

Testing and Care of Marine Diesel Engine Crankcase Oils*

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The title selected for this paper could cover a very wide field of interest; it is the author's intention to restrict himself to that section which deals with main engine crankcases employing a straight mineral lubricant oil which does not come under the category of a heavy duty dispersant detergent additive type.

INTRODUCTION

In the modern Diesel-engined vessel, there is an increasing amount of technical information being channelled to chief engineers and seagoing operating engineers, on subjects varying from the chemical treatment of boiler feed water to the selection of optimum timing for preferential tripping devices for alternator protection.

Technical information represents an investment of time and endeavour which costs the issuing authority a considerable sum of money. The expenditure of this money is made in the expectation that it will be returned in terms of increased reliability of equipment, which may reflect in longer periods at sea, with consequent enhanced earning power of the vessel, or reduction in maintenance costs, or in safety of life or property.

The correct utilization of technical information supplied may be divided into:

- a) thorough and detailed knowledge of the subject, or
- b) an awareness of general principles involved, followed by acceptance of the information given and its application to a set of particular circumstances.

This paper is intended to bring out the importance of the study and understanding of the information presented to ships' operating staff in the form of lubricating oil analysis reports.

The significance of the figures contained in the lubricating oil analysis report which is sent to the ship, either by the superintendent engineer or direct from the oil supply company, should be understood and, although the chief engineer is seldom in a position to initiate corrective action of a chemical nature when conditions depart from normal, he should be in a position to recognize the abnormal, and make recommendations to his own administrative authority.

Most shipping companies enter into a contract with an oil supplier to lubricate one or a group of ships in their fleet; some owners choose to divide their fleet between several oil suppliers. Most contracting oil companies undertake to make available supplies of recognized brands of lubricants in various ports throughout the world; they provide facilities for world wide credit payment to the home office; they undertake the collection and analysis of used oil samples, results of which are given, if time permits, to the chief engineer before the ship sails; at the same time his attention is drawn to figures indicating any defect (e.g. water or fuel leakage) which needs im-

mediate attention. Whether or not the results are passed to the chief engineer, they are given to the owners, with any technical comments or advice that may be necessary.

A service is usually available for plant lubrication surveys and the preparation of lubricants charts as an aid to ordering supplies in overseas ports where language variations are likely to occur. These are real benefits to shipowners whose vessels operate for long periods away from home ports.

OIL SAMPLING BY THE SHIP

For laboratory examination of used oil samples to be of value, it is essential that they should be representative of the oil in the system. To ensure this, they should be drawn preferably whilst the engine is running or, if this is not possible, the oil should be in circulation throughout the system. It is best to take the sample from a circulating pipeline and not from the filter body or from the sump, as these places tend to accumulate areas of stagnant oil and wear debris, and therefore are not truly representative of the oil in circulation.

The sample bottles should be clean and quite free from beads of moisture. They should be washed internally with distilled water if available, failing that with fresh water, then blown out with compressed air, followed by a further rinse with a small quantity of methylated spirits and another blowing-out with compressed air. The cock from which the oil is to be drawn should be wiped clean, and a quantity of oil run off to clear the cock and associated pipe of stagnant oil. The bottle should be flushed with oil and then completely filled, and the cork inserted and tied down with string.

Most oil companies supply clean sample containers and labels—efforts should be made to keep a stock of each in the ship.

The importance of accurately labelling the bottle is stressed. It should be realized that laboratories sometimes have scores of samples awaiting attention, and the poorly labelled sample causes unnecessary confusion and inconvenience to both ship and laboratory.

Fig. 1 shows a typical sample bottle label, setting out the information which should accompany the sample.

LABORATORY REPORTS

Opinions differ on the acceptable limits of variation of used oils from the new oil conditions, for various reasons. It is unwise to generalize on definite variations from standard without fully taking into account the various factors which influence the used oil conditions. Some of the more obvious factors are:

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S.S./M.V.

Owners

Grade Hours in service }

Position from which drawn } Date

Port handed in Date

REMARKS (INCLUDE REASON FOR ANALYSIS—ROUTINE CHECK, SUSPECTED WATER CONTAMINATION ETC.)

FIG. 1—Typical sample bottle label

- a) the mechanical maintenance state of the plant;
- b) the operating conditions of load and temperature;
- c) type of fuel and its combustion efficiency;
- d) effectiveness of the oil purification conditioning process;
- e) the nature of the base oil—its refining and ultimate formulation into the finished lubricating oil.

TABLE I.

Viscosity	25 per cent increase or decrease
Water content	above 1 per cent
Sediment insoluble in normal heptane	above 1 per cent weight
Ash	above 0.13 per cent weight
T.A.N. (Total acid No.)	above 2.5 mg. KOH/g.
S.A.N. (Strong acid No.)	above 0.1 mg. KOH/g.
Closed flash point	75 deg. F. reduction above 0.005 per cent.

As an indication of the order of departure from new oil condition at which concern should be felt, or corrective action taken, the figures in Table I may be some guide:

Fig. 2 illustrates a typical laboratory report as received by the superintendent engineer, and frequently by the chief engineer of the vessel. Without describing in great detail all the facets and shades of meaning involved, the author will examine the left-hand column, and discuss each item as it appears (many of these items were dealt with in detail in a paper⁽⁵⁾ read before the Bombay Section of the Institute in 1960).

Grade

This describes the market brand name of the oil; the physical characteristics of new oil of this brand name are available for comparison with the sample, or may be compared with earlier laboratory reports after the oil is known to be new or has done little work.

Laboratory No.

For use by the laboratory for their records.

Viscosity

- R.1 at 140 deg. F.
- E° at 50 deg. C.
- S.U. at 100 deg. F.

Viscosity should be reported to owners in the terms of the viscosity system used in their own countries—e.g. in Europe, the Engler degree system; in North and South America, the Saybolt Universal seconds at 100 deg. F.; in U.K. and the rest of the world, Redwood I seconds at 140 deg. F.

The Redwood and Saybolt systems of viscosity measurement may be broadly described as the time taken in seconds of time for a known quantity of oil, at a stated temperature, to flow through an orifice or short capillary tube of standard dimensions, and therefore these systems are purely empirical. The Engler system of viscosity determination is based upon the seconds of time for a measured volume of oil at a stated temperature to pass through a conical section outflow tube, but differs from the Saybolt and Redwood systems in that the Engler time is expressed as a ratio to the time which is required for a similar quantity of water at 25 deg. C. to flow through the tube; thus viscosity in degrees Engler at A deg. C. = seconds for 50 ml. oil at A deg. C.

seconds for 50 ml. water at 25 deg. C.
By the use of conversion tables or charts, conversion may be made from one system to another.

Viscosity varies with temperature, becoming thicker and more viscous with cold, or thinner and less viscous with heat; the temperature at which viscosity was measured must be stated for the figure to have any indication of the comparative viscosity at a temperature which is known.

Water Content

This is expressed as water contamination per cent by volume of the oil sample.

During operation of a large marine Diesel engine, con-

MARINE OIL ANALYSIS REPORT

LABORATORY (Capital City) AUSTRALIA DATE

NAME OF VESSEL

OWNER and/or OPERATOR

DATE SAMPLES DRAWN DATE SAMPLES RECEIVED

OIL SAMPLES

	MAIN ENGINE		OTHER SAMPLES
	Before Purifier	After Purifier	
Grade			
Laboratory No.			
Viscosity			
R1 at 140° F.			
E° at 50° C.			
SU at 100° F.			
Water % VOL			
Salt % Wt.			
Sediment insoluble in Normal Heptane % Wt.			
Sulphated Ash % Wt.			
Nature of Ash			
TAN Mgm KOH gm			
SAN Mgm KOH gm			
Closed Flash Pt. °F			
TBN-E Mgm KOH gm			
ADC Test			
Alkalinity			
Dispersency			
Contamination			

Remarks:

CHEMIST-IN-CHARGE

Distribution

Copies to

DETAILS advised Chief Engineer Date

Chief Engineer not advised details because

FIG. 2—Typical laboratory report form

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tamination of the bearing oil by water is practically unavoidable. In the absence of detergent additives, bearing lubricating oil should normally separate from water without difficulty, but if the oil is contaminated, or if it deteriorates badly, the possibility arises that the oil and water may form a permanent or semi-permanent emulsion. In particular, the products of oxidation of the oil in a bearing circulating system include polar compounds, i.e. substances whose molecular structure is such that one part of the molecule is electrically negative with respect to another part; for example, in the fatty acids such as oleic acid the acidic group is polar. The presence of such a polar group favours orientation of the molecule on surfaces and interfaces, and in mixtures such as oil and water this may contribute to the dispersal of one fluid in the other, so stabilizing the emulsion.

The emulsions liable to be formed in contaminated or used oil are usually only of water-in-oil type, but vary in consistency. It is possible for the entire oil charge to form an emulsion, but more often emulsification is identifiable with the precipitation of sludge, this taking place at a progressively increasing rate. Accretion in the oil of resins and asphaltenes will lead to sludging; sludge may consist largely of such matter, but may also consist largely of water and good oil, in dark, stiff emulsified mixtures stabilized by relatively small quantities of acidic products of deterioration. Apart from the more immediate products of oxidation such as acids, products of corrosion such as finely dispersed oxides and hydroxides of iron, or oil-soluble metal soaps, also tend to stabilize emulsions.

Whether the lubricating oil retains the ability to readily separate from water during operation depends primarily on its remaining sufficiently free from extraneous contaminants and from products of oxidation or corrosion. Extraneous contaminants of many kinds are capable of promoting emulsification of the lubricating oil—for example, fuel oil, cylinder drainings, scale, grease, paint and so on—and only good maintenance can prevent trouble on this account. The oil supplier is, however, able to ensure by suitable selection, refining and formulation of the oil that it does possess good demulsibility when new, and that it possesses sufficient resistance to oxidation to be capable of retaining adequate demulsibility during prolonged service.

As water contamination can be either fresh or salt, it is customary for appreciable water content to be so reported that the field of investigation for the leak is narrowed.

Salt

Salt is corrosive and its presence in the system oil is a potential danger. Whether corrosion will actually occur in any particular case depends on a number of factors such as concentration of salt, presence of water and electrolytes and whether an additive type oil which has anti-corrosion properties is in use, etc. Cases are known where system oils have contained appreciable amounts of salt without giving rise to any trouble. On the other hand in unfavourable circumstances quite small quantities of salt are liable to give trouble.

Even though the water content may be low or within acceptable limits, salt may still be present in the oil due to part evaporation of water which would result in a more concentrated salt solution, with the dangers of corrosion of highly polished bearing surfaces.

Bearing corrosion leads to a reduction of the load-carrying area of the journal, with consequent over-loading of the white metal in the bearing shell, with perhaps ultimate cracking or flaking of the metal and the destruction of the bearing.

If the reported salt content approaches 0.005 per cent weight of the oil sample, water washing of straight mineral oils at the centrifugal purifier is recommended.

The centrifuge should be adjusted as a separator—that is, with a dual discharge of cleaned oil from one discharge and water and other contaminants from the other. Warm fresh water should be admitted to the dirty oil inlet at a rate of approximately 5 per cent water; for severe salt contamination, it may be desirable to increase the water wash to a figure of

20 per cent of the oil throughput of the centrifuge. With an oil throughput of 100-200 gal./hr., water flowing from a $\frac{1}{8}$ -in. diameter bore pipe should suffice.

Sediment Insoluble in Normal Heptane per cent Weight

This is sometimes reported as sediment insoluble in I.P. spirit or sediment insoluble in benzene. The tests using normal heptane and benzene being two separate tests, normal heptane of recent years has replaced the I.P. spirit test.

The sediment insoluble in benzene determination gives an indication of the amount of insoluble contaminants in the oil such as combustion soot, wear products, dust and rust. Sediment insoluble in I.P. spirit includes benzene insolubles together with products of oxidation of the oil and fuel. (Solids that are dissolved in water will not, of course, appear as sediment, e.g. salt may be wholly or partly dissolved in any water present and only the part not dissolved will show up as sediment.) It will be appreciated from the foregoing that of the two sediment tests the I.P. spirit determination gives the more embracing information as to the level of insoluble solids in the oil—in fact, as I.P. spirit tends to precipitate oil soluble oxidation products, this test is likely to give a figure somewhat higher than the actual content of oil insoluble matter. The actual insoluble content will normally be somewhere between the I.P. spirit insolubles and the benzene insolubles.

If both methods for insolubles are presented, it may be to provide a guide to the extent of oil oxidation as represented by the difference between I.P. spirit and benzene insolubles. However, experience has shown that the large majority of marine oil samples examined exhibit no appreciable difference between I.P. spirit and benzene insolubles, and it is now considered that, if the benzene insolubles are omitted, sufficient information as to the degree of oxidation of the oil will still be obtained from the I.P. spirit insolubles in conjunction with total acid number. As oxidation tends to thicken the oil, viscosity may also give an indication in this connexion but will require careful interpretation in the light of results from other tests (flash point to indicate fuel dilution; water content to show whether an emulsion may have formed with consequent increase in viscosity.)

Sulphated Ash, per cent Weight

This is a measure of the incombustible materials contained in the oil sample. The test is carried out by heating a known weight of oil in a crucible which is open to the atmosphere; volatile constituents are drawn off until no more liquid remains, then the residue is strongly heated until the carbon and other combustibles are consumed and only metal particles, dust or metallic radical salts, emanating from additive type cylinder oil drainings, remain; the residue is then treated with sulphuric acid and heated strongly. This is weighed and reported as a percentage of the original sample weight. They are, of course, indicative of the metallic and silica contamination of the system oil.

Nature of Ash

This describes the main ingredients found in the ash remaining after the oil has been burned off. A simple flame coloration test usually suffices.

Closed Flash Point

It has been appreciated for some time that the Diesel fuel diluent test provides no reliable information on the presence of diluent in the oil where heavy fuels are used. Investigations have been carried out into the possible use of the closed flash point determination as a guide to fuel dilution, using a number of different viscosity fuels. Of the tests run, the results achieved when a 3,500 sec. fuel was being used were of particular interest and are, therefore, quoted in Tables II and III.

It will be seen that, even with 10 per cent volume 3,500 sec. fuel added to the straight mineral oil 30, no indication of fuel dilution was obtained in the Diesel fuel diluent test. The closed flash point on the other hand dropped by 45 deg.

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TABLE II.—TESTS WITH 3,500 SEC. FUEL

	Flash point (deg. F.) (P/Martens, closed) (I.P. 34)	Apparent (recovered) Diesel fuel diluent (per cent volume)
3,500 sec. fuel	255	—
Straight mineral oil 30	425	—
2 per cent volume 3,500 sec. fuel in straight mineral oil 30	420	<1
5 per cent volume 3,500 sec. fuel in straight mineral oil 30	400	<1
10 per cent volume 3,500 sec. fuel in straight mineral oil 30	380	<1

TABLE III.—EFFECT OF VARIOUS FUELS ON FLASH POINT OF A
SAMPLE OF STRAIGHT MINERAL OIL 30

Flash point of fuel (deg. F.)	Percentage volume* of fuel for drop in flash point of:			
	100 deg. F.	75 deg. F.	50 deg. F.	25 deg. F.
174	3	2	1	1
184	7	4	2	1
194	7	5	3	1
202	6	3	2	1
222	10	8	5	2
230	10	10	8	4
255	10	10	10	5

*To nearest whole number

Table III shows the actual amounts of a series of representative fuels (ranging from light distillate to marine Diesel fuels) in samples of the oil which corresponded to reductions in flash point of the oil of 25, 50, 75 and 100 deg. F.

These figures suggest that, given precise information as to the flash point of the fuel in use and of the system oil when new, a flash point determination on a used system oil sample would provide quantitative information on the extent of contamination of the oil with fuel. However, in practice, each viscosity grade of fuel can differ appreciably in flash point from batch to batch (in general the flash point of gas oil may vary within the range 150-200 deg. F. and that of marine Diesel and heavier fuels within the range 150-280 deg. F.). Furthermore, vessels may from time to time take on different grades of fuel. In consequence the flash point of the fuel in the ships' tanks is likely to vary continually and precise information on the flash point of the fuel in use is never readily available. In practice, therefore, the closed flash point of the system oil could not be used to assess the actual amount of fuel in the oil.

However, tests show that the closed flash point determination will be somewhat more informative than the diluent determination in indicating the presence (but not the actual amount) of heavy fuel in the system oil and therefore that it will provide a better basis for advising owners and/or chief engineers to check for fuel leaks. (This is, of course, the main object of endeavouring to detect the presence of diluent in the system oil—any effect of diluent in other important characteristics of the oil will be shown up by other tests, e.g. viscosity). Furthermore, the diluent test is by no means accurate even with gas oil and marine Diesel fuel. The closed flash point test (and possibly in some cases the viscosity of the used oil) can be used to obtain an indication of the presence of light distillate as well as heavy fuels.

It will be seen from Table III that a reduction in flash point of 25 deg. F. corresponded to a very small amount of fuel in the oil with all but the two highest flash point fuels used. At the other extreme a drop in flash point of 100 deg. F. corresponded to undesirably high amounts of fuel in the oil with all but the lowest flash point fuel. As a compromise, therefore,

and as a very general guide, it would appear appropriate to advise owners and/or chief engineers to check for fuel leaks whenever the flash point of the system oil shows a reduction of 75 deg. F. or greater. The closed flash point of unused straight mineral oil 30 is unlikely to vary greatly from 430 deg. F. (depending on source of supply it may vary in the range 400-450 deg. F.) and consequently with this system oil it will be appropriate to recommend checking for fuel leaks whenever the flash point of a used oil sample is below about 355 deg. F.

It will be appreciated that this figure can only be used as a very general guide and that it might prove necessary to modify it in the light of further experience. Moreover, with gas oil and to a lesser extent with marine Diesel fuel and very heavy fuels (of the order of 3,500 sec.) the viscosity of the system oil sample may also give an indication of fuel dilution (see Table IV). Thus, in such cases, this property of the used oil should also be taken into account after making due allowance for any contamination or oxidation of the oil (as evidenced by I.P. spirit insolubles, water content and total acid number).

TABLE IV.—EFFECT ON OIL VISCOSITY OF CONTAMINATION WITH
VARIOUS FUELS

Fuel	Viscosity at 140 deg. F.	
	Kinematic (cs)	Redwood I (sec.)
Straight mineral oil 30	41.5	171
Straight mineral oil 30 + 10 per cent volume gas oil	25.8	108
Straight mineral oil 30 + 10 per cent volume marine Diesel fuel	31.7	132
Straight mineral oil 30 + 10 per cent volume 600 sec. fuel	41.5	171
Straight mineral oil 30 + 10 per cent volume 950 sec. fuel	42.5	175
Straight mineral oil 30 + 10 per cent volume 3,500 sec. fuel	46.6	191

A further point to bear in mind is that in the presence of appreciable amounts of water it may not be possible to obtain a flash point. The water content, above which no flash point is obtained, varies; it may at times be as low as 0.5 per cent weight. However, experience has shown that occasions when no flash point is obtained on used marine engine oils are actually very rare.

T.A.N. (Total Acid Number)

Some laboratories report this as Neutralization Number or as Acidity. The term—total acid number—will be used here.

Acidity of a system oil in service is brought about by the formation in the oil of two types of acids—these are strong acids, such as sulphuric and sulphurous acids formed from the products of combustion, and the weak acids resulting from the oxidation of the oil itself. Each type of acid may exist in the oil, either together or singly. The summation of the strong and weak acids is called T.A.N. The presence of strong acid in proportions exceeding 0.1 mg. KOH/g. could point to blow-by of combustion gas contaminating the oil supply at the diaphragm gland and conditions allowing this oil to find its way into the crankcase, either by way of the gland carrier box seating or from a drain pipe discharging to a non-oiltight joint or crankcase door, etc.

In recent years there appears to have been an increase in the cases of rapid oxidation of system oil in marine Diesel engines. In some instances, failure of crankshaft and cross-head bearings has been attributed to oil oxidation.

It is now clear that rapid oxidation with rise in T.A.N., i.e. neutralization value of system oil, is largely a function of:

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- contamination of system oil with cylinder drainings and products of combustion which can act as catalysts;
- higher heat loadings imparted to the oil by higher piston and sustained exhaust temperatures;
- in some designs, an insufficient quantity of oil is in circulation, which gives rise to a more frequent cycling of the oil from hot to cold, which promotes oxidation.

The probability is that contamination by strong acids is the cause of the bearing failures. It would appear that strong acids attack the journals and pins and by pitting and etching reduce the effective bearing area to the point where, due to overloading, the bearing metal collapses.

The most effective way of overcoming the problems of rapid oil oxidation and bearing failure is, of course, to stop adventitious material entering the crankcase and to reduce the heat load on the oil. The first is impossible to achieve completely and the second, which would probably require the engines to be modified structurally, is not popular with the builders.

There are three possible ways of eliminating corrosive attack resulting from high acidity of system oil; these are:

- converting from heavy fuel oil to marine Diesel fuel;
- treating the system oil on board ship with, for example, an aqueous solution of tri-sodium phosphate to neutralize strong acids and remove weak acids;
- using an oil suitably fortified against the adverse conditions encountered.

As regards a), some shipowners have made this change, but the vast majority appear to be reluctant to burn a more expensive fuel.

In highly rated engines, there is a trend away from straight mineral oils toward the oxidation inhibited or fortified blends; considerable work has already been done, and field experience has been gained which appears to indicate that the thinking is along the right lines.

Total acid number of a used straight mineral oil is one of the tests which give an indication of deterioration due to oxidation. In engine oils, however, there is always the possibility that the determined acidity may be due, wholly or in part, to contamination by fuel combustion products rather than to oxidation of the lubricating oil. It is sometimes possible to assess the relative importance of these two effects, because the acidic material derived from oxidation of the oil is largely organic acidity, whereas that from combustion of the fuel is partly inorganic (e.g. sulphur acids). A determination of the total acid number (T.A.N.) gives a measure of the organic plus inorganic acidity, whilst the determination of the strong acid number (S.A.N.) gives a measure of the inorganic acidity. The organic acidity can therefore be obtained by the difference between T.A.N. and S.A.N. It is customary to determine periodically the neutralization value of the crankcase oil in large marine Diesels. In most cases, where these engines are of the crosshead type and are provided with separate lubrication for cylinders, oil draining from the cylinders should not (in theory, at least) find its way into the crankcase, provided that a diaphragm is fitted and the diaphragm glands are properly maintained. Deterioration of the crankcase oil is then very slow, and the neutralization value rises only slowly over a number of years. Provided this rise is gradual and the value is less than 2.5 mg. KOH/g., no trouble should be experienced. A rapid increase in neutralization value, however, is an indication of oxidation developing and a warning that, from then on, oxidation may proceed more rapidly.

In some engines there have been several instances of an early rapid rise in neutralization value, and values as high as 10 mg. KOH/g. have been attained after a few months. These abnormal increases in neutralization value have been found to be due to leakage of the hot products of combustion into the oil used for cooling the pistons and/or contamination with cylinder drainings, which introduce strong sulphur acids from the combustion of the fuel and catalysts which promote oxidation of the oil. In such cases, the oils contained small amounts

of strong acid, as well as the organic acids formed from the oxidation of the oils. If crankcase oils are regularly tested, the neutralization value provides a useful indication when the oil requires attention (for example, by water washing) in order to extend its life in the engine.

Straight mineral oils have an inherent resistance to oxidation, and under optimum conditions are in use for long periods without a marked rise in neutralization value. When the natural oxidation resistance has been expended, oxidation, hence acidity, rises rapidly.

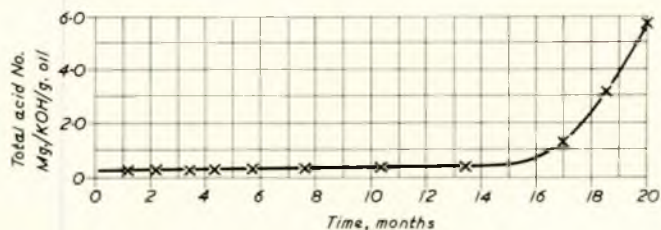


FIG. 3—Graph of total acid number

Fig. 3 shows the graph of T.A.N. plotted against time in months. Although the horizontal axis denotes the months beginning at 0, this does not of necessity indicate the oil charge was new at this time; it could represent a steady state of T.A.N. over a long period prior to the plot being commenced. At 14 months, some abnormality occurred which triggered off the rise in T.A.N.

It is interesting to note the rise in T.A.N., from 0.5 to 1.0, in four weeks. In a further five weeks, the figure had reached a point where some concern should be felt and positive action taken to arrest the rise and reduce the figure to more acceptable standards. In the next four weeks, the figure has exceeded the danger point and it is probable that no corrective action of which the ship is capable would remedy the position. Six weeks later, the system oil charge was discharged and a special cleaning routine carried out before the new oil charge filled.

It is recommended that the chief engineer keep an up-to-date graph of the information presented in the laboratory oil analysis report, as a line on a graph often catches the attention whereas one is sometimes reluctant to turn back over past records in a thick file.

Shipboard Acidity Test Kits

One oil supplier endeavours to give an additional service to shipowners by developing and making available to ships, a testing kit which resembles in some respects the technique for the testing of boiler feed water. It will determine T.A.N. and S.A.N.

The kit is not intended to replace regular full scale laboratory testing of samples, but to enable ship staff to keep a closer check on system oil conditions in cases where the neutralization value is known to be rising, in some cases the rise in neutralization value has been so rapid that no warning was obtained from routine samples taken at four or six-monthly intervals.

The Total Acid Number Test

This is carried out by shaking 5.5 ml. of oil and 50 ml. of alkali blue indicator solvent in a graduated glass cylinder and adding alcoholic potassium hydroxide solution from a hypodermic syringe until a colour change takes place. A simple calculation then gives T.A.N.

Strong Acid Determination

This method detects the presence or absence of strong acids by shaking 10 ml. of oil, 10 ml. of a solvent and 10 ml. of aqueous methy orange indicator together in a graduated glass cylinder. When the water layer has separated its colour is observed: yellow indicates the absence of strong acids and pink that they are present.

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Correction of a Rising T.A.N.

Referring to Fig. 3, at the seventeenth month, the change in slope of the graph indicates that the oil supplier should be consulted and asked to suggest corrective measures.

Experience has shown it to be possible to arrest and then reduce the rising T.A.N. by the addition of tri-sodium phosphate to the water wash admitted to the centrifuge.

In one case of rising T.A.N., the corrective treatment advised was the addition of 3lb. of tri-sodium phosphate (Na_3PO_4) dissolved in four gallons of warm fresh water allowed to drip at the rate of 60-70 drops per minute into the oil inlet of the centrifuge over a period of twelve hours. At the end of four days, Na_3PO_4 was discontinued and plain fresh water admitted to the centrifuge at the rate of 48 gallons in 24 hours for three days.

Table V shows the improvement in T.A.N. of the system oil condition over an eight month period as a result of this treatment.

TABLE V.

	December	March	Early August	Late August
T.A.N.	2.7	1.45	0.95	—0.7
S.A.N.	Nil	Nil	Nil	Nil
Salt	0.0005	Nil	Nil	0.001
Insolubles in normal heptane	0.08	0.19	—	0.34
Flash	410	420	425	375
Viscosity R.1 at 140 deg. F.	199	197	184	183

Total Base Number—Electrometric (T.B.N.-E)

T.B.N.-E is a test which refers to the reserve of alkalinity determined by electrometric titration method of a used detergent/dispersant additive type crankcase oil, and therefore does not come within the scope of this paper.

A.D.C. Test

This is a "blotting paper" and indicator test to assess the alkalinity, dispersing powers and the contamination burden of carbon, etc. of a used detergent/dispersant additive type oil, and therefore does not come within the scope of this paper.

COMPLETE OIL CHANGE

Twelve subject headings which appear on the laboratory report have been discussed; the conditions which lead to deterioration of the system oil have been examined, and means of controlling and correcting deterioration of the oil charge have been considered.

Sometimes, despite our best endeavours, the point is reached where a complete oil change becomes necessary, so now let us consider the routine involved in removing the used charge, cleaning the system, then taking on the fresh oil charge.

We will consider the case of a vessel in an outpost where the normal dockyard facilities of labour and guidance of the superintendent engineer are not available. In fact, it devolves upon the ship's chief engineer to be responsible for minimum delay to the ship, but at the same time to protect adequately the machinery under his care.

The work involved in the oil change may be summarized:

- removing used oil from system;
- cleaning crankcase;
- cleaning and scraping the double bottom sump tanks;
- circulating of the flushing oil charge which may be divided into two separate flushes;
- taking on a new running charge of oil.

If the change is to be carried out in a port where the facilities available are not known, it is as well to call a conference, on arrival, with the port agent, the oil supplier's representative and the ship's executive staff; here it must be

decided how to dispose of the used oil; whether ship's staff or shore labour will clean the double bottom tanks, and how long this operation will take; the pumping time for delivery of flushing and main charge of oil. A probable time-table of events should be worked out.

It must be borne in mind that some ports have difficulty in arranging for the disposal of large volumes of used oil. In some instances, a sullage barge may have to be hired, which could cause a time delay, or rail or road tankers used, it being left to the agent to arrange the method of disposal from barge or tanker. Customs clearance is sometimes necessary for the oil to be sent ashore for dumping. An alternative is to pump the oil to a double bottom tank and later discharge it to the sea, or work off in small quantities as boiler fuel.

The engine should be inspected internally for signs of white metal runs at bearing ends. If possible, random bearings could be opened for inspection of journals and bearings for corrosion; this knowledge will be used later to decide if chemical additions should be made to the flushing charge.

Having removed the bulk of the oil from the engine, the system must be drained—i.e. piston cooling pipes broken, oil coolers, filter bodies and large diameter pipelines drained. It is important that no pockets of oxidized oil be left to act as catalysts to promote the deterioration of the new charge.

The main engine lubricating oil pump will leave some inches depth of oil in the double bottom tanks, depending upon the trim of the ship. It is sometimes possible to use the oil purifier pump to get a suction for the dregs remaining in the double bottom tank; if this is not possible, provision should be made for a reinforced flexible suction hose from another pump. If this aspect is organized before the operation commences, valuable time will be saved in manual bailing by buckets in the confined spaces of the double bottom when tank cleaning commences.

Highly oxidized oil has an acrid odour; the prudent engineer would no doubt have previously organized a ventilating fan of about 1 h.p. capacity, with a canvas air trunk to reach from the floor plates into the tank top manhole cover, so that forced ventilation may be carried out before allowing men to enter the tank. If forced ventilation is not possible, the prudent engineer may decide to have a chemist certify the space safe for men to enter.

In some systems, it is possible to close an isolating valve between the crankcase and the double bottom tank, and take a suction with the lubricating oil pump direct from the crankcase. Where this arrangement is possible, the tank cleaning team can continue while the engine is being circulated with flushing oil.

The Flushing Charge

A low viscosity straight mineral oil, or a low viscosity detergent/dispersant Diesel crankcase oil may be chosen for this duty. When possible, the flushing charge should be taken aboard at a temperature of between 100 and 130 deg. F. as the hot oil has a better solvent action on gums and lacquer deposited by the oxidized oil.

If the water content of the used oil is high, it may be desirable to add 10 per cent fresh water containing 7 per cent sodium nitrite to the flushing charge to minimize the corrosion of polished surfaces within the engine. Note: Sodium *nitrite* should be used—not Sodium *nitrate*.

The engine should be rotated, by the turning gear, for a few minutes every half an hour for the duration of the flush. If straight mineral oil is used, the effectiveness of the flushing may be judged by plotting T.A.N. of samples taken every four hours. The graph will rise rapidly in the first few hours then flatten out. If it was decided to split the flushing charge into two sections, the first flush could be removed when the graph shows that T.A.N. has stabilized; this may take 12 or more hours. The second part of the flushing oil can then be circulated for a further 12 to 24 hours. Some authorities advocate the running of the centrifuge purifiers during the flushing operations.

Testing and Care of Marine Diesel Engine Crankcase Oils

A thorough inspection should be made of the interior of the double bottom tank to be sure that scale and rust flakes have been removed from the underside of the tank top as well as the sides and bottom.

The inspections carried out, covers and pipes re-tightened, there only remains the taking on of the new running charge of oil.

To have on record the success of the flushing and cleaning operations with respect to the new oil change, an early sample should be taken, within a few days for preference, so that the new oil figures are available for comparison with samples taken at a later date.

CONCLUSION

Time spent by a ship's staff in the study of oil analysis figures and the recording and charting of the information presented, is time well spent; periodic perusal of the records can lead to forecasting the need for closer attention to some aspect of maintenance or the saving of materials, labour, and perhaps

contribute to avoiding delays to the vessel's programme.

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Correspondence on "Boiler Cleaning"

A further contribution to the discussion on the paper by Commander R. M. Inches, published in the September 1962 issue of the TRANSACTIONS (Volume 74, page 289), has been received and is given below, together with a reply by the author.

MR. A. WALKER, M.A. (Member) wrote that he had been one of the surveyors employed on a temporary basis by the Admiralty for the D-day operations and was a member of COREP (Combined Repairs). He had had possibly one of the most interesting jobs, being employed partly in the dockyard at Portsmouth and partly in combined headquarters at Fort Southwick. COREP'S job was to try to keep the merchant ships running and no-one else had any say in the matter during those operations. He was released from those temporary duties and then was asked to criticize the arrangements which had been made for COREP. He had had only two criticisms to make, in fact the planning had really been wonderful. The first criticism was not relevant to Commander Inches' paper.

There were a number of cross-channel vessels which had been lying for weeks and even months at various south coast ports before D-day. A few days after D-day each one of them in turn was demanding to clean her watertube boilers for fear of breakdown. Instructions were received from the Admiralty to disregard the boilers and for the vessels to carry on. Mr. Walker's second criticism was to ask why those vessels had not been allowed to clean their boilers during the weeks and months of waiting before D-day. The answer was that those watertube boilers took seven or eight days to clean properly and had the enemy known that a ship was having

her boilers cleaned, he would also have known that D-day was not for another seven or eight days.

Commander Inches said, in reply, that Mr. Walker's contribution to the discussion illustrated admirably how, at the time to which he referred, boiler cleaning dominated (or perhaps bedevilled was a better word) ship usage.

As mentioned in the paper, the challenge presented by that situation was taken up and stimulated progress, both in the field of boiler water treatment and that of water distillation. Admittedly, the advances made had not been universally adopted (indeed one must be honest and say that there was no requirement for their universal adoption), but with highly rated machinery such as that in Channel packets, or where a comparatively expensive set of machinery of advanced design was fitted, distillation and water treatment to the latest standards were allowing much longer running, between overhauls and with less risk of breakdown at that, than used to be the case.

In the author's opinion, full exploitation of that potentially strong point of steam plant (a very long time between overhauls) would strengthen its position vis-à-vis both Diesel and gas turbine plant.