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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants



TEXACO

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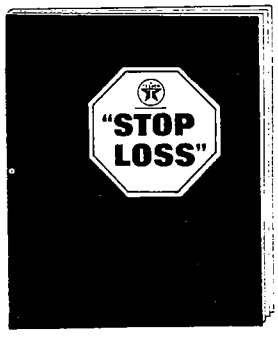
high parts inventory
high lube inventory
rising maintenance costs
rising production costs

Rx:



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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

Published by

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European Medium-Speed Marine Diesels

THE ROLE of the medium-speed diesel engine in marine service is an important one. In addition to providing auxiliary power in a vast number of motorships and emergency power in steam turbine vessels, the compact medium-speed engine is an obvious choice for the propulsion of coasters, tugs, trawlers, dredgers, small passenger vessels on short sea passages, ferries of various types and, of course, stationary power plants on land. In recent years, the list of applications has been extended to include quite large bulk carriers and other freight vessels on extended voyages.

For present purposes, the medium-speed range can be considered as between the approximate limits of 250 and 750 revolutions per minute: those engine builders who have concentrated their efforts on the development of diesel engines in this range are continually seeking to extend the use of these engines to larger and larger vessels, not just for auxiliary power, but for main propulsion duties. As illustrated in Figure 1, the medium-speed engine secures compactness and low height by substituting trunk pistons for cross-head construction. Figure 2 shows a non-supercharged, straight eight direct-reversing engine by the same manufacturer, while Figure 3 illustrates a similar engine equipped with an exhaust turbine supercharger and driving an alternator.

In the United States the low-speed crosshead type marine diesel engine never established itself since medium-speed diesel engines took over directly from steam reciprocating machinery, even for quite sizable vessels. Generally, in deep sea trade, the steam turbine has held sway and only now with increasing interest in automation is there any sign that this position will change. Even now it is uncertain whether the low-speed diesel engine will find its place or whether multiple medium-speed units geared to one or more shafts will have preference.

For many years in Europe, and in fact the rest of the world, low-speed diesel engines have been displacing steam turbines further and further up the horsepower range and now the medium-speed engines are following up, as it were, to increase their range of application.

It is generally recognized that the medium-speed engine will not be a serious contender to the low-speed engine in deep sea trades until it can utilize the same type of residual fuel with proven reliability and comparable maintenance costs. This day is not far distant, however, and in fact, there are

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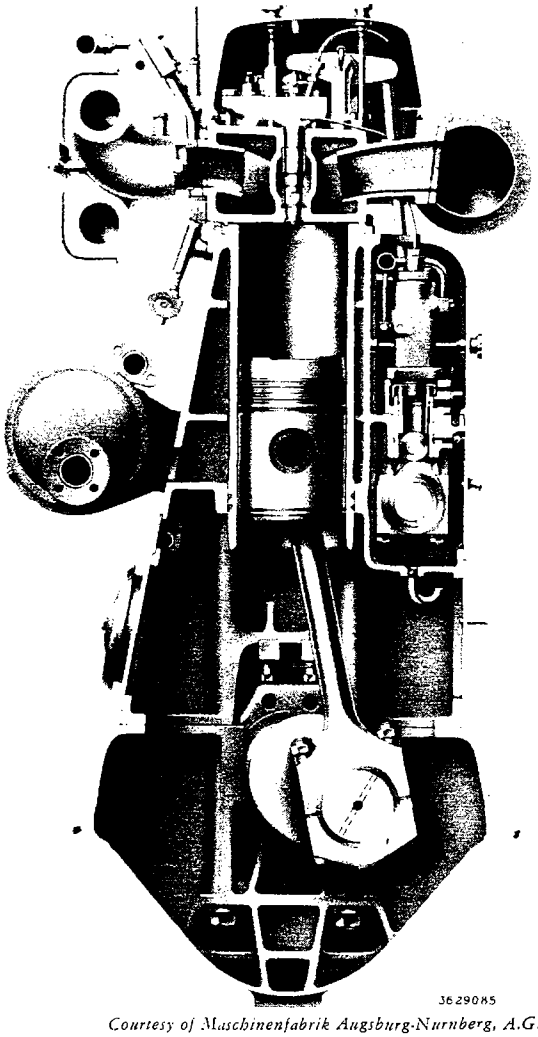


Courtesy of Maschinenfabrik Augsburg-Nurnberg, A.G.

Figure 1 — Cross-section of one cylinder in a M.A.N. model G8V 23.5/33 diesel engine, a type which operates satisfactorily on intermediate fuels.

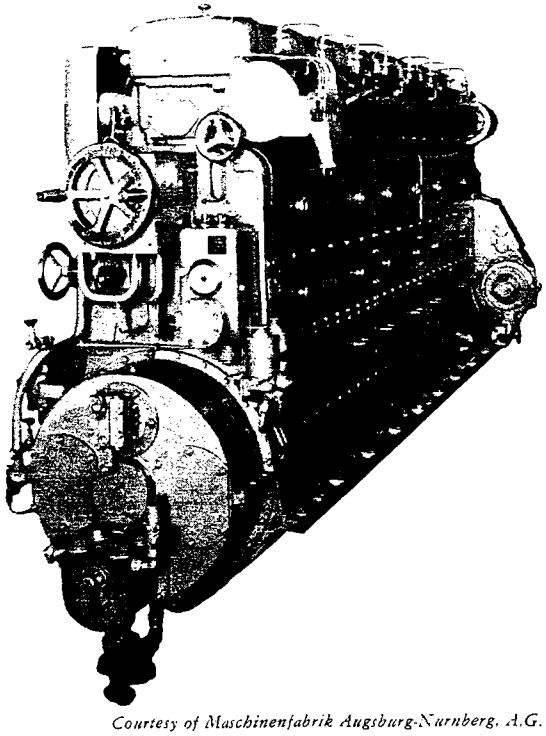
already a few large cargo vessels in service equipped with medium-speed machinery operating on residual fuels. Figures 4, 5 and 6 illustrate the results of two conversions from reciprocating steam engines to diesels.

Once the economies of medium-speed diesels have been proven equal to those of low-speed engines, other factors will weigh in their favor. Engine horsepower is a direct function of total cylinder volume multiplied by engine speed: thus, the designer can use an increase in permissible operating speed to obtain either increased power for the same engine size, or equal power from a lower and more compact engine, or total power can be divided among two or more engines. For a given total output, multiple medium-speed engines provide greater flexibility in engine-room layout. The lower headroom required by medium-speed engines is of great importance in vehicle ferries and passenger vessels, and in the case of tankers and other bulk carriers, the alternative of a reduced engine room length is also attractive.

Another factor influencing their choice is automation. If, and when, automation achieves the desired object of reducing the number of the engine room staff and there is not the manpower to carry out shipboard maintenance, repair by unit replacement will be the logical alternative, and in this regard, the medium-speed engine offers obvious advantages. The multi-engine installations which are envisaged provide greater flexibility so that if a major engine breakdown occurs at sea, ample power is still available from the remaining engines to reach the home port, where due to its moderate size, an engine replacement could be effected. Automation is also easier to apply to smaller engines, since valves and other controls are lighter. Also, since reverse reduction gearboxes or variable-pitch propellers enable uni-directional engines to be used, complicated sequence controls required by reversing engines for maneuvering can be virtually eliminated.

FUELS

In all applications of medium-speed engines, the search goes on for greater economies of operation,



Courtesy of Maschinenfabrik Augsburg-Nurnberg, A.G.

Figure 2—An eight-cylinder naturally-aspirated M.A.N. model G8V 23.5/33 diesel engine which develops 390 BHP at 514 rpm.

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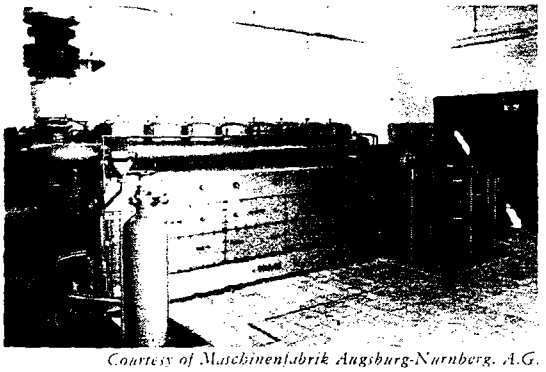


Courtesy of Maschinenfabrik Augsburg-Nurnberg, A.G.

Figure 3 — An eight-cylinder M.A.N. model G8V 23.5/33 MA diesel engine similar to that in Figure 2, but equipped with an exhaust-driven turbo supercharger which increases its output to 590 BHP at 514 rpm. Note high pressure air bottle in left foreground for use in cranking the engine during starting.

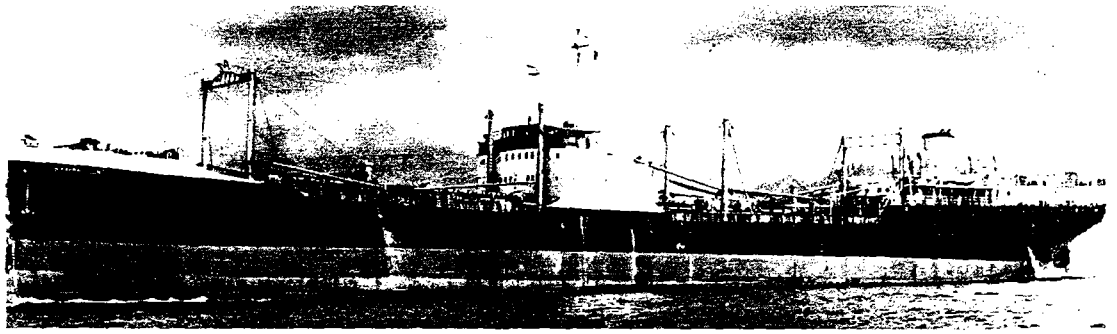
and fuel costs are constantly under review. It should be emphasized here, however, that only where medium-speed engines can be called upon to operate for long periods under fairly steady load conditions is any real net saving available from the use of low grade fuels. Although at first sight, the price differential between various fuel grades might show an attractive saving by a switch to a lower grade, when additional costs of heating the fuel, providing increased maintenance and perhaps employing a more expensive lubricating oil are analyzed, plus capital expenditure on equipment for fuel treatment and temperature controls, a different picture can emerge. Nevertheless, recognizing the need for all possible economies in these days of highly competitive freight and passenger rates, engine manufacturers have been engaged for some years in research and development aimed at widening the range of fuels which could be burned in medium-speed engines without, however, incurring any serious increase in maintenance or reduction in the period between overhauls.

Fuel prices vary considerably in different countries and, in fact, from port to port, depending on distances from main installations: in order to assess what savings may derive from a change to a lower grade, however, it is sufficient to consider the differentials applying at main installations in the United Kingdom. First, however, let us consider the characteristics of the grades available.

The British Standards Institution classifies fuels according to their suitability for various purposes. The main considerations are viscosity, water content and sediment, but limits are also placed on other specifications in the case of the first two classes. For marine use, fuels fall into one of the classes shown with specifications in Table I.

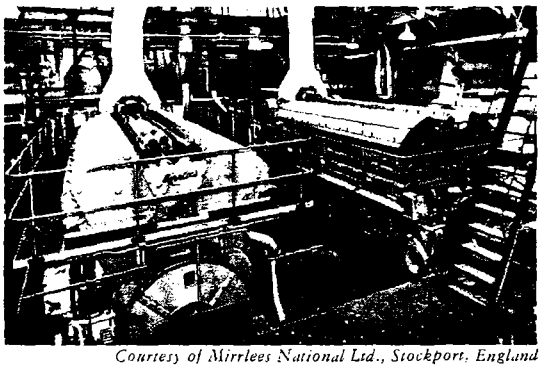
Additional specifications are laid down for Class A and B fuels, but these have little significance where medium-speed engines are concerned.

While these classes are useful to the engine manufacturer in specifying the fuel or range of fuels which can be used in a particular engine, it is common in marine practice to refer to a Class A fuel as "gas oil," a Class B fuel as "marine" or "bunker" diesel oil and thereafter to refer to a fuel by its viscosity figure in Redwood No. 1 seconds at 100°F. Oil companies have their own designa-



Courtesy of Mirrlees National Ltd., Stockport, England

Figure 4 — The M.V. Bahama Count, an old vessel which has been given a new lease of life by the installation of medium-speed diesel engines in place of the original steam plant.



Courtesy of Mirrlees National Ltd., Stockport, England

Figure 5 — View of engine room in the M.V. Bahama Count showing its two Mirrlees model KVSSDM12, 12 cylinder Vee type, direct-reversing main propulsion diesel engines, each developing 2100 shaft horespower at 310 rpm.

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TABLE I

	CLASS A min.	CLASS A max.	CLASS B max.	CLASS E max.	CLASS F max.	CLASS G max.
Viscosity, Redwood No. 1, seconds at 100°F[1]	30	45	65	250	1000	3500
Water Content, per cent by volume, max.		0.1	0.25	0.5	1.0	1.0
Sediment per cent by weight, max.		0.01	0.05	0.15	0.25	0.25
Carbon Residue, Conradson, per cent by weight, max.		0.1	1.5	—	—	—
Sulphur content, per cent by weight, max.		1.3	1.6	—	—	—

[1] Magazine LUBRICATION, Jan. & Feb. 1961, "Viscosity"

TABLE II

Class A or "gas oil"	100 per cent
Class B or "marine" or "bunker" diesel oil	88 per cent
Class E or "250 sec. fuel"	64 per cent
Class F or "1000 sec. fuel"	56 per cent
"1500 sec. fuel"	54 per cent
Class G or "3000 sec. fuel"	50 per cent

tion for fuels up to 1500 seconds but, in general, intermediate blends can be supplied at major ports to meet individual requirements. Prices, however, are fixed according to a viscosity range.

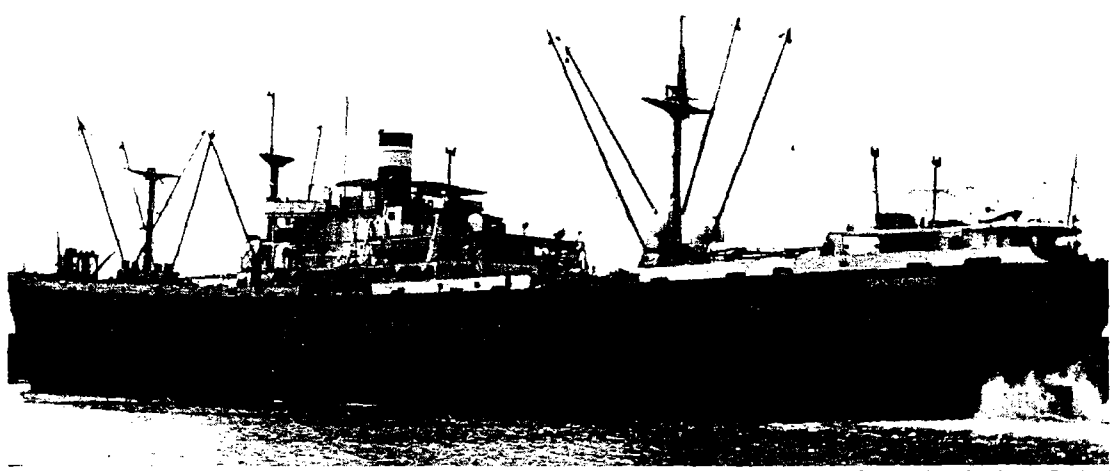
Table II presents current approximations of the prices applicable to the various fuel grades expressed as a percentage of the Class A or gas oil price.

Although many medium-speed engines in industrial service, mainly for electricity generation, are operating satisfactorily on 3000 sec. fuels, this range can be discounted for medium-speed marine propulsion engines since the shipboard treatment costs, plus increased maintenance, far outweigh the saving over the price of a 1500 second fuel.

It will be seen, however, that there is a very useful saving to be made by changing from gas oil to a marine or bunker diesel fuel. Until recently, the latter fuel contained approximately 10% of residual stock, was black or dark brown in color and opaque. Nowadays, however, in most European ports and some ports further afield a distillate marine diesel fuel is available which, at times, may meet the Class A specification, although not guaranteed to do so in all respects. The difference in performance of medium-speed engines on this fuel in comparison with gas oil is scarcely noticeable, and it is, therefore, not surprising that shipowners who previously used gas oil are taking advantage of the saving offered by the lower grade. Figure 7 shows one such engine which uses either Class A or Class B fuel with equal facility.

Supply and Demand

In the petroleum industry, it is necessary to establish markets for all the products derived from crude



Courtesy of Mirrlees National Ltd., Stockport, England

Figure 6 — The M.V. San George, a converted Liberty ship now propelled by two Mirrlees model KLSSDMR8 diesel engines, each developing 1595 BHP at 350 rpm with economical residual fuel and driving a single propeller through a RENK gearbox.

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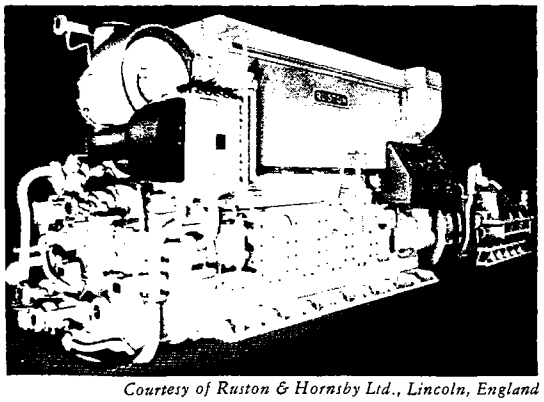


Courtesy of Ruston & Hornsby Ltd., Lincoln, England

Figure 7 — A Ruston & Hornsby 6 cylinder Mark 6ATCM marine diesel propulsion engine equipped with an exhaust-driven supercharger and intercooler and developing 1210 shaft horsepower at 520 rpm on either Class A or B fuels.

oil in order to maintain economical operation. Nothing can be wasted. However, there is an ever-increasing demand for the lighter products like motor spirit, kerosine (including, of course, aviation jet fuels) and gas oil or "DERV," as it is called in the European automotive field. This demand is met by increasing refinery throughput which, in turn, means an increase in the volume of the heavy residual byproducts. Though greater proportions of the lighter fuels are obtained from the crude by improved refining techniques, profitable markets must still be found for the heavier products remaining. Industry generally is utilizing more and more heavy residual fuel for furnaces in preference to coal. In the marine field, however, it is the diesel engine rather than the steam turbine which is proving more popular for general application and which is now providing the alternative market for residual fuels by virtue of its ability to accept the wider range without increased maintenance.

The rigid quality control, which must be applied to the lighter products to suit them for the more sensitive automotive and aircraft engines, cannot be extended to residual type fuels if their low cost is to be maintained. Modern shipboard treatment methods, however, easily remove the minor amounts of contaminants so that trouble-free combustion is achieved.



Courtesy of Temple Press Ltd., London, England

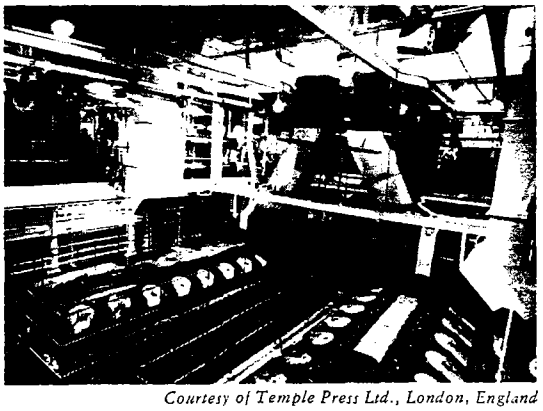
Figure 8 — The four Pielstick supercharged 12 cylinder diesel propulsion engines of the cargo vessel Rio de Janeiro which produce a total of 12000 BHP at 425 rpm and drive two controllable pitch propellers through electro-magnetic couplings and reduction gears.

Grades

At the present time, the use of residual-type fuels in medium-speed engines, that is to say, any fuels below Class B, is confined to those applications where long runs are possible at reasonably steady speeds. These include main propulsion engines in vessels spending several days at sea between ports, and auxiliary engines in large vessels where the load at sea is reasonably constant. Even then the use of residual type fuels is by no means widespread. Figures 8 and 9 show two large main propulsion engine installations.

There are many reasons why the cheaper fuels have not been considered for the smaller vessels on coastal trades, the main ones being as follows:

1. Steam, to provide economical heating of residual fuels prior to purification and injection, is not readily available as it is in the larger vessels.



Courtesy of Temple Press Ltd., London, England

Figure 9 — Two Pielstick Vee type 16 cylinder diesel engines in a large tankship. These, together with two smaller engines, burn residual fuel to produce a total of 17,920 BHP and drive two controllable pitch propellers through single-reduction gearing and hydraulic couplings.

2. Any increased maintenance cannot be tolerated due to the smaller engine-room staff and the shorter periods in port.
3. Engine-room space is generally severely limited with little room for the additional equipment necessary to purify residual fuel.
4. The proportion of maneuvering time and operation at low speeds in rivers and canals is much greater, and these operating conditions are particularly unsatisfactory for residual fuels.

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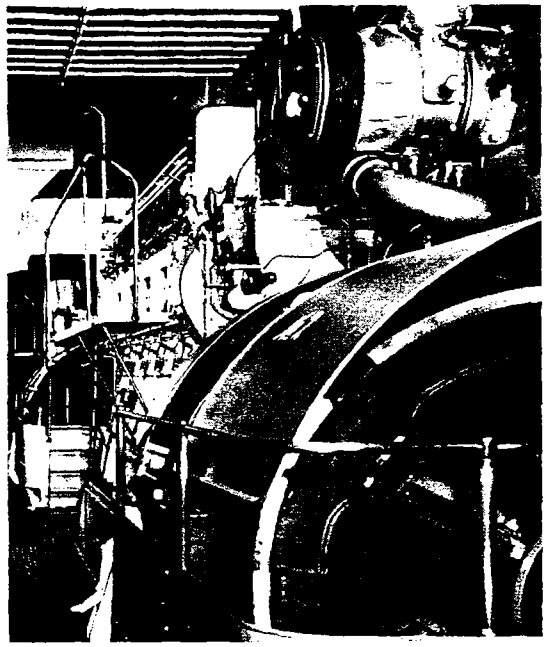

Courtesy of W. H. Allen & Co. Ltd., Bedford, England

Figure 10 — A 500 KW direct-current diesel generator which operates on the same 1500 second fuel (Redwood No. 1 @ 100°F) as the main propulsion engine of the cargo vessel.

These limitations, rather than the inability of the engines concerned to burn lower grade fuels, have delayed any sweeping changes in fuel grades. Similar types of engines to those used in coastal vessels when used for power generation in larger vessels are operating satisfactorily on fuels up to 1500 secs. viscosity with little additional attention.

While the number of medium-speed engines operating on residual fuels in marine service is still very small, most of the engines which, until a few years ago, were run on gas oil only, are now operating on a distillate type of Class B fuel, that is to say, one that contains no residual stock, but which is cheaper than gas oil. This type of product usually has a slightly lower cetane number than gas oil, a slightly higher sulphur content and a slightly higher carbon residue figure. In medium-speed engines, however, these factors have no noticeable effect on performance, and any tendency toward increased deposit formation can be dealt with by the use of a heavy duty lubricant.

This distillate type of Class B marine diesel fuel is not universally available, and in many countries, the Class B fuel contains about 10 per cent of residual stock, is almost black in color and has a higher carbon residue figure. Nevertheless, it is a satisfactory fuel for most medium-speed engines: where turbo-charging is employed, however, an increase in lubricant quality is generally necessary to maintain engine cleanliness.

Treatment

Much of the experience gained in the burning of residual fuels in the large slow-running cross-head-type engines is proving of value in extending the range of fuels which can be used satisfactorily in medium-speed engines. Much has been learned about the shipboard treatment of fuels to insure the degree of cleanliness necessary to maintain combustion efficiency and reduce abrasive wear. Great strides have been made in the design of centrifugal purifiers, not only to improve their efficiency, but also in the development of self-cleaning units which relieve the engine-room staff of the unpleasant task of manual cleaning. Fuel filters are also important aids to efficient fuel combustion in that they remove contaminants having a specific gravity close to that of the fuel itself and which might, therefore, pass through a centrifugal purifier. These filters have been improved considerably so that not only do they provide finer filtration, but they are easier to clean, provide a greater interval between cleaning or changing and are unlikely to clog without warning.

The importance of efficient fuel purification, clarification and filtration in regard to engine performance cannot be over-emphasized whatever the grade of fuel. A very large proportion of operating troubles experienced with diesel engines is attributable to combustion troubles which, in turn, are largely due to fuel contamination. Laboratory tests have shown that cylinder liner wear rises rapidly when fuel contaminated with minute rust particles, silica dust and other abrasive materials reaches the combustion chambers.

Another useful piece of equipment, developed originally for low-speed engines is an automatic device for measuring fuel oil viscosity just prior to injection. To this can be coupled a sensing device which increases the fuel pre-heating temperature as the viscosity rises and vice versa. With this equipment, the viscosity of the fuel at the injectors is maintained very close to the optimum, regardless of variations due to different bunkerings and tank temperatures. Figures 10 and 11 illustrate a shipboard diesel generator and the fuel system which enables it to operate on the same fuel as the steam boilers.

High on the list of developments which have resulted in fuels in the 1000-1500 seconds Redwood One viscosity range being universally accepted for all modern low-speed diesel engines are the relatively new heavy-duty alkaline cylinder oils which reduce cylinder liner wear rates to, or even below, that which was expected when high quality Class B fuels were used with straight mineral cylinder lubricants.

The developments mentioned, and many more, are well established and are readily available to

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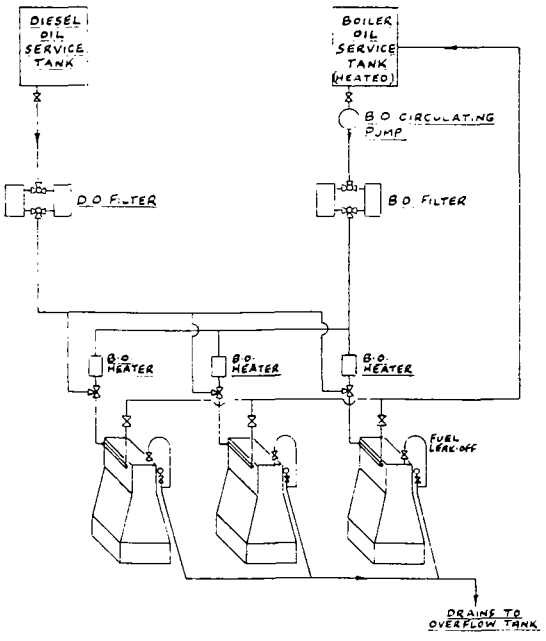

Courtesy of W. H. Allen & Co. Ltd., Bedford, England

Figure 11 — Typical layout of fuel lines when operating diesel generators on residual fuel. Provision is made for starting and stopping each engine on D.O. (Class A or B diesel fuel) and for circulating B.O. (residual boiler-diesel fuel) continuously to insure even heating and good atomization in both diesel injectors and boiler burners.

those manufacturers of medium-speed engines to insure satisfactory operation on the cheaper fuels.

MECHANICAL DEVELOPMENTS

Obviously the speed of an engine has a very considerable bearing on the grade of fuel which can be burned: the higher the speed, the less time is available for ignition and complete combustion of the fuel charge, thus "after burning" can become a problem when fuel quality is lowered. In low-speed marine engines, combustion deposits leading to ring sticking and port-plugging, provided the first problem to be overcome, followed by excessive liner wear resulting from the corrosive and abrasive products of fuel combustion. Improved fuel treatment methods and the development of the new heavy duty alkaline cylinder oils gradually led to extended overhaul periods and reduced liner and ring wear, to the extent that periods of 6000-7000 hours between piston inspections are common and allow such overhauls to be undertaken during dry-docking. This is an important factor in the case of tankers and bulk carriers where quick turn-around leaves little time for pistons to be withdrawn.

In the case of medium-speed engines, the additional problem of exhaust valve deposits, leading to grooving, has to be overcome as most engines are of the 4 stroke type or, if 2 stroke, have uniflow scavenging employing exhaust valves. Exhaust valve life has generally been the limiting factor in the use of lower grade fuels since corrosion or grooving, both the results of "after burning" of the fuel charge, promoted valve leakage with a consequent increase in exhaust temperatures and a rapid loss of power.

In the first instance, when experimenting with residual fuels, engine designers found that advancing the fuel injection timing improved matters. Also, in some engines, it was necessary to increase injection pressures or to modify injectors so as to improve atomization and promote more rapid flame propagation. In other cases, "after burning" could only be reduced by improving combustion chamber design. Such modifications resulted in lower gas temperatures at the time the exhaust valve opened and valve life was appreciably extended.

Certain constituents of some residual fuels, namely vanadium and sodium compounds are responsible for exhaust valve corrosion and grooving. Vanadium is recognized as the principal offender, although sodium plays its part by reducing the critical temperature at which vanadium causes damage. Vanadium compounds are in solution in the fuel and, therefore, cannot be removed by centrifuging. However, sodium can be removed or reduced by water-washing the fuel, but this requires fresh water with expensive and bulky equipment. In the combustion process, a vanadium compound is formed which passes out with exhaust gases in the form of a fine ash if gas temperatures are below 1275°F: above this temperature it becomes molten and may deposit on hot metal surfaces in the form of a glass-like slag which is highly corrosive. When combined with sodium, the critical melting temperature may be reduced to around 1000°F, thus bringing it within the temperature range of the gases passing over the exhaust valve at the time of opening or below the temperature of the exhaust valve face.

Deposition of vanadium compounds on the exhaust valve face leads to grooving, either by actual corrosion of the metal or by preventing the valve from closing completely. Incomplete closure not only restricts the heat flow from valve to seat, but leads to further overheating and burning by allowing combustion gases to pass.

Valve life may be increased in two ways: firstly, by reducing the temperature of the valve face and, secondly, by increasing its resistance to the corrosive and erosive effects of combustion products. For exhaust valves seating directly in cylinder heads, increasing the flow of cooling water in the vicinity of the valve seat generally provides a cure. Many engine builders, however, prefer caged valves whereby the exhaust valve, its guide and seat are inserted in the cylinder head as a separate unit.

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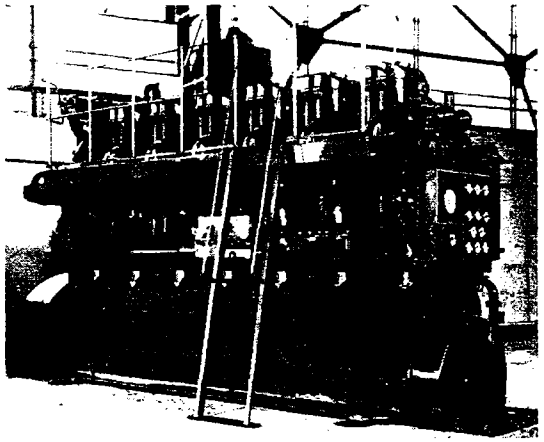

Courtesy of Klockner-Humboldt-Deutz A.G. Cologne, West Germany

Figure 12 — A Deutz model RBVGM 358 6 cylinder diesel which develops 1350 BHP at 391 rpm in marine propulsion service on Class E (250 second) fuel.

The great advantage of these units is, of course, that they can be withdrawn without disturbing the cylinder head so that valve and seat can be cleaned and ground in. They have the disadvantage, however, that heat transfer from valve face to valve seat and thence to cylinder head cooling water is interrupted by the necessary clearance provided between cage and cylinder head. For caged valves, therefore, alternative cooling must be provided either by excess air from the turbo-chargers or by cooling the valve internally, or by a combination of both methods. Sodium-cooled valves have not proved very successful in the larger sizes due to distortion, thus water-cooling is being developed by at least one engine-builder. Although costly, it is hoped that water cooling will increase the permissible power output of the engine while maintaining a satisfactory period between valve overhauls.

Other methods being practiced to extend valve life are: (1) welding an overlay of proprietary heat and corrosion resistant alloy on the valve face and (2) installing a mechanism which rotates exhaust valves slowly during opening and closing so as to redistribute or minimize the effects of deposits. Both methods, used separately or in conjunction, greatly increase valve life.

Although water-washing of fuels has been dismissed as being too costly and bulky for the types of engines under review, it might be worthwhile mentioning that where the price differential between, say, 1500 sec. and 3000 sec. fuel is significant, the heavier fuels, usually referred to as "Bunker C" fuels, are sometimes used in motor ships. The higher vanadium and sodium contents of these fuels can be troublesome even in the modern omnivorous low-speed engines and water-washing is desirable. This is accomplished by introducing a regulated flow of fresh water (with an emulsion breaker and/or a water soluble gravity increaser) into the fuel in a pre-mixing chamber and thoroughly mixing the two mechanically. The resultant mixture or emulsion is then pumped through centrifugal purifiers or clarifiers which reduce water and sediment to acceptable limits. Since sodium (usually in the form of common salt) is soluble in water, most of it is removed with the water. During combustion, the vanadium which still remains is converted to vanadium pentoxide which has a higher melting point than the sodium vanadate which would be formed if sodium were allowed to remain in the fuel to exist in its molten state in the exhaust gases. While this treatment is unlikely to be of interest to users of medium-speed diesel engines in marine service, such engines do operate on Bunker C fuels in land installations. Water washing might then be worth considering in the event that the fuel available has a high sodium and vanadium content.

Vapor Phase Cooling

Land-based prime movers lend themselves to more satisfactory control of temperatures and many medium-speed trunk-piston engines in industrial service are, therefore, being operated on residual fuels. Vapor phase cooling is sometimes employed whereby the jacket cooling water is held under pressure by the hydraulic head from a gravity tank and is maintained automatically at the boiling point of water at that pressure, say 230°F. By this means, the temperature of the engine cylinder liner surfaces is never below the dew point of the combustion gases and, since there is no condensation of water to react with sulfur dioxide and trioxide, none of the highly corrosive sulfurous and sulfuric acids can be formed. Under such conditions, a normal heavy duty (detergent) cylinder lubricant suffices and higher alkalinity is virtually unnecessary.

Though vapor phase cooling presents problems aboard ship, it is being increasingly recognized that efficient operation and long cylinder liner and piston ring life are only achieved when engine jacket temperatures are maintained at an optimum level. This temperature control becomes more difficult in the smaller vessels, where the proportion of maneuvering time is greater, but thermostatically operated by-pass valves which maintain constant jacket temperatures under such widely fluctuating load conditions are now in general use.

This high proportion of maneuvering time means that the saving in fuel costs by using intermediate fuels during short sea passages does not justify the additional capital expenditure involved in equipping engines to burn the lower-grade fuel. Also to insure no increase in maintenance would probably mean de-rating the engine by perhaps 10% and these smaller vessels seldom have much reserve of

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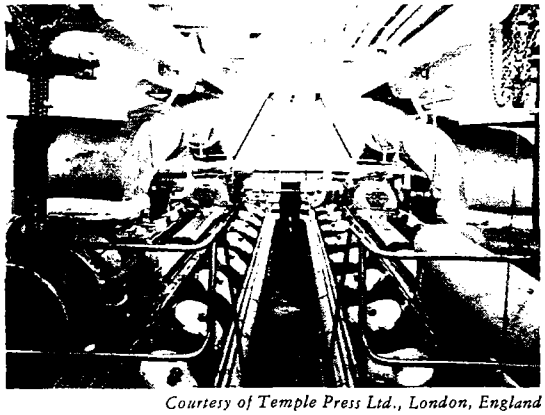

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Figure 13 — The two turbo-supercharged Pielstick 4 cycle Vee type 16 cylinder main propulsion engines on the MS Yakima Valley which develop a total of 9600 BHP at 425 rpm on 600 second fuel and drive a single controllable-pitch propeller through hydraulic couplings and single-reduction gears.

power in any case. For these reasons, the engines of most vessels of the coaster type and also tugs and ferries operate on the higher quality marine diesel fuels or, sometimes, gas oil. For sea passages of upwards of three days, however, some small vessels in the 1000 to 3000 horsepower range are now operating on light residual fuels of 200 to 250 seconds (Redwood #1) with a substantial saving in the annual fuel bills and an almost negligible increase in maintenance. Figure 12 shows one type of engine which has been highly successful in this type of service with Class E fuels. Figures 13 and 14 illustrate the two large supercharged V-8 engines and their control room on a large modern freighter designed to use heavy fuel.

LUBRICATION

Most oil companies market a wide range of lubricants suitable for medium-speed engines although, of course, their use is not confined entirely to these engines. A number of factors govern the choice of an oil which will give optimum performance at an economical cost. Obviously fuel quality is one of the major factors, the carbon residue figure and sulphur content of the fuel to be used being taken into consideration when estimating the degree of detergency or alkalinity necessary to minimize deposit formation and to neutralize acidic combustion products.

Operating temperatures play an equally important part in the choice of lubricants for trunk-piston engines and, in marine service, over-cooling is often a major problem. Tugs and fishing craft, especially, spend long periods with their engines running under light load conditions resulting in excessive piston and ring clearances and, therefore, considerable blow-by of combustion products into the crankcase. Carbon particles and acidic condensate reach the crankcase lubricant in major quantities. Even excluding blow-by, vapors condensing on the comparatively cool liner surfaces contaminate the oil draining from cylinders and unless the oil is capable of neutralizing the strong acids thus formed, a dangerous level of this acidity can be built up in the crankcase lubricant with the consequent risk of journal corrosion.

The combination of acidic condensate and carbon particles reaching the crankcase results in what is generally known as low temperature sludging. The acids contribute to undesirable emulsions in the crankcase oil which coalesce the carbon particles into a soft sludge. Under these conditions, and unless a lubricating oil is used which has the ability to prevent emulsions and to disperse the carbon particles, the sludge formed will be thrown onto the sides of the crankcase by the action of the crankwebs, resulting in a generally dirty engine. This sludge will also adhere to the underside of piston crowns and reduce piston cooling. Such sludge as is retained in circulation will cause a rise in the apparent viscosity of the oil resulting in sluggish circulation and consequent loss in bearing cooling ability. Filters will also need frequent cleaning. Unless an oil change is carried out immediately after such symptoms are noticed, a thorough flushing operation and even extensive manual cleaning may become necessary. In extreme cases, piston seizures and bearing failures can be caused by sludged oil.

High temperature deposits which may lead to stuck piston rings can be dealt with readily by a lubricating oil of the right quality and having sufficient detergency. By dispersing or neutralizing carbon and the resinous products of incomplete fuel combustion, these oils can prevent carbon particles from adhering to piston and rings, thus maintaining piston cleanliness and freedom of ring movement.

The major oil companies market at least three grades of detergent, or heavy duty oils, approved by specific engine testing under carefully controlled conditions laid down by British and United States Government specifications and also individual engine manufacturers like the Caterpillar Tractor Company. In order to qualify against any of these specifications, a lubricant must give a specified minimum performance when run in an engine under test conditions prescribed in detail by the specifications.

The accepted minimum performance level for a heavy duty oil in England is qualification against British Government Specification DEF-2101B or U. S. Government Specification MIL-L-2104A (so-called "DEF" and "MIL" oils) although in the United States this minimum level has recently been raised. A higher level of performance is provided for in the Supplement I category of MIL-L-2104A

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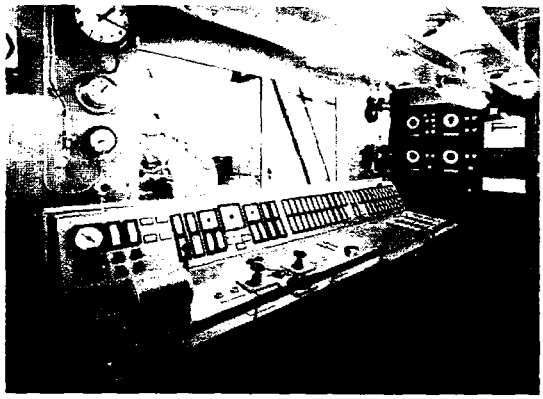

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Figure 14 — The Yakima Valley's well-equipped control room for the engines shown in Figure 13.

(oils qualified being referred to as "Sup. I Oils") and still higher levels in the Series 3 (MIL-L-45199A) specification initiated by the Caterpillar Tractor Company. The new U. S. Government specification which supersedes MIL-L-2104A is called MIL-L-2104B, and although there is no direct comparison between this test and the others mentioned, it could be said that the detergency level required by it is something between that of the Supplement I and Series 3 specifications.

Many medium-speed trunk-piston engines are provided with separate cylinder lubrication systems wherein oil is pumped by mechanical lubricators direct to the cylinder liner surfaces through two or more injection holes drilled in the liner wall. By this means, a more accurate control of cylinder lubrication can be exercised, and there is less chance of wastage of lubricant through an excess reaching the combustion space. No oil will withstand the heat of combustion, except for a thin film on the liner walls, kept at a reasonable temperature by the cooling system. Any excess oil swept up by the top firing, or compression ring, will certainly be burnt and may lead to deposits on the piston crowns, exhaust valves, or scavenge and exhaust ports. Port deposits are particularly troublesome and are the main reason why separate cylinder lubrication is provided for two-stroke engines.

Where oil sprayed from connecting rod big-end bearings is the only method used to lubricate cylinder liner walls, oil control is dependent on the action of one or more "scraper" piston rings, these being designed to allow a certain amount of oil to pass for the lubrication of the upper piston rings. It could be argued that this is a rather hit-and-miss method of lubrication, but against that, it can be said that the spread of lubricant is undoubtedly far more satisfactory than can be achieved from, say, two oil points alone.

No doubt a combination of splash and separate feed is the best system as it is often desirable to use a different oil in the cylinder oil feed from that in the circulating system, although in a trunk piston engine the two types will ultimately become mixed and must, therefore, be entirely compatible. It is often an advantage, for instance, to use an alkaline heavy-duty oil in the cylinder feed and a normal heavy-duty oil or even a straight mineral oil in the circulating system which lubricates the remainder of the engine. This reduces the cost of an oil change should accidental contamination with fuel or water render this necessary. In a large system holding many hundreds of gallons, this may be a major consideration.

The special alkaline cylinder oils originally developed for use in large crosshead-type diesel engines burning residual fuel have achieved remarkable reductions in the very high cylinder liner wear rates previously experienced with straight mineral lubricating oils. But for these special alkaline cylinder oils, savings in fuel costs by using residual fuels would have been offset largely by the cost of frequent liner replacements. In many cases, the use of these more expensive cylinder lubricants was found to be justified fully in terms of reduced liner wear even when a high quality marine diesel fuel was in use. This indicated that even the relatively modest sulphur content of these Class B fuels was still sufficient to cause appreciable corrosive wear under low temperature operation. In other words, it was not the initial sulphur content that mattered as much as how much of that sulphur was converted during the combustion process into acids. This, in turn, depended to a very large extent on the minimum temperature of the liner as maintained by the jacket cooling water.

Generally, in the larger engines, it is a simple matter to maintain jacket temperature (and therefore liner temperatures) between close limits, and even when starting and maneuvering, if sufficient attention is paid to cooler by-passes, etc. In medium-speed engines used for main propulsion in small vessels, wide and rapid variations of load during long periods of maneuvering make temperature control more difficult, and under low-load conditions, the lower parts of liners may be well below the dew point of combustion vapors with the resultant formation of acids. These acids may only be in the form of a weak solution and may not in the lower section of the liner be actively corrosive. When swept up by the piston rings, however, to the hotter area of the liner, even a weak solution becomes actively corrosive. Normal abrasive wear also reaches a maximum at or near the top limit of piston ring travel where the lubricating oil viscosity is at a minimum and ring pressures are highest. Acid solutions reaching this area can thus contribute considerably to overall wear rate.

Corrosion of cylinder liners in medium-speed en-

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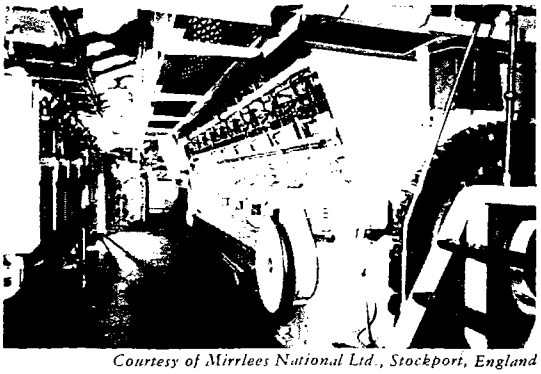

Courtesy of Mirrlees National Ltd., Stockport, England

Figure 15 — A Mirrlees Model KVSSA16, the main sand pump engine on the "Port Sunlight," one of the largest cutter dredgers in the world. This Vee type 16 cylinder engine develops 3500 BHP at 375 rpm and is equipped to operate on residual fuel.

gines is seldom of sufficient severity to be readily and visually apparent since the polishing action of the piston rings removes corrosion products as rapidly as they are formed. Liner measurement quickly shows, however, that such corrosion can and does take place, even with gas oil as the fuel, if liner temperatures are sufficiently low.

Normal heavy duty oils, developed primarily to prevent ring-sticking and maintain cleanliness of working parts, reduce liner wear primarily by reducing or eliminating blow-by caused by ring-sticking. Blow-by can destroy the protective oil film on liner surfaces and accelerate abrasive wear. The relatively high alkalinity, which is necessary to combat corrosive wear, reaches significant levels only in the more costly Series 3 oils.

It has been recognized, following experience in low-speed marine engines, that in all types and sizes of marine engines, the alkaline content of a cylinder lubricant is of major importance in view of the particular conditions under which marine engines operate. Since copious amounts of cooling water are available, marine diesels are often over-cooled in the misguided belief that this provides a factor of safety in preventing cracked liners, cylinder heads and burned valves. It has been proved that medium-speed engines can operate satisfactorily on residual fuels, but in marine service particularly, alkaline oils are necessary to achieve normal liner wear rates. The degree of alkalinity required will depend on both the sulphur content of the fuel, and the lowest liner wall temperature likely to be reached which is a function of the degree of load variation, and the effectiveness of temperature control. Alkaline oils will also maintain a high degree of piston cleanliness in marine engines which are treated more conservatively than their industrial "dry-land" relatives.

The success of alkaline oils for the cylinder lubrication of low-speed diesel engines encouraged their trial in trunk piston engines. At first, their use was confined to those engines where the oil could be supplied separately to the cylinders, while retaining the original separate oil in the circulating system.

Cylinder oil drainings from low-speed engines are trapped and lead off to waste with only a very minor amount reaching the crankcase oil; in trunk piston engines, however (and most medium-speed engines are of this type) all oil draining from the cylinders enters the crankcase oil. When alkaline oils for low-speed engines were formulated, it was assumed that they were to be fed to and drained off the cylinders on a "once through" basis and would not be subjected to continual agitation, heating and cooling over long periods as were crankcase oils. They had to withstand high temperatures only during their short residence in the cylinder, and resistance to oxidation was, therefore, a minor consideration. High degrees of alkalinity and detergency were their primary requirements.

When these alkaline oils were tried in trunk-piston engines, the effects of their drainings on the characteristics of both heavy duty and straight mineral crankcase oils were carefully watched. For the most part, these effects were negligible. On the other hand, the beneficial effects of these alkaline cylinder oils on piston cleanliness and cylinder liner wear were most impressive. Additional testing showed, however, that the level of alkalinity was generally higher than actually required for medium-speed engines, either because the sulphur content of the fuel used was lower than that envisaged for low-speed engines, or because high jacket temperatures were maintained. It was recognized, therefore, that an oil of medium alkalinity (and therefore lower cost) would meet the requirements of most medium-speed engines operating under widely differing conditions.

Where separate cylinder oil feed is not provided, the necessary alkalinity must be provided in the circulating oil; hence, the so-called dual-purpose alkaline oils were developed which combine the alkaline and detergent properties necessary for cylinder lubrication with the desirable characteristics of a crankcase lubricant. The main properties of a successful dual-purpose alkaline oil are, therefore, as follows:

1. Sufficient alkalinity to fully neutralize acidic combustion products and thereby prevent cylinder liner and journal corrosion and rusting for a substantial period.
2. Sufficient detergency to insure piston cleanliness and complete freedom from ring-sticking and (in two-stroke engines) to prevent port plugging.
3. Adequate oxidation resistance to insure long life in circulating systems.
4. Must protect copper-lead and other bearings.
5. Adequate foam control to maintain oil film thickness in bearings.

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6. Resistance to emulsification with water.
7. Adequate detergency and dispersancy to suspend fuel carbon particles and prevent deposition.
8. Good "clean-up" characteristics to permit easy removal by centrifuging and/or filtration of water, carbonaceous material, abrasive dirt, metal wear particles, and other contaminants.

Such dual-purpose oils are finding ready acceptance by engine builders and ship owners, since their use is resulting in real savings in piston-ring and liner replacements and fuel costs. Also, by increasing the intervals between piston overhauls, the engine-room staff have more time to devote to other maintenance operations and thus increase general engine-room efficiency.

These oils have been designed specifically for marine purposes and to increase the versatility of medium-speed marine engines. There is a trend, albeit a slow one, towards operating auxiliary diesel engines on the same fuel as that used in the low-speed propulsion engine, generally in the range 1000-1500 secs. R.1 viscosity. Since the necessary heating, purification and clarification equipment is already provided on board, a considerable saving can be made by operating the generator engines on this same residual fuel. As many auxiliary engines are splash-lubricated, dual-purpose oils have contributed considerably to this development. Figure 15 illustrates the largest of four diesel engines which drive the sand pump, two large generators and a smaller "port" generator on one of the largest cutter dredges in the world. All engines can use the same heavy fuel.

Apart from the obvious duties of lubricating and cooling working parts, a circulating oil must also act as a cleansing agent by collecting combustion products and other contaminants which reach the crankcase and by keeping them from depositing or otherwise harming the engine until they are either drained with the oil, or removed by filtration or centrifuging.

Medium-speed engines are invariably of the dry-sump type whereby oil draining into the crankcase from the cylinders, bearings and piston-cooling returns, is continually pumped out of the sump, filtered, cooled and then pumped back through the engine. Centrifugal purifiers operate on the by-pass principle by taking a proportion of the oil from the main circuit, purifying it and returning it to the main circuit. Only those contaminants which are solids and are carried by the oil through the external circuit can be removed by the filters and purifier. Since straight mineral oils are strictly limited in the amount of contaminants they can carry in suspension, contaminants will be deposited unless the degree of filtration/purification is such as to maintain a level of contamination safely below that where deposition begins. Furthermore, and unless it contains an adequate amount of an effective oxidation inhibitor, the life of the circulating oil will be shortened by buildup of soluble oil oxidation products which not only increase the acidity and viscosity of the oil, but catalyze and accelerate its further deterioration.

Heavy duty oils, including dual-purpose alkaline oils, in circulating systems of medium-speed engines are to be recommended since they insure crankcase cleanliness and bearing protection. Unless the quantity in circulation is small, however, and regular oil changes are acceptable, it is desirable to provide a centrifugal purifier. It is often, but wrongly, supposed that heavy duty oils cannot be centrifuged without losing their additives, or that centrifuging does little good because all solid impurities are in colloidal suspension. Both suppositions are largely incorrect. Additives which are still unchanged are dissolved in the oil and cannot be removed by centrifuging. Furthermore, virtually all abrasive material, such as metal wear particles, rust from storage tanks, dust from the atmosphere, and ash from fuel-combustion, as well as much of the fuel soot, can be removed by effective centrifugal purification. Finally, it is reassuring to recall that material which cannot be removed deliberately by an efficient purifier is not likely to be accidentally deposited elsewhere in the system.

In trunk piston engines, where cylinders are open to the crankcase, the problem of contamination of the crankcase charge is, of course, much greater than in crosshead type engines where a diaphragm with a suitable gland provides a seal between cylinders and crankcase. On the other hand, the volume of oil in circulation is very much less and renewal is not such a serious expense.

As previously mentioned, oil longevity can be increased by reducing the stress on it, often through suitable modifications to cooling systems, adjustments to fuel injection equipment and improved piston sealing to reduce blow-by. Since "prevention is better than cure", the aim should be to reduce the amount of contamination reaching the crankcase, which can frequently be accomplished by some relatively simple modification like the provision of thermostatic control of jacket cooling temperatures.

SUMMARY

Medium-speed marine diesels burning fairly good quality fuels have been used for many years in Europe as propulsion engines for river and coastal craft, small passenger and cargo vessels. Recent developments in engine design and special lubricants, however, have enabled them to operate reliably, efficiently and economically on heavy residual "bunker" type fuels; consequently, their use is being extended to large ocean-passenger and freight vessels, both as main propulsion and auxiliary engines.

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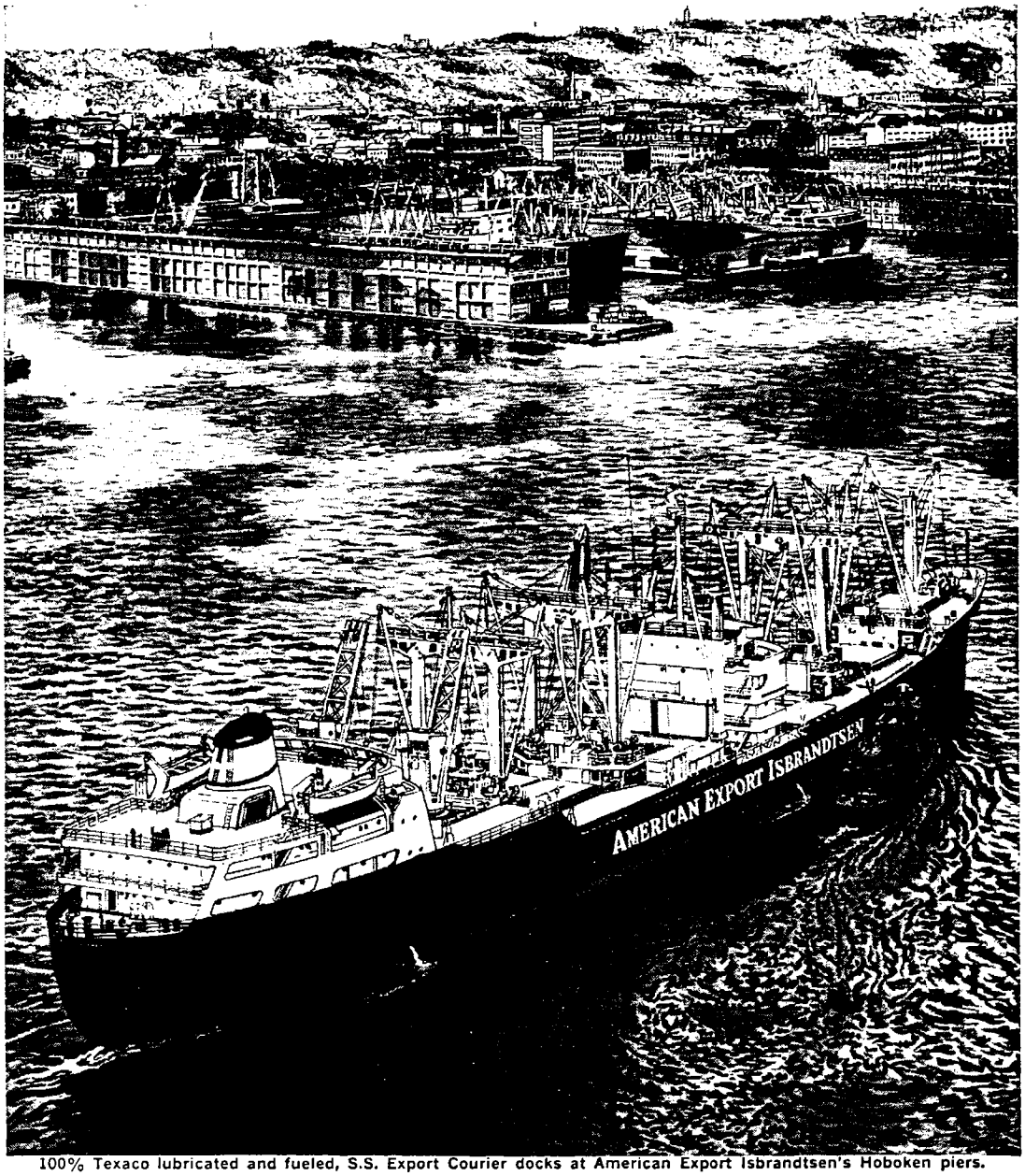

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