1.

THE OPERATION OF DIESEL ENGINES.

Detailed records of the practical operation of Diesel Engines are somewhat scanty, while the need for information on this subject is often acutely felt by those whose own experience has been mainly confined to other channels. The following article, giving in some detail the results of practical experience with Diesels under sea-going conditions, is published in the form in which it was received, in the hope that not only will the information be of both value and interest, but also that similar contributions from other Engineer Officers will be thereby encouraged.

The opinions expressed are those of the Author, and are not necessarily concurred in by the Admiralty, neither should the publication of any of the suggestions made therein be taken as an official sanction for their adoption.

The collection of notes forming the body of this article applies principally to Diesel-driven electric generators of the Mirrlees type as fitted in the various vessels of the Fleet, the practical running of the machinery fitted in submarines being outside the the writer's experience, although many valuable suggestions have been obtained from that source. There seems to be no reason, however, why the general principles here advocated should not be equally true for all types of Diesel engines.

Any engine, however driven, is required to produce any output within its rated capacity whenever the demand is made, and thus a discussion of the points affecting the operation of a given machine involves a consideration of those factors which influence its reliability and maximum power.

The Diesel engines fitted in naval vessels are necessarily somewhat highly rated, with the result that the temperature conditions in the combustion spaces are such that at full output the parts are subjected to high heat stresses; any appreciable overloading is sufficient to cause cracking of the piston crowns and cylinder heads, owing to the inability of the material to pass away more than the designed quantity of heat.

Overloading may be produced either deliberately or by the more common method of attempting to develop the full rated output from an engine which is out of condition. In the latter case excessive quantities of fuel are introduced into all the cylinders, with the result that overloading occurs in those cylinders which are able to burn the charge, while excessive fouling is experienced in the less favourably conditioned units; it may be observed also that this practice incurs the danger of developing very high pressure in any cylinders where firing is irregular. The troubles arising from unintentional overloading can, of course, be avoided by suitable adjustment of the governor, but this entails an undesirable reduction in the maximum output unless all the cylinders are in approximately the same state of "tune." The dangers of cracking may be minimised to some extent by due attention to the cleanliness of the jackets and to the maintenance of adequate supplies of cooling water; but, even with the maximum cooling effect, the amount of heat which can be safely passed away is limited by the thickness and the nature of the materials forming the walls of the combustion space.

The foregoing argument indicates, therefore, that reliability is chiefly determined by the extent to which similar working conditions obtain in the various cylinders; and experience shows that, unless approximately equal powers are developed in the individual units and regular firing at the predetermined intervals is assured, satisfactory service cannot be expected.

Reasonable similarity is best achieved by adopting the principle of (say) annual refits of the whole engine, coupled with adequate maintenance; the common alternative procedure of adjusting each cylinder in turn as opportunity may permit does not in practice prove as satisfactory as the former.

The main portion of this paper is devoted, therefore, to a discussion of the various practical points which influence the realisation of the above ideal, and, as a starting point, it is proposed to consider the factors affecting the power output of the cylinder.

Factors affecting the Power of a given Engine.

The power developed in a given engine depends upon the following factors, viz. :—

(*a*) Compression.
(*b*) Quantity of fuel injected per stroke.
(*c*) Air supply.
(*d*) Back pressure.
(*e*) Valve settings.

These will now be dealt with individually, practical suggestions regarding the running and adjustment of the engine being given in connection with each item.

(*a*) *Compression.*—A suitable value for the compression is determined by the makers and the requisite cylinder clearance to give this is usually noted on the drawings. Adjustment of the compression is, of course, made in the usual manner by fitting suitable liners under the foot of the connecting rod, measurements of the actual clearance being taken by placing four pieces of lead on the piston crown at the opposite ends of two mutually perpendicular diameters, one of which is parallel to the crankshaft: by this means not only is the clearance measured, but also the alignment of the gudgeon pin, crankhead and main bearings is checked.

The effect of compression upon the running of the engine, and thus upon maintenance, is very marked. High compressions result in lively, smooth running, and enable the engine to be started readily. On the other hand, too low a compression entails sluggish starting, while the firing point may be delayed thereby to such an extent that the accumulation of fuel in the cylinder gives rise to detonation and excessive explosion pressures: cases are by no means uncommon in which the studs securing the cylinder heads have been fractured solely on this account. In this connection it may be remarked that different fuels may require different compressions, and thus detonation may be experienced when a change of fuel is made.

It is desirable that the maximum difference between the compression pressures in the various cylinders should not exceed about 15 lbs. per sq. in., or, say, 4 to 5 per cent., in order that reasonable similarity in this respect may exist between the various cylinders.

The compression under running conditions should be checked at intervals by means of an indicator, it being convenient for this purpose to cut off the fuel from the cylinder under test: any considerable departure from the original compression indicates defective rings or valves or badly worn bearings. The gas tightness of the valves is, of course, of prime importance, and it is suggested in this connection that whenever these are refitted or cleaned, the cylinder should subsequently be tested by air pressure of about 1,000 lbs. to detect any compression leaks.

It may also be noted that the compression will be influenced by the timing and also by the tappet clearances of the valves. An excessive " overlap " between the air and exhaust valves may lead to difficulties in starting and in slow running owing to the consequent reduction in compression.

Liner wear is not in general a factor in causing faulty compression, and frequently does not exceed about 1/1,000th of an inch per 1,000 hours running.

Admiralty Note.—It may be of interest that indications are not wanting to show that excessive wear of the liner and pistons may be mainly due to faulty combustion, as the resulting free C.O. is thought to attack the metal under high temperature conditions.

(*b*) *Fuel Injection. Quantity.*—The quantity of fuel injected per stroke is, of course, determined by the governor, which in general acts upon the suction valves of the fuel pumps, and as the amounts to be supplied are very small, it follows that small differences in the adjustment of the operating gear for the individual cylinders may exercise a marked effect.

In engines, such as the six-cylinder Mirrlees, where two fuel pumps are provided, each supplying three cylinders and each controlled by separate link work from the governor, it is frequently found that uneven running and lack of power results from slackness developing in one set of control gear only.

The clearances at the tappets of the fuel pump suction valves are of great importance, and particular care is required in setting these. These settings do not usually alter greatly while the engine is running, but it is worth while checking them at fairly frequent intervals, and also whenever irregular running or loss of power is experienced.

Two frequent causes of inaccuracy in this adjustment may be noted, namely, tappets wearing hollow, thus preventing accurate measurements of the clearance by means of feelers, and secondly, failure to ensure that the starting lever is always properly in the "Run" position when clearances are being measured.

Variations in the diameters of the fuel pump plungers are somewhat common sources of variation in output, and it is desirable to measure these parts by micrometer whenever a complete overhaul is undertaken, replacing worn plungers as necessary to keep the variation in their area within a limit of about 5 per cent.

(c) *Air Supply.*—The provision of the necessary supply of pure air in which to burn the fuel is settled mainly by the diameters of the air and exhaust valves, and also by the lifts and timing of these parts. The first of these factors is outside the control of the operator, who must, however, ensure that due attention is paid to the two latter.

The opening of the valves in the various cylinders should be within 5 per cent. of that designed, giving a possible maximum variation of about 10 per cent., an amount which can be tolerated without giving rise to undue trouble.

Attention should be paid also to the cleanliness of the induction pipe system, including especially that of any silencing devices or dirt excluders which may be provided: resistance to the air flow at such points as these may be considerable in some cases, resulting in an appreciable reduction in the quantity of air actually entering the cylinder.

(d) *Back Pressure.*—It is also important that the exhaust gases should have a free egress from the cylinders, and the exhaust manifold and silencers should therefore be kept reasonably free from deposit.

Admiralty Note.—In this connection it appears, from the results of some trials carried out at an experimental station, that the back pressure in the exhaust system can be very considerably increased without greatly affecting the power developed: thus the B.H.P., engine speed and fuel consumption are practically unaffected by a back pressure of 1 *lb. per sq. in., but an increase to* 4·0 *lbs. back pressure is attended by a reduction of some* 20 *per cent. in B.H.P. and an increase of* 6 *per cent. in fuel consumption. In these trials a butterfly valve was fitted in the exhaust pipe for the purpose of producing an artificial resistance; it was found necessary to close the valve to within* 2° *of its shut position before* 4 *lbs. back pressure could be attained, thus showing that pressures of this order correspond to very considerable local restrictions. It is of interest to note that* *analyses were made of the cylinder charge during these tests, it being found that the contamination of the charge by exhaust gases was not seriously increased under conditions of high back pressure, and thus it does not appear that the falling off in power can be attributed to this factor, as has been sometimes suggested.*

(*e*) *Valve Settings.*—The power of the cylinders and the smoothness of running are principally influenced, apart from the foregoing considerations, by the setting of the various valves. The standard settings given by the makers are those best suited for the specified conditions of working, and it is generally advisable to adhere to the figures given.

The necessary fineness of adjustment will be obtained if the settings for the air and exhaust valves are within 5° of the designed figure, this being especially necessary where the operations take place in the immediate vicinity of a dead centre: the settings of the fuel valves in engines of the Mirrlees type, where the rate of opening is rapid, should be within 1° of the designed position.

It may be found of advantage when using particular fuels to alter the fuel valve settings, and as far as possible the maximum practicable degree of advance should be worked to, thus reducing fuel consumption; insufficient advance results in sluggish running, accompanied by excessive fouling of the flame plates and undue deposits of carbon: excessive advance on the other hand leads to difficulty in starting.

As regards tappet clearances, in the writer's opinion it is considered that if these agree within 2/1000″, the adjustment in this respect may be considered as good, within 7/1000″ may be tolerated, while a variation of 12/1000″ or more is definitely bad and will result in erratic running and reduced power. It has been found that the tappet clearances of Air and Exhaust Valves do not remain constant for long periods of running, and should not only be set when valves are cleaned or changed, but should also be checked at regular intervals not exceeding seven days apart.

In the appendix will be found a few unusual points which may affect the timing of the valves.

Setting the Fuel Valves.—The following method for checking the setting the fuel valves has much to recommend it:—

> Set the engine a few degrees before the assumed opening of the fuel valve, then prime up the blast pipes with air from the blast bottle (any pressure between 600 and 1,000 lbs./sq. inch), after which close the valve on the blast head.
>
> Now bar round slowly forward with the indicator cock open, holding a thin piece of tissue paper near the mouth of the indicator cock.
>
> The fuel lever should be in "running" position, and so the instant the fuel valve is lifted it will be shown on the tissue paper.

(Compare this method with the roller clearance method: the former is usually from 2 to 3 degrees later.)

Should it be desired to find this setting by experiment, it would be necessary first of all to see that the compression, the fuel pump tappet clearance, and the fuel valve lever clearance are all in order. Having done this, take an indicator diagram at not less than $\frac{3}{4}$ full load, then make an adjustment to the position of the toepiece as may appear necessary, bearing in mind the type of diagram required, *i.e.*, with a broad square top, not lagging on the ignition point, nor yet continuing the compression line to a higher pressure producing a thin, peaky top.

It will be found that in these particular engines, as might be expected, the setting of the fuel valves tends to become "later" as the engine warms up, but those of the air and exhaust valves on the other hand tend to advance under these conditions, and care should be taken to ascertain whether or not the makers' settings are intended to apply to the "cold" condition, as is generally the case.

Maintenance.

Indications of the condition of an engine.—In order to maintain the engine in proper tune, means are required to indicate any incipient defect before it becomes too pronounced. The proper instrument for this purpose is, of course, the indicator, but as the use of this instrument in Internal Combustion Engine is, however, none too easy, it will be found of great assistance as an alternative to fit thermometers in the cooling water discharge from each cylinder. The cooling water supplies to the individual cylinders should be adjusted so that the temperature of discharge is the same in all cases when the engine is properly tuned up and all jackets are clean: any variation in the working of cylinders can then be readily detected by the thermometer readings.

In this connection it may be remarked that the cooling water temperature appears to affect the running of the engine and that there is an optimum temperature which is best found by experience. Valves are ground in when cold, and if thereafter any considerable variation in temperature exists between valve and seating, leakage will occur—hence the importance of finding the correct temperature and in ensuring that all cylinders are alike in this respect.

Electric pyrometers in the exhaust pipe serve the same purpose even better, but are not so readily improvised as thermometer fittings, and in any case it must not be forgotten that the exhaust temperature is influenced by the blast pressure.

The governor settings for full load should be noted after complete overhaul of the engine and the cause of any subsequent variation from these should be investigated. Any obvious reduction in power should not be permitted to continue, and it is desirable to arrange the notations in the Diesel Engine Room Register to provide a warning in this respect.

The power distribution between the various cylinders should be checked periodically, preferably with the engine on about three quarter load. The obvious method of doing this is by means of indicator diagrams, but these cannot be regarded as reliable under service conditions, chiefly on account of unavoidable slacknesses in the " rig " and of the unknown personal error in taking the diagrams.

A satisfactory method is to cut out each cylinder in turn and note the " power drop " in each case. Alternatively open the test cocks and reduce the blast pressure; the strongest cylinder will usually show black smoke before the others; this test is sometimes of service, but is of course, only very rough, while it is decidedly a noisy one.

The blast pressure forms a useful guide to the cleanliness of the fuel valves, pulverisers and flame plates ; this will in general require to be raised as the parts mentioned become foul. It may be mentioned that restrictions in the air supply may be remedied by increasing the blast pressure, that is by employing what is in effect a type of supercharging : thus, if a clean engine makes a gradually increased demand for blast air, the condition of the induction system generally should be investigated.

Upkeep.—This resolves itself into the adoption of a satisfactory routine for the refit and running of the engine. It is thought that in a warship the heavy oil engine routine should be arranged in such a manner that at all times it is maintained in a " fighting " condition. There is not generally the necessity, nor is it desirable, to run these engines in anything but in the most efficient condition, and they should be maintained at all times ready for an emergency, just as is the case with any other main or auxiliary engine. Undoubtedly many breakdowns occur through attempting to run these engines for long continuous periods, as is usual wtih steam engines, but it requires stressing that while the latter will run with gradually developing trouble, an internal combustion engine will not. This is due firstly to the minor effects which may give rise to differences in power between the individual cylinders, with the possibility of consequent failures due to heat stresses, and secondly to the fact that the maximum cylinder pressures in these units are several times greater than those met with in steam engines and hence the hammer blows resulting from small slacknesses in the moving parts are correspondingly destructive in their effects. In fact, troubles must be tackled very much earlier in internal combustion engines than in their steam-driven rivals.

The question of upkeep is very closely allied with that of training the personnel, and some brief notes on this subject are added in the form of an appendix to this paper.

It is proposed to pass on to discuss briefly a few points of importance as regards the maintenance of the engine.

Cooling Water.—The reliability and cost of upkeep of internal combustion engines depends to a great extent upon the efficiency of their cooling systems, excessive deposits resulting in cracked castings, rapid cylinder wear and likelihood of piston seizures. The removal of deposits cannot be properly carried out in many designs of engine unless the liners are withdrawn and the cylinder covers are parted, this latter being usually a lengthy operation: the provision of special scrapers for cleaning the water spaces in the latter is to be recommended.

The formation of deposits appears to occur principally during the period when the engine is cooling down, and may be largely prevented if the circulating supply is maintained till the temperature of the liners and covers is too low to cause separation of the scale-forming material from the sea-water. This temperature is about 110° F., and, in order to be on the safe side, it is suggested that a *slow* circulation be kept up after the engine is stopped till the water is discharged at say 70° F.

If this precaution is consistently adopted, then a really thorough cleaning of the jacket spaces once a year will usually be found to meet all requirements, especially if the cooling system can be well flushed through from the firemain at intervals in order to wash out deposits of mud. Periodical attempts to remove scale through the doors provided for the purpose are not to be recommended, owing to the danger of partially choking the system by loose particles which it may not be possible to remove.

Lubrication.—In cases where oil coolers are not fitted, it is suggested that it is worth while providing a coil of say 30 feet of $\frac{5}{8}''$ copper pipe in the oil suction well.

It appears advisable to change the oil once a quarter or say after 1,000 hours' running, fresh oil, usually amounting to about $1\frac{1}{2}$ to 2 gallons per 24 hours, being added at intervals as necessary to make good wastage. The lubricating value of Special Mineral should not have been greatly affected, but the oil is undoubtedly becoming very dirty after such a period and the very finely divided matter in suspension appears to pass through strainers and centrifugal separators alike, and may cause clogging of the oil channels. A great deal of the oil may, however, be reclaimed by prolonged settling and is of value for use in engines not provided with forced lubrication systems. The mixture of even minute quantities of fuel oil with the lubricating oil will gravely affect the value of the latter and cannot be removed by any process of separation. The sense of smell can be relied upon to detect such an adulteration.

Admiralty Note.—The Centrifugal Separators now being fitted to service Diesel engines will remove all but the very finest particles of solid matter suspended in the oil, as well as freeing the oil from water. They will not, however, remove any fuel oil which may have become mixed with the lubricant, but should otherwise renovate the oil and prove valuable adjuncts to the installation.

The vital part of the lubrication system is undoubtedly the supply to the "little end" bearings, and, as this depends on the amount of oil which escapes from the crankheads, it is specially recommended that the latter should be adjusted whenever even a suspicion of slackness arises: the time spent in this adjustment is never wasted.

It is desirable that whenever oil is changed (quarterly) the hand oil pumps should be worked till oil *flows freely* from both ends of each gudgeon pin bearing, the piston being lifted up by small screw jacks till the clearances in the gudgeon pin bearings are at the top, thus ensuring that the oil supply holes in the pin are not masked by the brass. This precaution should also be taken after refitting gudgeon pin bearings or if the engine has been stopped for more than a week. This is admittedly somewhat of a counsel of perfection in view of the time required, but it is believed to be well worth the trouble.

Exhaust valve guides are lubricated with sperm mineral or fuel oil, applied by means of a brush every 15 minutes: the use of lubricating oil for this purpose will result in sticking of the valve in the guide.

Valves.—A complete set of spare valves should be carried, and kept clean: this is necessary in order to effect changes in the somewhat limited time usually available. The condition of the valves may be tested conveniently by means of radial pencil marks on the seatings. As far as possible, "grinding in" the valves should be avoided, but they should rather be rubbed in dry or with oil only—this refers chiefly to fuel and air valves as exhaust valves are generally too pitted to allow of this treatment.

Fuel valves should be examined whenever the flame plates are cleaned. Experience shows that when any of the fuel valves and flame plates of an engine require cleaning, all should be done at the same time. It will be found that if only a few of the flame plates are cleaned, the remainder being left in a partially dirty state, then the engine will suffer from a rapid falling off in power.

The soft packing known as "Sentinel" has been found satisfactory for fuel valve glands as it reduces the wear on the valve stems and also permits the use of valves with stems of different diameters.

Valve guides.—Cases of fracture at the point where the flange joins the body of the guide are not uncommon—this may frequently be traced to the practice of hammering up the securing nuts which preferably should be set up hard by hand and can beneficially be gone over again when the engine is hot.

Smoking at Exhaust Valves into Engine Rooms.—This is usually due to an unduly large clearance between the upper portion of exhaust valve cage and the orifice in the cylinder head. A simple cure is to fit annealed copper washers between the cage and the spigot on the exhaust valve guide, the washer being made a close fit in the cylinder head. The suggestions on page 50 of "Papers on Engineering Subjects," No. 5, in connection with the seatings of exhaust valve cages in the cylinder heads are well worth adopting. It has been found, however, that the casings are in many instances so loose a fit in the cylinder cover as to make accurate grinding a very difficult proposition and special arrangements are needed to take care of this condition.

Cams.—In order to produce as far as possible the same valve openings in the various cylinders, it is advisable to check the wear of the cams at each complete overhaul of the engine, fitting new when the throw has been reduced by say 5 per cent. due to wear. The level of the oil in the troughs under the cams may beneficially be raised by extending the end of the oil drain pipe upwards into the trough, suitable splash guards being fitted: the cams then dip in the oil, noise is somewhat reduced and the wear on the cams should be less.

Admiralty Note.—The use of forced lubrication is being extended to all parts of the engines in new designs.

Seized Pistons.—In case of a seized piston, the engine should be turned by hand till the piston has thoroughly cooled down. If the urgency to keep the engine running is very great, it is safe to do so at moderate load if the cylinder where seizure occurred is kept "cut out" for several hours (say at least 24) when the effects of the seizure will have been mechanically removed. In such a case, however, before running the engine the oil supply to the gudgeon pin must be ensured, as must also the cooling water supply to that cylinder.

The above has been applied on three occasions when no other dynamos except the Diesels were available, and the results were entirely successful, the pistons and liners being slightly scored but undamaged in any other way.

Air Compressors.—The periodical cleaning and refit of the various valves and intercoolers is most important, but otherwise little trouble should be experienced.

It is suggested that the troubles due to the presence of large quantities of lubricating oil in the compressors may be mitigated (if not entirely eliminated) by running the compressors on open throttle and discharging the excess air through a permanently open drain fitted to a small separator, arranged at the outlet from the L.P. stage. A silencer is required on this drain and also a screw-down valve; the blast pressure is regulated by adjustment of the valve.

Admiralty note.—Arrangements of this nature are provided in some of the later designs of Diesel generators.

The fracture of air compressor valves of the plate type may be mitigated if the sharp edges of the plates are rounded off with a file.

The I.P. Intercooler pressures should be frequently observed and logged, while the intercooler drains should be blown down every 15 minutes.

Bearings.—Ratings do not nowadays get the experience that they formerly did in refitting reciprocating engines and for this reason somewhat close supervision is required as regards the adjustments of the main, crank and gudgeon pin bearings of oil engines. Defects attributed to the fashionable complaint of "Torsional oscillations" have on occasion failed to reappear after intelligent attention has been paid to the alignment of the crankshafts and the proper adjustment of the other principal bearings.

It, is of course, quite unnecessary to enumerate to senior Engineer Officers the points to be observed in refitting the journal bearings of reciprocating engines, but is it generally realised that the younger generation of both officers and men have not been drilled in the same school in which the former were trained 20 years ago? The steam turbine has rendered this training of less general importance, but certainly no E.R.A. can afford to despise it, as the day of "push and pull" engines is not yet over, although the internal combustion type remains their chief representative.

In view of this it is suggested that a very complete record of bearing adjustments should be kept, and in particular that bridge gauge readings of the main bearing journals and crown thicknesses of all brasses should be regularly taken and entered in a suitable table. The record should also contain notations of the gaugings of the cylinder liners and the throw of the cams.

Running faults.—Much might be written on this subject, but intelligent diagnosis is a far better guide than any detailed list of possible faults, and a fund of experience is soon accumulated. The usual defects which may prevent the proper starting or running of a Diesel are but few in number; it is probably sufficient to state that, provided the fuel supply is adequate, the compression good and the valves properly timed, the engine cannot fail to run.

There is, however, one common type of defect, namely stoppage of the fuel supply on account or air-locks, which can be absolutely prevented if suitable precautions are taken. This particular occurrence may be a very real nuisance in some engines and is not always readily recognised, so it may not be out of place to add a few notes on the subject.

Air-locks do not usually occur after an engine has been in use for some time, unless either leaks exist in the fuel suction system or the fuel tank is allowed to become empty. The defect is generally experienced immediately after starting, which may on occasion be entirely prevented by these means. Thus if a correctly timed engine, which is known to be in good condition, fails to start, the existence of air-lock should always be suspected after it has been ascertained that the suction valve on the fuel tank is open and that the suction strainers are clear.

The best method of clearing air locks, which almost always occur in the fuel pump itself, is to flood through the fuel system with the discharge pipes and the fuel pump suction and delivery valves removed: flooding should be continued till no signs of air bubbles can be seen. This procedure should invariably be adopted whenever any part of the fuel system between the tank and the discharge union on the pump has been dismantled.

Persistent air-locks are sometimes caused by the valve seats projecting into the chambers formed below each valve: pockets are thus created, and air trapped in these is not readily got rid of by flooding. A somewhat similar effect is produced if the lower part of the valve seat is an unduly slack fit in the body of the pump.

Leaky delivery valves on the fuel pumps may also cause air locks and faulty starting. Thus, if the blast air is put on the cylinder for any length of time, during which the pump is cut out, or if the engine is allowed to stand with the blast air pressure on the fuel valves, the air will gradually force the fuel back into the pump and may eventually obtain access to the latter. The purpose of the double discharge valves fitted to fuel pumps is partly to avoid air-locks.

A somewhat infrequent cause of this trouble is leakage at the point where the tappet rod, actuating the suction valves, passes through the pump casing.

It is suggested that much benefit may be derived from the various Articles on the Diesel Engine which have appeared in "Papers on Engineering Subjects," and also in various papers which have been read before "The Diesel Engine Users' Association."

It may be of interest that a staff of 2 E.R.As. and one stoker, assisted occasionally by two more stokers when heavy work is to be done, has been found ample to deal with two Diesel engines and also two turbo-generators. One E.R.A. is changed every three months, thus each works for about six months on the machines, and this arrangement has given every satisfaction. The Diesels are stopped and started by E.R.As. from the Duty Watch, all E.R.As. being required to pass a practical test in starting these engines.

In conclusion it is suggested that every effort should be made to get rid of the somewhat commonly held opinion that Diesel engines are complicated pieces of machinery and subject to developing mysterious complaints. When those in charge of them realise how simple they are, despite the multiplicity of parts, and how comparatively few are the causes of trouble in a well-conditioned engine, one half of the battle is won. The other half lies in establishing the best settings for the engine, *e.g.*, valve timing and compressions, and in ensuring that these are adhered to within reasonable limits in each and every cylinder.

APPENDIX.

I. *Routine of Running and Cleaning.*—The routine to be adopted necessarily depends upon the circumstances of the case, but it is desirable in devising suitable arrangements to bear the following points in mind :—

(a) *Minimum of starting and stopping.*

(b) *Examination and Refit of Valves, &c.,* as nearly as possible in accordance with the requirements of Article 163 of Engineering Manual.

(c) *Cleaning of Flame Plates* at intervals to suit the fuel in use. With Burmah Oil 144 hours appears almost exactly right—at the end of this period the engine has just begun to smoke, despite raised blast pressure, but the flame plates may be cleaned readily, so avoiding damage to the orifices.

(d) *Obtaining the maximum running hours possible from the Diesels.*

The period for which an engine can be run without major attention is very considerable, depending, of course, upon circumstances, and 4,000 to 5,000 hours running may be considered a very satisfactory year's work, which should be readily obtainable if the engine is well maintained and if the general overhaul is properly carried out. The possible duration of non-stop runs at full output depends principally upon the character of the fuel, being determined by the rate at which the flame plates become foul, but in the writer's opinion it is preferable to restrict periods of continuous operation to intervals not exceeding, say, 140 to 200 hours in order that the engine may be maintained in the desired condition. Longer intervals between stops (and subsequent minor adjustments) are always attended by a risk of damage to the engine if heavy demands are made upon it towards the end of such periods.

A satisfactory routine to meet the foregoing requirements in the case of a battleship provided with two turbo-generators and two Diesel-driven dynamos, is to arrange that the latter are run alternately "continuously" and "intermittently" for periods of four days in each condition, the machines working continuously, however, over each week-end. During the "intermittent" period each engine is run during the night watches only, refitting and adjustment being effected during working hours. Larger adjustments may be deferred when possible till the ship is at sea for more than one day, under which condition it is necessary to employ steam-driven dynamos at all times.

The following, then, are suitable intervals at which the various parts may be cleaned, refitted and adjusted, assuming that the foregoing routine is adopted :—

	Hours.
Flame Plates and Pulverisers	144
I.P. Intercoolers and I.P. Valves	144
H.P. and L.P. Valves Exhaust Valves	576
H.P. and L.P. Air Coolers, Pipes and Valves	576
Air Valves Fuel Valves	1,152
Exhaust Pipe	1,728
Flush through Jackets, clean Silencers (air and exhaust) Examine Protectors	1,728

II. *Training of Stoker Ratings.*—Every Engineer Officer has his own views on how best to train his auxiliary watchkeepers and tries to turn out men well equipped for advancement, but there is sometimes a tendency for a harassed senior engineer to keep a good heavy oil engine watchkeeper tending such machines all the commission, when once he has trained him : this is neither good for the man nor the service.

A few notes on the duties of a watchkeeper may not be out of place. A list of defects likely to occur when running should hang in every oil engine-room. It should be made quite clear what a man's duties are and how far and what faults he may attempt to remedy himself, and what he must report to the officer in charge at once. He must clearly understand the necessity of keeping in close touch with the switch-board and be prepared to stop the engine as quickly as possible should certain symptoms develop.

Meters and gauges must be vigilantly watched, particularly the compressor, air bottle, oil and cooling water-gauges.

The parts requiring particular attention in lubricating should be named.

The necessity for cleanliness is imperative, and a man who is naturally untidy or dirty will always be unsatisfactory.

Oil and water leaks must be reported. Causes of defects and the procedure he must take when they occur should be made plain to him.

The watchkeeper should maintain a close touch with the E.R.A. responsible for the engine, particularly during silent hours, in order that any symptoms he does not recognise may not be disregarded.

III. *Timing of the Valves.*—The timing of the valves may be affected by the following factors :—

(1) Length of the valve levers and the condition of the rocker arm bushes.

Bent levers, eccentrically bored bushes, &c., will affect timing and also lift of valves. It is desirable to check the distances between the roller, pivot bush and the tappet in cases where valve timing appears to be affected.

(2) Rocker arm shafts should be parallel to and at the same distance from the camshaft in each cylinder.

This point should always be checked when new cylinder heads are fitted..

(3) Torsional yield of the camshaft.

Cases have been known where the camshaft has suffered permanent torsional "set," increasing in the course of time till the valve timing had been appreciably affected.

The possibilities of trouble arising from these or any similar defects will be obviated if a practice is made of checking the timing of *all* the valves at suitable intervals, and particularly after a complete overhaul. This is an operation which is too often carelessly performed, owing to the time required : a little intelligent thought will indicate how the timing may best be checked in the minimum number of revolutions of the engine.