LUBRICATING OILS FOR SHIPS' MACHINERY.

In recent years, considerable advances have been made in the manufacture of lubricants and many new materials and additives have been prepared to meet the ever-increasing needs of engineering developments. Many of these new materials are now being used in naval practice and the following brief survey indicates some of the more important points of interest.

As turbine machinery predominates in H.M. ships, it is natural that its lubrication should be of the first importance. The quality of the oil must stand up to all conditions of service and maintain complete reliability of the machinery. Fortunately the requirements are simple. The bearings are lightly loaded and with full film lubrication complete immunity from break-down is ensured provided the oil flow is maintained. The gearing is also comparatively lightly loaded and so far does not demand the use of an " extreme pressure " lubricant. To maintain full flow to the bearings and gears it is only necessary to provide an oil of the correct viscosity which has sufficient stability to avoid possible shortage of oil due to the blocking of oil channels by sludge or emulsion brought about by " breakdown " products of the oil.

The oil commonly used for turbine lubrication is well known as S.M.L.O. (Special Mineral Lubricating Oil) which has to satisfy a very close specification. This limits the specific gravity to 0·880 and defines the viscosity at different temperatures in such a way that only oil produced from Pennsylvania crude complies with the specification. Uniformity in quality of oil throughout the fleet has thus been ensured and difficulties which might possibly arise due to sludge resulting from mixtures of different types of oil have been eliminated.

With the advent of the U.S. Navy into the war and the essential need of pooling resources by using the same lubricants in U.S. and British ships, the question of using turbine oil to U.S. Navy Specification 2190T has required careful consideration.

An important advance.

The specification for U.S. 2190T oil differs considerably from that of S.M.L.O. in the following respects. S.M.L.O. specification excludes the use of solvent refined oils, whereas practically all U.S. turbine oils are produced by solvent refining. This process represents probably the most important advance in recent years in the refining of lubricants and enables good lubricating oils to be obtained from far more types of crude oil than was at one time thought possible. The broad effect of this treatment is to eliminate undesirable constituents of the original oil, thus leaving the final product equal to, or superior to, that obtainable from oils derived from Pennsylvania crudes treated by normal refining methods.

Certain important differences may be noted between 2190T oil and S.M.L.O. In the case of 2190T oil no limit is set to the specific gravity whereas in the case of S.M.L.O. the limit of 0·880 S.G. practically confines the supply of this oil to a particular source of paraffinic crude. The viscosity limits of S.M.L.O. are specified at three different temperatures in such a way that only an oil of high viscosity index can satisfy the specification.

Viscosity index or V.I. is a term indicating the rate of change of viscosity with temperature and came into prominence chiefly in the selection of lubricants for motor vehicles where it is clearly important that the oil in the engine should retain as uniform a viscosity as possible over wide changes in temperature, i.e., to ensure satisfactory starting under very cold conditions and at the same time to provide sufficient viscosity to satisfy conditions under high load and temperature. V.I. is a method of assessing viscosity/temperature changes and was originated by the American Society for Testing Materials (A.S.T.M.). Broadly, the method consists in comparing the viscosity of the sample with two reference oils A and B, each having the same viscosity at 210° F. as the oil under test. The reference oils A are selected from a range of standard paraffinic oils having a relatively small viscosity/temperature change, i.e., of high V.I. and reference oils B from a range of standard naphthenic oils having a relatively large viscosity/temperature change, i.e., of low V.I.

The standard reference oils A have a V.I. which is empirically defined as " 100 " while the standard reference oils B have a V.I. similarly defined as " 0."

If therefore the results show that—

H = the viscosity at 100° F. of oil A
L = the viscosity at 100° F. of oil B
and U = the viscosity at 100° F. of sample.

Then the viscosity index of the sample is—

$$\frac{L - U}{L - H} \times 100$$

Thus if U = L, the viscosity index is " 0."
if U = H the viscosity index is " 100."

Any intermediate value depending on the test on the sample will reveal the viscosity index which may range from a negative value to above 100. The values of L and H can only be obtained from tables published by A.S.T.M. giving the viscosities at 210° F. and 100° F. for the whole range of standard reference oils.

The specification of S.M.L.O. does not mention V.I., but, as already stated, the limits of viscosity specified at three different temperatures in fact demand an oil having a V.I. in the region of " 100."

The 2190T specification also makes no reference to V.I. and the viscosity is merely specified to lie within the limits of 185 to 205 seconds Saybolt Universal at 130° F. The practical effect on the viscosities of the two oils is that at the higher temperatures in the region of operating temperatures the viscosities of both oils are reasonably the same. At low temperatures, however, the viscosity of 2190T may be considerably higher than that of S.M.L.O. in view of the fact that neither V.I. nor low temperature viscosities are specified in the case of 2190T.

Greater resistance.

Viscosity index or viscosity characteristics at low temperature are unlikely to be of much practical importance as there is in any case adequate fluidity to provide lubrication during starting up and working up periods. In the case of the higher viscosity oil it may, however, be necessary under low temperature conditions, to ease the forced lubrication pumps to avoid the development of excessive pressure in the system due to the greater resistance of the high viscosity oil.

Deterioration of lubricating oils in service is chiefly brought about by the gradual formation of carbonaceous material or oxygenated bodies as a result of heat and aeration. Although all mineral oils are generally very stable, the effect of heat and the severe churning and spraying of the oil in turbine gear cases or diesel engine crankcases tends to cause breakdown or decomposition. The effect of such decomposition material is to increase the risk of emulsification if water is present and also to develop acidity which may, in some cases, affect bearing materials. Furthermore, the deposition of sludge may check or impede the flow of oil in oil pipes and channels.

S.M.L.O. is known to be a very stable oil while the stability of U.S.2190T is brought about by including " additives " or " inhibitors " which are special organic compounds added to the oil in very small quantities in order to promote stability and reduce the changes of oxidation. In addition, an inhibitor is also included to minimise the possible rusting of journals or gears due to the presence of water in the oil. The inclusion of such additives has proved to be very effective and it seems likely that in the course of time all turbine oils will contain additives for minimising the possibility of oxidation or rust. In addition it is probable that additives will be introduced in order to deal with any new developments demanding more highly loaded gear teeth than are at present employed.

A point of importance in connection with the introduction of U.S.2190T oil is the effect of mixing or topping up a system containing S.M.L.O. with 2190T or vice versa. While S.M.L.O. is essentially of paraffinic type, U.S.2190T may be mainly naphthenic and although both oils can mix without ill effects when new and in storage, the following results will occur to a greater or lesser degree when new oil is added to used oil which is already in a partly oxidised condition.

Care in topping up.

If S.M.L.O. (paraffinic) is used to top up a system containing 2190T (naphthenic) some of the oxidation products held in solution in 2190T oil will be precipitated and sludge will result. The greater the quantity of oil added during topping up the greater will be the effect. It is therefore necessary to reduce the amount of topping up oil to a minimum, i.e., top up frequently with small quantities so that the resulting small increase in sludge can be taken care of by the centrifugal separator. If 2190T is used to top up S.M.L.O. its effect will be to loosen any sludge or deposits which may have accumulated in pipes, drain tanks, etc., during the use of S.M.L.O. A sudden increase in sludge may therefore be expected unless the topping up is carried out gradually as indicated above.

Another and most important cause of trouble in any forced lubrication system is contamination which may arise from various causes. In the case of turbines, leakage of gland steam into the forced lubrication system is the most obvious cause, but several instances have also been reported and investigated that have revealed the presence of sea water arising from leakages in oil coolers or drain tanks. The obvious remedy is to pay particular attention to all possible sources of contamination either from steam leakages, or water leakages, into the system. Also, the centrifugal separators and filtering arrangements require to be maintained in the highest degree of efficiency and should be checked and overhauled at frequent and regular intervals.

Acidity and viscocity.

There is no certain method of determining the general fitness of turbine oil for further service. The formation of emulsion or sludge on a scale which the centrifuge cannot deal with adequately is a clear indication of instability, but before this stage is reached an indication of approaching breakdown may be obtained by observing any rapid increase in the acidity of the oil and also any increase in viscosity. Although acidity and viscosity always tend to increase gradually, any sudden increase shows that a change of oil is necessary.

The lubrication of diesel engines presents quite different and more difficult problems. The oil has to satisfy bearings intermittently and far more heavily loaded than in the case of turbines. Gudgeon pins, in particular, are subject to intermittent loading as well as a reverse in rotational direction, which are conditions far more difficult to satisfy than the steadily loaded bearing in a turbine where full film lubrication is assured at all times.

Apart from bearings, however, the oil has at the same time to deal with the lubrication of cylinder liners, pistons and rings where the oil is at times exposed to combustion gases with temperatures up to 2,000° C. At this high temperature, oxidation or " cracking " of oil occurs and deposits carbon, which together with combustion products may cause ring sticking and even piston seizure under extreme conditions. The escape of carbonaceous products past the piston also causes formation of crankcase sludge in engines of the trunk piston type where cylinders are not separate from the crankcase.

Ring sticking is the most serious problem to contend with as it may eventually result in seizure and complete breakdown of the engine. It is essentially a heat effect and is therefore more pronounced in highly rated engines. It is initiated by the trapping of oil and carbon in the piston grooves where oxidation may result in the formation of sticky resinous products which prevent the free working of the rings in their grooves. Partial sticking takes place, followed by " blow-by " of combustion gases, which accelerate the heat effect and may indeed cause seizure by removing the lubricant from the liner surface.

Ring sticking.

It has long been recognised that naphthenic types of oil have less tendency to cause ring sticking than the paraffinic types. This is due to the fact that although naphthenic oil may be more prone to oxidation effects and carbon formation, it has a greater tendency to retain these breakdown products in solution. The carbon formed is therefore not so liable to cake in a hard mass as in the case of paraffinic oil, but remains in a sludgy or softened condition in which it may return to the crankcase while leaving the rings free. As against this advantage, the naphthenic oil has, however, a lower V.I. than paraffinic oil and is thus open to the objection of sluggish supply to bearings and cylinders during starting up periods at low temperature.

The modern tendency is to provide I.C. engine oils with detergent additives. These when added to oil which may have the same high V.I. characteristics as paraffinic type oil, have the effect of loosening or washing away carbon products, thus keeping the pistons and rings in a clean condition. It will be appreciated, however, that greater contamination of the crankcase oil will be involved particularly if an oil with detergent additive is used in an engine in which carbon has already accumulated due to the prior use of a non-detergent oil. When therefore a change-over is made to detergent oil, special attention must be paid to filters in the forced lubrication system and frequent cleaning is necessary until all accumulated carbon has been removed. The precautions necessary in changing over from Admiralty I.C.E. oil to detergent OE–30–HD oil have been described in greater detail in A.F.O.5320/44.

Wear inhibitors.

Additives are likely to be found to an increased extent in all modern oils and may include wear inhibitors, oxidation inhibitors, extreme pressure additive agents, detergents, etc. Wear inhibitors are organic compounds which have the effect of producing a chemical polish on the bearing surfaces concerned. They may be such compounds as organic phosphates, phosphites, phosphides and also compounds of arsenic, antimony and bismuth. The effect is a chemical one which produces alloys or compounds of lower melting point at the sub-microscopic peaks of bearing surfaces with the result that momentary metallic contact facilitates flow of the alloy into the surrounding depressions in the surface. The surface thus becomes smoother and a wider area is created to carry the load ; also a protective film is formed which prevents local welding and tearing away of metal surfaces coming momentarily into contact. The action of extreme pressure additives appears to be similar. They are widely used in back axle boxes of motor vehicles where the gear teeth are excessively loaded and where an ordinary oil would allow a metallic contact and welding and tearing of the teeth surfaces. A large number of additives of this type are in use and include various metallic soaps and organic compounds. Corrosion or rust inhibitors are also sometimes included in oils and have similarly the effect of producing chemically a surface film on the metal surfaces which resists corrosion.

In the case of oils for diesel engine lubrication the most importance is attached to the detergent property of the oil, and the type of additives vary considerably according to the nature and V.I. of the oil. Low V.I. oils may contain additives usually of the metallic soap variety, while in the case of higher V.I. oils many different kinds of organic compounds are also used. In fact, the most suitable type of additive for a particular oil must be determined more or less experimentally. In addition, additives to inhibit oxidation or corrosion may be included with detergency additives.

While it will be seen that many advantages may result from the use of additives, the specification of such oils is much more difficult than in the case of normal oils where simple chemical and physical tests sufficiently define the product. With additive oils, the best additive can only be determined by actual mechanical tests, as, for example, in the case of OE–30–HD which has to conform to U.S. Navy Specification Symbol 9250, the oil is subjected to long duration engine tests and has to satisfy specified requirements as to the condition of pistons, piston rings, bearing surfaces, etc., after test. This elaborate method of specifying and testing an oil is obviously much more difficult than the simple chemical and physical tests applied to straight oils, but so far no simpler method seems possible. The position is in fact somewhat analogous to the testing of petrol where no means other than an engine test has been found possible for assessing accurately its anti-knock rating, or octane number.

Pooling resources.

Reference has been made to the need of pooling resources with the U.S. Navy. Supply problems have necessitated a very much wider application of this principle in the co-ordination of lubricants used by the British Navy, Army and Air Force. A complete survey of all lubricants in current use by the three services has been carried out with the object of reducing the number of grades by adopting common grades for similar applications in all services. The results of this survey will be promulgated by an A.F.O. which lists all lubricants used by the Navy, with their applications. Against each application is listed the grade which will be used in future for the same purpose, many of these grades being new to Naval service although all are in use by one or the other services or by the U.S. Forces.

It will be obvious that, if lubricants are to be common to all three services, a common nomenclature must be adopted so that a particular lubricant is known to all services by the same name. The opportunity has therefore been taken to adopt a nomenclature which gives some indication of the nature of the lubricant and not its application or use, which may be varied and extensive, e.g., torpedo lubricating oil may be suitable for a variety of purposes apart from torpedoes.

The principle of the system is to describe each lubricant by letters followed by numbers. The letters indicate its nature, thus—

O.M. represents oil mineral,
O.C. ,, oil compounded,
S.G. ,, soda base grease,
L.G. ,, lime base grease,
P. ,, protectives.

The numbers following the letters indicate one of its leading properties which in the case of oils will be the viscosity in centistokes at 100° F. and for greases their approximate consistency at 77° F. A rough indication of the contents of a drum or container with any of these markings is immediately obtained. For example, the description "S.M.L.O." which would be meaningless to an Army or Air Force user now becomes O.M.–65, indicating that it is mineral oil, and not grease, paint or putty, and that it has a viscosity of about 65 centistokes at 100° F.

A few exceptions to this principle of nomenclature have been made in the case of oils such as OE–30–HD which is already well known in the British and U.S. Services. This title is an abbreviation for "Oil, Engine SAE Number 30, Heavy Duty" and indicates the viscosity according to the SAE (U.S. Society of Automotive Engineers) scale. The oil is of the special detergent type which is replacing Admiralty I.C.E. Oil for use in all types and sizes of internal combustion engines. It may be considered remarkable that a single grade of oil will equally serve a range of engines varying from a small 5 H.P. generator engine up to the largest diesel propulsion engines of 10,000 H.P. or over, but so far this appears to be the case. Further experience may indicate the advisability of including a lighter grade for engines operating under Arctic conditions and perhaps a heavier grade for the cylinder lubrication of some of the larger engines, but such exceptions are likely to be insignificant.