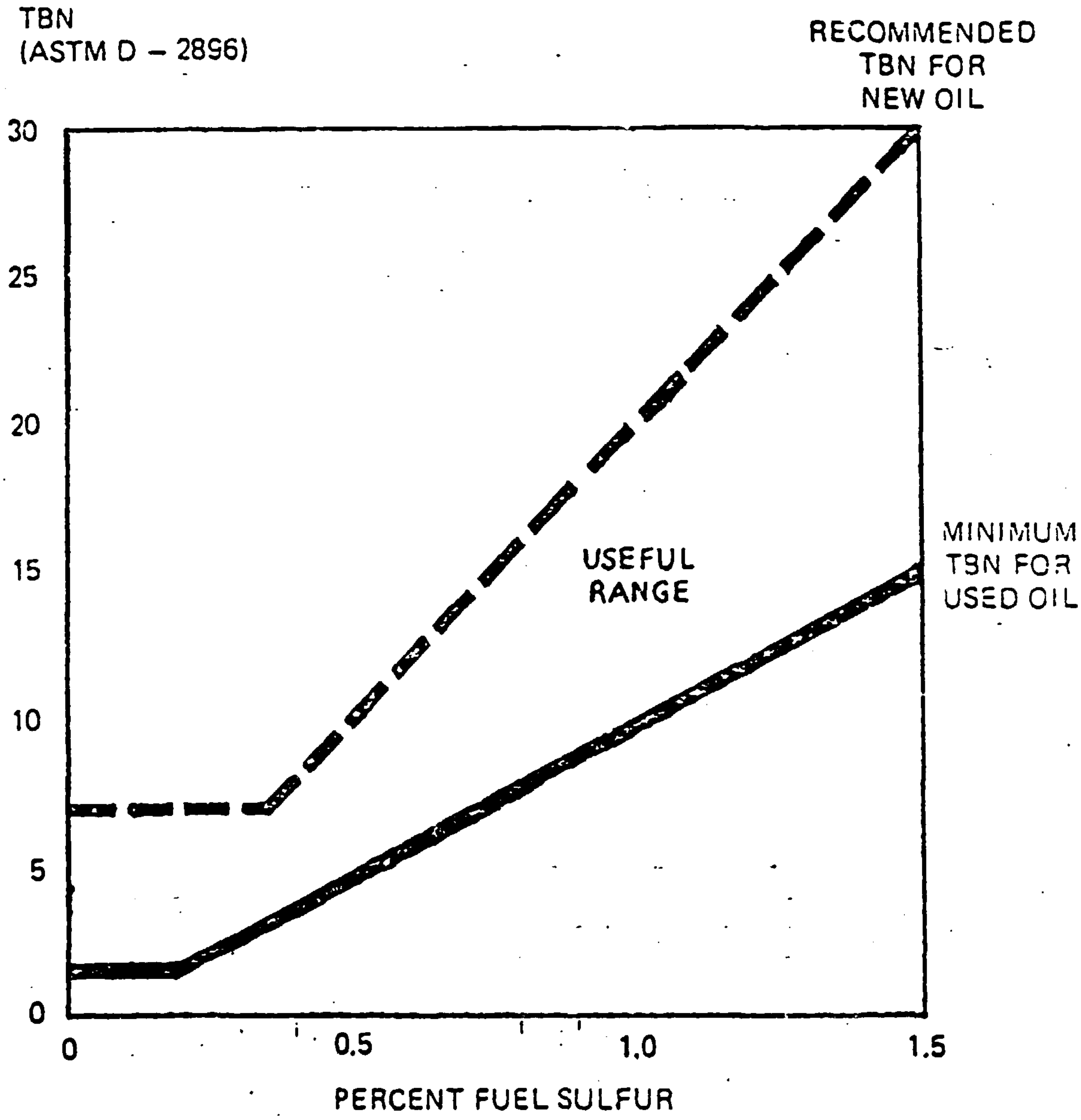


Figure 9

Detergency and Dispersancy

By virtue of its detergent properties an oil is able to maintain the critical parts of an engine in a clean condition. Detergents act by first neutralising the acidic products generated by combustion and then preventing their adhering to the metal surface to form varnishes and lacquers. Detergents are additives whose molecule consists of an alkaline metal (such as calcium) bonded to a hydrocarbon group (such sulphonate or phenate).

Dispersants are additives which tend to peptise insoluble carbonaceous matter and prevent agglomeration of deposits. They thus assist the detergents in keeping the engine clean and we have evidence that they also contribute to the speed of acid neutralisation to give better all round performance. Dispersants are ashless additives, often consisting of an hydrocarbon polymer containing a nitrogenated basic group.

Alkalinity

The additives which give alkalinity reserve to a lubricant are simply detergent additives to which has been added an excess of alkaline metal (usually calcium). They are therefore commonly known as over-based additives and the neutralising power of the finished lubricant will depend to a great extent on the level of overbasing. This level is expressed as TBN (Total Base Number) which relates to the quantity of acid expressed as mg of KOH required to neutralise all the basic constituents present in one gram of the oil. Various test methods have been used to determine TBN but the most widely accepted method now used is the ASTM D 2896. In any current heavy duty lubricant the major constituent will be the alkaline additive, often either calcium sulphonate or calcium phenate or a combination of both, and the performance of the lubricant will depend very much on the quality of the overbased additive. It is essential to select and use a sulphonate which has a high level of stability, particularly hydrostatic stability, so that the lubricant may maintain its alkaline reserve (TBN) in service and also resist additive depletion in the case of water contamination.

It is for this reason that Castrol maintain a rigorous monitoring of calcium sulphonates, use only a high quality product, and do not consider using any of the many cheaper sulphonates currently on the market.

Anti-Oxidation

The oxidation of a lubricant is a chain reaction process involving the formation of peroxides to produce gums, resins and weak organic acids. Their effect is to cause the oil to thicken and the acids may also attack bearings metals, particularly lead bronze. It is therefore essential that anti-oxidants be incorporated in a lube oil formulation and although there are many different types available they fall into two main groups, reaction chain terminators or peroxide destroyers.

Anti-Rust

Protection against rusting is particularly important in the marine environment and this is achieved by the inclusion of specially selected low base sulphonates. These are highly polar compounds which form a protective absorbent film on the metal surfaces.

Anti-Wear

Good anti-wear properties are especially important for the protection of cams, rocker arms and gears and this is commonly achieved by the inclusion of zinc in the form of ZDDP (zinc dialhyl dithiophosphate). The load carrying ability of a lubricant is often evaluated in the Germa' FZG gear rig test where the highest performance level is classed as load stage 12.

Anti-Foam

Anti-foam additives are normally silicone additives which are added at only a few parts per million. Their mode of action is to reduce tne interfacial tension between air and oil to allow quicker collapse of air bubbles.

Pour Point

Pour point depressants are polymers which prevent the agglomeration of wax crystals and allow the oil to flow at much lower temperatures. If carefully selected they will not have a derating effect on the oil's performance but, of course, they need only be used in oils which are likely to be subjected to low temperatures.

By careful selection of high quality additives a modern heavy duty lubricant should be able to provide:

1. Overall engine cleanliness.

2. Neutralisation of combustion acids to minimise piston ring and liner wear.

3. High temperature and oxidative stability to avoid oil thickening and prevent chemical attack on bearing metals.

4. Protection against rusting.

5. Good load carrying ability.

Lubricant Development

Lubricant development demands considerable time and money but nevertheless a continuous effort is necessary to maintain lubricant performances in line with engine design trends and with existing and future service requirements. Engine oils are classified and specified according to internationally recognised performance levels based on selected laboratory engine tests which endeavour to reproduce conditions that arise in service.

The first steps in the development of any oil are laboratory bench tests which, besides the many glassware tests, are likely to involve panel coker and other rig tests.

After bench test evaluation, selected formulations are being submitted for laboratory engine testing in accordance with the performance level being aimed for. In marine applications, the most widely used yardstick is the API-CD performance level which is sufficient to satisfy the majority of engines in service. Similar to the military MIL-L-2104C specification, the diesel engine requirements are given in table 2:

SPECIFICATION	API-CD	MIL-L-2104C
Caterpillar IG2		
Top Groove Filling % max	80	80
Weighted Total Demerit max	300	300
CRC L-38		
40 Hour Bearings WT. Loss mg max	50	50
Piston Skirt Varnish min (10 = clean)	9.0	-

TABLE 2: API-CD & MIL-C Diesel Requirements

In Europe, the severe Petter W.1. engine test is preferred for the evaluation of oxidation resistance. This uses a Petter petrol engine with a test duration of 36 hours while the lubricant is artificially heated to 135°C. At the end of the test the bearings are inspected and weighed for metal loss due to chemical attack, the piston skirt is rated for lacquer and the oil is checked for thickening. The limits of this test are shown in table 3:

Petter Engine Type	W.1.
Bearing wt. loss mg. max.	25
Piston start lacquer (10 = clean)	8.5
Oil viscosity increase max %	50

TABLE 3 - Petter W.1. test limits.

In addition to the various engine tests, for marine oils we carry out a programme to evaluate their demulsibility characteristics. This involves the use of our laboratory centrifuge to carry out water removal tests after the oils have been artificially contaminated with water.

After we are satisfied that a particular oil will meet all of our performance targets, the final step is to have the product fully field tested before it is allowed to be marketed.

Analysis of Used Oils from Service

The analysis of used diesel engine crankcase oils from service can not only indicate whether the oil is fit for continued service but can also reveal early symptoms of engine distress or malfunction. There are many tests which can be conducted ranging from spectrographic analysis to the more simple tests which require minimal equipment and which anyone can carry out.

Spectrogaphic analysis can be carried out on a direct reading emission spectrograph in which wear metals, additive metals and other elements such as phosphorous and silicon can be identified quantitatively. For such analysis to be of any real value, it is essential that sampling of the lubricant be carried out on a regular basis so that a statistical history of the oil can be established. Then a change in the established pattern will indicate when action is required. It will thus be appreciated that 'one-off' spectrographic determinations can often be virtually worthless.

It is for this reason that for marine applications we tend to rely on the more practical tests which can be carried out quickly to give a maximum of information in the minimum of time. The main tests which we carry out on a used oil are as follows:

DENSITY
VISCOSITY
FLASHPOINT
TOTAL INSOLUBLES
INITIAL pH
T.B.N.
WATER CONTENT
NATURE OF WATER

DENSITY IP 160 ASTM D1298

Density is of value in allowing the Engineer to select the correct purifier bowl gravity ring but could also indicate contamination with another grade.

VISCOSITY IP 71 ASTM D 445

Viscosity is the fundamental property of a lubricating oil which determines its suitability for use in a particular system. Most engine oils are classified according to the S.A.E. viscosity system whose limits are given in Table 4.

S.A.E. No.	cSt @ 100°C	cSt @ 40°C *
20	5.6 to 9.3	34 - 75
30	9.3 to 12.5	75 - 120
40	12.5 to 16.3	120 - 170
50	16.3 to 21.9	170 - 270

TABLE 4 - S.A.E. Viscosities * At a Viscosity Index of 100.

The S.A.E. system only recognises these viscosities at 100°C but we prefer to calculate the viscosity at 40°C also using a viscosity index figure of 100 which is an average figure for today's modern parafinnic oils. We always prefer to measure the viscosity of used engine oils at 40°C rather than 100°C because carbon particles in a used oil can block the small capillary tube used for 100°C viscosity determination, thus giving a false reading.

As a general guide an oil will tolerate a viscosity change of 25% or to its next S.A.E. number, when some action should be taken.

Reduction in viscosity can arise from:

Fuel dilution.
Topping up with oil of a lower viscosity.

Viscosity increase can be due to:

Build up of carbonaceous insolubles.
Oxidation of the lubricant.
Topping up with oil of a higher viscosity.
Excessive water contamination causing an emulsion.

FLASHPOINT PM CLOSED IP 34 D93

A reduction in closed flashpoint is usually associated with fuel contamination and table 5 gives an indication of the expected flashpoints:

Gas Oil Contamination % wt.	P.M. Closed Flashpoint °C
0	241
2	171
4	152

TABLE 5 - Effect of fuel contamination on flashpoint.

The figures in table 5 should only be taken as a guide since flashpoint reduction cannot give a quantative estimation of fuel in a lubricant. Indeed it is extremely difficult to establish how much of a particular fuel may be present in a lube oil. Nevertheless, some steps should be taken, at least to stop the fuel ingress if the closed flashpoint drops to 180°C. A reduction in closed flashpoint should be considered in conjunction with the viscosity in making a decision as to whether the oil should be replaced.

TOTAL INSOLUBLES IP 316

The insolubles in a lubricating oil will consist mostly of carbonaceous matter originating mainly from blow-by products of combustion. As mentioned under detergency and dispersancy, a high performance lubricant will be able to hold in suspension insoluble levels of at least 5% without deposition of soots on the engine surfaces. However, a high level of insolubles will cause a viscosity increase and it is likely that the oil would have to be condemned on the basis of viscosity before the insolubles level became a problem.

A rapid build up of insolubles would point to excessive blow-by indicating that attention should be paid to the mechanical condition of the engine.

INITIAL pH IP 177 D664

The initial pH test can be applied as a quick substitute for the TBN test since it will indicate whether the oil has a tendency to acidity. Since pH 7 is neutral any lower figure is tending to acidity and it is considered that strong acids will be present at pH 4.

TOTAL BASE NUMBER IP 276 D28896

The total base number gives a measure of the alkalinity remaining in the oil. As a very general guide, concern should be felt if the TBN in service falls to less than 40% of its original value. In this case consideration should be given to renewal of the oil charge and for persistent problems with TBN the oil grade should be changed for one with a higher initial TBN.

The TBN retention of an oil will be influenced by the following:

Quality of the Lubricant.
Amount of blow-by.
Amount of lube oil make-up.
Contamination with water.
Oxidation of the oil.

WATER CONTENT

Although water content can easily be accurately measured by distillation methods, it can often be very difficult to extract even a drop for analysis. We test contaminating water to check whether it is fresh or salt and whether it is acidic or not.

As already stated, water is extremely undesirable in lube oils and every effort should be made to restrict it to less than 0.2%. High levels of water contamination in lubricating oils will tend to form emulsions which are likely to cause serious problems with filter blocking in the first instance. The operation of an engine with a high level of water in the lube oil is almost certain to give rise to serious bearing damage.

Portable Test Kits

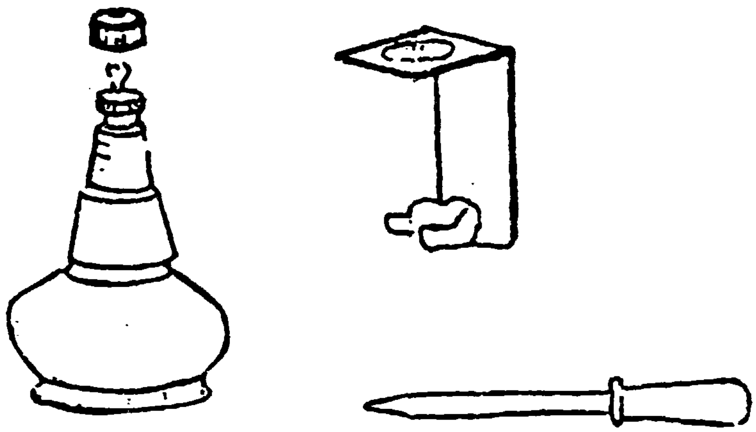
There is no doubt that portable test kits can be especially useful in the marine industry, particularly on fishing vessels which stay away from their home port for extended periods while being serviced by a mother ship.

We believe that the simpler the test kit the better and we favour the type which can allow the Engineer to make four basic but critical determinations, namely:

PRESENCE OF WATER
VISCOSITY
INSOLUBLES LEVEL
ACIDITY

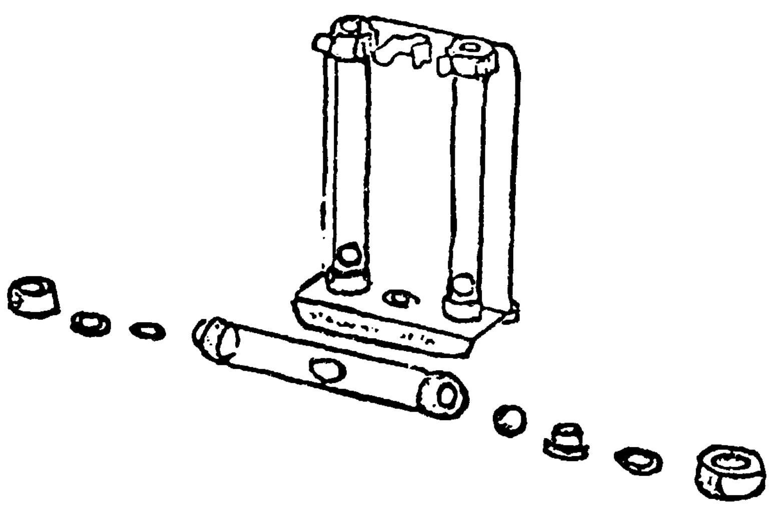
The methods are all simple and consist of:

Test 1 - Water determination



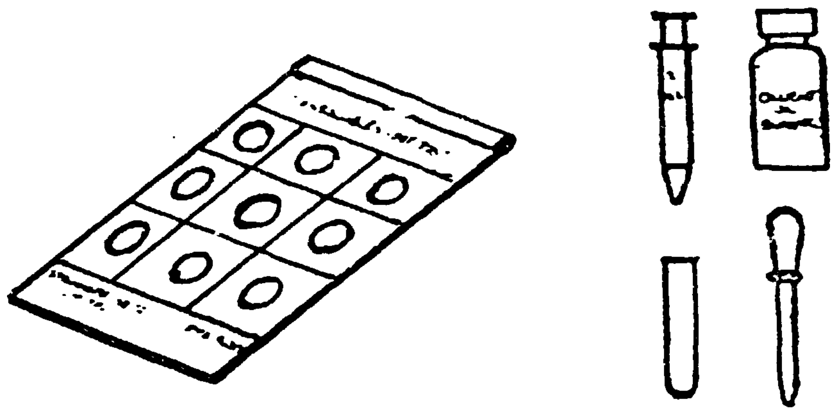
A hotplate is heated by a spirit lamp to above 100°C and a spot sample of oil placed on the surface. The amount of moisture present is indicated by the intensity of crackling and frothing as the water boils away.

Test 2 - Comparative Viscosity



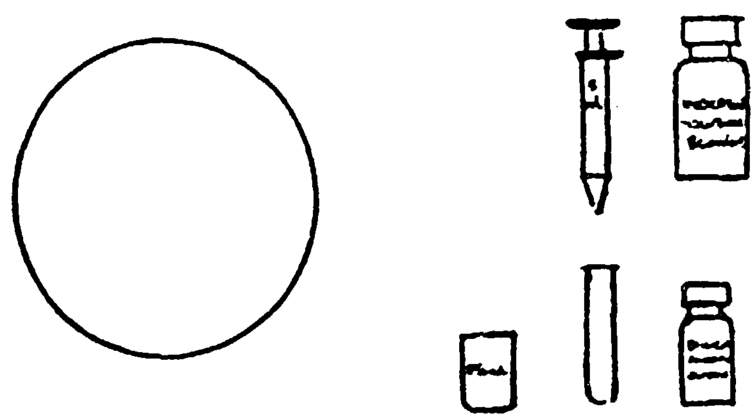
A tri-gauge viscosity comparator is used for comparing the relative viscosities of the oils. Steel balls are placed in glass tubes containing oil samples and the rate of fall of the balls is dependant upon the viscosity of the oil. The test sample is compared with standards of acceptable viscosity limits and classified as GO or NO-GO.

Test 3 - Insolubles



A spot of in-service lubricating oil is placed on a printed filter paper and allowed to stand. The paper is then inspected for blackness and the intensity of contamination is compared against previously prepared standards.

Test 4 - Acidity



The total acid value of the in service oil is shown by colour indicator method using Bromocresal Green indicator. When mixed with the oil and allowed to settle the colour of the lower layer will indicate the following:

a) Blue - no acid.
b) Green - weakly acid.
c) Yellow - strongly acid.

The most important point about portable test kits is that they are used regularly and that the test apparatus are kept clean and that the reagents are regularly replenished.

Castrol Oils For Marine Applications

Castrol provide a range of high performance heavy duty oils for virtually every application in the marine industry and the following grades are specifically intended for use in medium to high speed diesel engines burning distillate fuels.

CASTROL MARINE MPX

Certainly the most versatile product in the entire Castrol Range, MPX is a multi-purpose lubricant with a diesel performance to API-CD level. With a TBN of 9, MPX is available at 3 viscosity levels as shown in Appendix 1. It is approved by virtually all the European manufacturers of medium to high speed engines and is very successfully used in a wide variety of engines. In addition Castrol Marine MPX can be used in certain steering gears, turbo-chargers, gear-boxes and hydraulic systems.

CASTROL MX SUPER

A very high performance product which greatly exceeds the API-CD diesel requirements, MX Super is intended for very highly rated diesel engines which have to burn high sulphur distillate fuels. It has proved to give excellent performance in Caterpillar engines using such fuels as indeed it has in a wide variety of other engines. It is also widely approved by engine manufacturers and full characteristics are also given in Appendix 1.

DEUSOL RX SUPER

Deusol RX Super is a heavy duty lubricant 'borrowed' from the Castrol Industrial range to meet specific manufacturers requirements, particularly Detroit Diesel who have an ash limitation of 1%. The performance of this oil is also to API-CD requirements and it is successfully used in a wide variety of diesels such as General Motors, Daimler Benz, Volvo, Penta, Caterpillar, Mack, Ford etc. RX Super was designed specifically to achieve extended oil change periods and this it achieves by virtue of its high detergency/dispersancy level. Typical characteristics are given in Appendix 1.

Outboard Engine Oils

Castrol supply a full range of fuel miscible outboard engine oils to cater for the demanding requirements of these engines. Their most advanced product is Castrol Biolube 100 which, as its name suggests, is able to satisfy the stringent specifications which are being evolved to avoid environmental pollution.

CASTROL BIOLUBE 100

Castrol Biolube is a superior quality, synthetic based lubricant specially formulated to combine the requirements of high powered, water cooled, two-stroke outboard engines with environmental demands such as biodegradability, low hydrocarbon emission and low toxicity. It has been evaluated against the tentative BIA TC-W 100 Specification and satisfied all the requirements. As such, it is readily miscible with fuel and contains selected ashless additives to give excellent piston cleanliness, thermal stability, resistance to plug fouling, anti-wear and corrosion protection performance.

The biodegradability of Castrol Biolube 100, in comparison with other super outboard oils, has been assessed by two methods namely measurement of chemical oxygen demand (COD) and measurement of biochemical oxygen demand (BOD), and in both tests, Castrol Biolube 100 consistently demonstrated a greater degree of biodegradability than super outboard motor oils.

Although more expensive than conventional oils Castrol Biolube 100 can be used at half the concentration, i.e. a fuel/oil mixture of 100:1, which makes it an economically viable product. Typical characteristics are given in appendix 2.

CASTROL SUPER OUTBOARD OIL

Castrol Super Outboard Oil is a superior quality lubricant specially formulated to meet the requirements of high powered two-stroke outboard engines. It is ready miscible with fuel and contains selected ashless additives to give excellent piston cleanliness, thermal stability, resistance to plug-fouling, anti-wear and corrosion protection performance.

Castrol Super Outboard Oil meets the requirements of the stringent U.S. Boating Industries Association (BIA) Specification BIA TC-W, and is suitable for use in high powered two-stroke outboards at a fuel/oil mixture ratio of 50:1. Typical characteristics are given in appendix 3.

CASTROL OUTBOARD GEAR OILS

Castrol Outboard Gear Oils Light and Medium are SAE 80 and SAE 90 mineral based extreme pressure gear oils which respectively meet the API GL4 and GL5 specifications. Castrol Outboard Gear Oil Light is particularly suited for use in OMC stern drive units fitted with electrically actuated gear shift mechanisms while Gear Oil Medium is suitable for use in Mercury, Chrysler, Yamaha and Volvo-Penta gears where an SAE 90 oil is required. Typical characteristics are given in appendix 4.

In conclusion, Castrol are able to supply the full range of lubricants and greases which may be required on board any vessel of any size. As well as in the main propulsion engine, Castrol products will satisfy the requirements of hydraulic systems, gears, stern tubes, C.P. propellers, telemotor systems, refrigerators, indeed wherever there is a need for lubrication Castrol will be able to supply a suitable product at an economic price.

APPENDIX 1

Typical Characteristics of MPX and MX Super

Castrol	MPX 20	MPX 30	MPX 40	215 MX SUPER	220MX SUPER
Relative Density @ 15°C	0.888	0.895	0.896	0. 898	0.901
Kinematic Viscosity @ 40°C cSt	65	105	150	103	147
Kinematic Viscosity @ 100°C cSt	8.3	11.5	14.7	11.8	14.6
Viscosity Index	100	96	96	98	97
S.A.E. Number	20	30	40	30	40
Closed Flashpoint °C	213	222	225	234	210
Pour Point °C	-15	-9	-9	-18	-15
T.B.N. mg/KOH/g	9	9	9	16	16
Sulphated Ash %	1.1	1.1	1.1	2.2	2.2

Typical Characteristics of Deusol RX Super

Deusol RX Super	20	30	40
Relative Density	0.888	0.895	0.890
Kinematic Viscosity			
at 40°C	65.4	96.0	151
at 100°C	8.65	11.3	14.9
Viscosity Index	104E	104E	98
Closed Flashpoint °C	222	240	267
Pour Point °C	-27	-21	-18
T.B.N. mg/KOH/g	10	10	10
Sulphated Ash %	0.9	0.9	0.9

APPENDIX 2

Typical Characteristics of Castrol Biolube 100

After diluent addition

SAE Rating	20
Specific Gravity @ 15°C	0.889
Viscosity @ 100°C cSt min	7.0
Viscosity @ 40°C cSt min	38
Viscosity Index min	150
Pour Point °C max	-40
Flash Point °C min	108

Chemical Characteristics

Sulphated Ash % wt max	40 ppm
Total Base No. min	17.0
Nitrogen % wt min	1.1

APPENDIX 3

Typical Characteristics of Castrol Super Outboard Oil

After diluent addition

SAE Rating	20
Specific Gravity @ 15°C	0.872
Viscosity @ 100°C cSt min	6.6
Viscosity @ 40°C cSt min	30
Viscosity Index min	140
Pour Point °C max	-40
Flash Point °C min	85

Chemical Characteristics

Nitrgoen % wt min	0.50
Sulphated Ash % wt max	40 ppm

APPENDIX 4

Typical Characteristics of Castrol Outboard Gear Oil Light & Medium

	Light	Medium
SAE Rating	80	90
Relative Density @ 15.0°C	0.885	0.900
Viscosity @ 100°C cSt min	8.0	15.0
Viscosity Index min	95	95
Pour Point max °C	-12	-12
Open Flash Point °C	227	210
Closed Flash Point °C	179	

Chemical Characteristics

Phosphorus %wt min	0.045	0.09
E.P. Type	Sulphur and Phosphorus	Sulphur and Phosphorus