CARE AND MAINTENANCE OF DIESEL ENGINES.

A paper recently read before the Diesel Engine Users' Association on the care and maintenance of Diesel Engines is of special interest to the Naval Service, in so far as the designs discussed were of the Mirrlees, Bickerton and Day type, similar in many respects to the engines fitted for electric power generators in a number of Capital Ships, while the observations made represent the considered view of makers with a particularly comprehensive experience of oil engines. The paper dealt in a thorough fashion with the practical running problems experienced with this type of oil engine in its application for shore purposes and appears to have covered many of the more important defects now being experienced.

Abstract.—The Author first advocated a simple routine to ensure that parts requiring inspection, renewal or overhauling shall be attended to in the correct sequence and proceeded to discuss the question of the life of an engine, reaching the conclusion that the life has no limit, other than that determined by obsolescence, provided the engine receives reasonable skilled care and attention.

Generally speaking the parts which may require attention are :—

(1) Valves, seats and springs of main engine and of compressors and fuel pumps.
(2) Liners of main engine and compressor.
(3) Pistons and rings of main engine and compressor.
(4) Bearings.
(5) Cylinder covers.
(6) Cams and valve gear.

In practice it is found that exhaust valves and seats require more frequent renewal than any other parts. Next in order come liners, pistons, rings, springs, bearings, cylinder covers, and at longer intervals, cams and valve gear. As worn parts can be replaced time after time, the efficiency of the engine can be maintained indefinitely. Engines which have been working for over twenty-one years are still running well, maintaining their high standard of economy and giving every satisfaction.

Water spaces.—In introducing this subject a diagram was shown (not produced) indicating the path of the heat passing away to the water spaces viâ the piston, cover, liner and valve casings.

Approximately, a Diesel engine in good running order utilises in useful work or brake horse-power 34 per cent. of the heat units of the fuel oil delivered to the combustion chamber; 30 per cent. of the heat units pass away with the exhaust gases and 25 per cent. pass away through the water jackets.

The importance of keeping the surfaces to be cooled free from deposits such as carbonate of lime, sludge, vegetable matter and other refuse will be readily appreciated; otherwise an uninterrupted flow of heat to the water jackets will not be maintained. Neglect of this important point produces serious overheating and causes :—

(*a*) Loss of power through distorted valves and seats.

(*b*) Seized pistons through destruction of the oil film between liner and piston.

(*c*) Cracked cylinder covers and pistons.

A long series of investigations has indicated that deposits are not necessarily formed on the surface while the engine is running, but more generally after the engine has been shut down, the reason being that the heat units stored in the valves, cover, piston and liner are sufficient to raise the temperature of the water lying in the jackets and to cause precipitation of the lime salts. Recommendations and arrangements have been made to allow water to flow through the engine 15 to 20 minutes after stopping, this being usually effected by means of an auxiliary overhead tank. By this means the water jacket temperatures are kept sufficient low to prevent precipitation and the engine parts are allowed to cool down gradually. This method of dealing with the circulating water has proved invaluable to all internal combustion engine users.

It is nevertheless important that the water-cooled surfaces should be examined periodically and for this purpose suitable openings are now generally provided in all water-jacketed details. Where openings are not provided, the possibility of cutting them in the water-jackets should be considered, but the engine builder should first be consulted on this matter both as regards the feasibility of the scheme and, if feasible, the best position for the openings.

If the examination indicates the necessity for cleaning, but shows that mud, sludge or soft matter only has to be dealt with, then a thorough washing out of the jacket spaces will be sufficient. On the other hand, if the deposit is found to be ***hard***, then the main liners and air compressor liners will have to be withdrawn and the internal surfaces scraped and cleaned. It has been found that, owing to the muddy state of harbour waters, the water spaces of internal combustion engines fitted in ships which are frequently in and out of harbour are more readily silted up than those of engines fitted in ships which are the greater part of their time at sea.

In cases where exceptionally hard water is the only source of supply, it is desirable to instal a small water softening apparatus. It is not necessary to soften the whole of the water used, but only the small quantity of "make-up" which is required due to evaporation (usually about 5 per cent.). It is, of course, understood that a cooling tower is used in conjunction with such a scheme.

Where river or canal water is used, it has been found undesirable to draw the water direct from the river or canal as, when the former is in spate or the latter is stirred up by shipping, a considerable portion of the suspended matter is taken over and deposited in the jackets.

An interesting communication from a user of an engine of this type was mentioned. Some liners had shown signs of collapse internally while others did not and the opinion had been formed that the distortion was due to the liner being prevented from expanding longitudinally as is intended. It was thought that this was owing to the liner being held rigidly at the bottom of the belt by accumulations of rust and scale and arrangements were made to examine and calibrate the bores of the liners. These measurements were tabulated in graph form. The liners were next removed and the difference in the effort required to remove each liner was carefully noted. Reference to the graphs showed that the liners which indicated internal collapse were very difficult to remove. This would appear to be an important discovery and may account for some of the mysterious piston seizures which have taken place.

Crankshafts.—This important detail used to be considered a source of anxiety, but within recent years more careful supervision in manufacture has reduced troubles to a very low percentage. A simple self-registering instrument consisting of an inside micrometer with dial gauge was commended for use in taking periodical measurements between crank webs; this instrument is also suitable for measuring liner bores. It was recommended that the readings should be taken in four positions of the crank pin each 90° from the other, and that the main bearings should receive attention if the gauging showed an extension exceeding ·002 in. for shafts between 6 in. and 8 in. diameter, ·003 in. for shafts between 8 in. and 11 in. diameter, and over ·004 in. for shafts above 11 in. diameter.

If for any reason a new crankshaft has to be fitted or a new bearing or bearings fitted to an existing shaft, care should be taken that sufficient clearance is allowed at each line of cylinders on the crankweb nearest the flywheel. The necessity for this will be seen when it is remembered that the skew gear-wheel is generally fitted between two bearings so as to prevent the longitudinal movement of the shaft which is produced by the angular thrust of the skew gear-wheel. By reason of this arrangement, the shaft is prevented from expanding at that end. Therefore, due allowance must be made for the shafts expanding wholly towards the other end. Serious damage has been done and shafts have even been bent owing to this important point not having received attention.

Again, it should be remembered that where a dynamo is connected to the engine shaft, sufficient clearance must be provided between its bearing flange and its oil flinger to allow for a continuation of the longitudinal expansion of the shaft.

Fuel or Needle Valve.—This simple and yet important valve and its accessories require care and attention. The author knew of no detail on the Diesel engine which gives so little trouble if manufactured and fitted properly. There are several methods of actuating this valve, but for the purposes of this paper, the two types which are most commonly in use need only be considered :—

(*a*) The torsional spindle type.
(*b*) The gland-packed type.

At one time the former was most commonly used, but as the whole of the fuel casings, upper and lower, are subject to the full pressure of the injection air, considerable difficulties were experienced in its manufacture and generally speaking it was abandoned on the score of excessive cost of production.

This torsional spindle arrangement has the advantage that the valve does not have to work through a packing gland, although the actuating mechanism has to do so. Its construction was not always understood and consequently, in practice, trouble was experienced with it. Further, it had the disadvantage that its construction prevented the removal of the air and exhaust valve casings without first dismantling the fuel valve and its upper casings.

The gland packed type of fuel valve is now almost universally adopted and if it is properly manufactured gives very little trouble indeed. This valve generally takes the form of a long and somewhat slender spindle, with a guide portion at one end and the valve seat at the other end. Care must be taken in handling this valve. It should not be laid about on the work bench when removed from its position on the engine, as it can easily be damaged by articles being laid upon it. The author recommends that a wooden rack, pierced with holes, be fitted up in the engine room and arranged in such a manner that the fuel valves can be stowed away vertically on it. Spare fuel valves should also be stowed away in this manner to prevent their becoming bent or otherwise damaged.

Perhaps the most important point in connection with this part is the keeping of the valve seat in condition. It is important to observe that this valve should not be ground on to its seat with hard abrasives such as carborundum or flour of emery. These abrasives are difficult to remove from the seat and wear away the seating at a very rapid rate.

It is recommended in the first place that the valve be rubbed on to its seating quite dry, and any hard portions removed with a small, smooth file; continue to rub metal to metal and touch up the faces with the file until an even bearing surface is obtained; then finish off with liquid metal polish and a little oil, gradually removing the oil and abrasive until a metal to metal condition is obtained again.

This process is somewhat slow but a fuel valve once conditioned in this manner will continue to remain so for long periods and should only require rubbing on its seat occasionally with a little lubricating oil.

Many troubles on the Diesel engine have been traced to the unsatisfactory condition of the fuel valve seat, not because of lack of attention to it but because it has received the wrong kind of attention. Continually grinding in of a fuel valve with hard abrasives produces a serious wearing down into the valve seat and the valve becomes buried in the manner shown in Figure 2. Such a condition brings a number of troubles in its train : for instance :—

(*a*) Loss of power and speed.

(*b*) Overheating and cracking of the parts exposed to the products of combustion, *e.g.*, pistons, cylinder covers.

(*c*) Distortion of the valves and their seatings in consequence of this overheating.

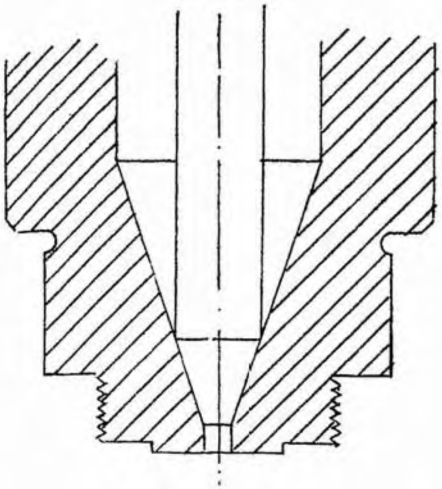
(*d*) Difficulty in starting.

Unfortunately, this difficulty has not in the past been readily recognised. The first sign of it is late fuel admission accompanied by an attenuated combustion line, as shown by the indicator diagram. Instead of investigating the cause of the trouble the fuel setting is usually advanced to overcome the late admission and the air injection pressure raised to try and flatten out the top of the indicator diagram. People have been known to alter their pulveriser flame plates and even their cams, but such modifications cannot be condemned too strongly. Consider what is happening. When the fuel valve is in good condition it should, immediately it is lifted off its seat by the cam and lever, permit fuel oil to pass down into the cylinder. If, however, the fuel valve has worn down into the seat, it forms a parallel recess into which the body of the valve spindle fits exactly. Consequently, when the valve is lifted, the parallel portion has to rise clear of the recess before the oil can pass on its way to the combustion chamber. A glance at the figure makes this point quite clear.

Now the result of this is to reduce the active lift and also the time that the valve is kept open, thus reducing the space and time available for the fuel oil to pass through to the combustion chamber. This causes the speed to fall; the governor drops to a lower position and admits more fuel oil still, but as the oil cannot pass into the combustion chamber at the correct time, " after-burning " takes place with its attendant trouble of overheating. The trouble is accentuated by the dilution and overheating of the incoming air with inert gases which reduce its ability to sustain combustion of the fuel oil blown into it. Loss of power and speed, accompanied by knocking, overheating and the emission of heavy black smoke at the exhaust ensues if the engine is kept running under these conditions. Further, the valves and their seatings become distorted and burnt and there is a danger of the piston seizing and of cracking of the parts exposed to the combustion space.

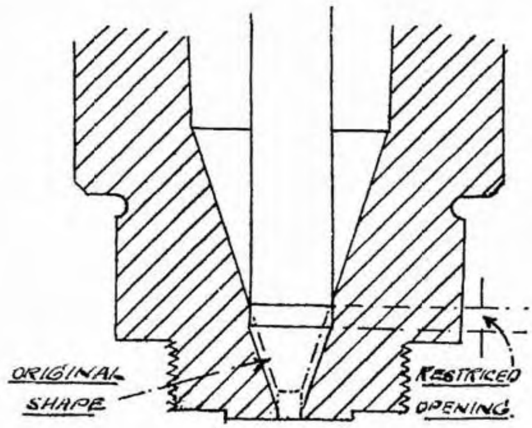
It can be readily appreciated how difficult it is in the ordinary way to analyse this trouble and discover the extent of the wearing

FIG. 1.



ARRANGEMENT OF FUEL VALE WHEN NEW

FIG. 2.

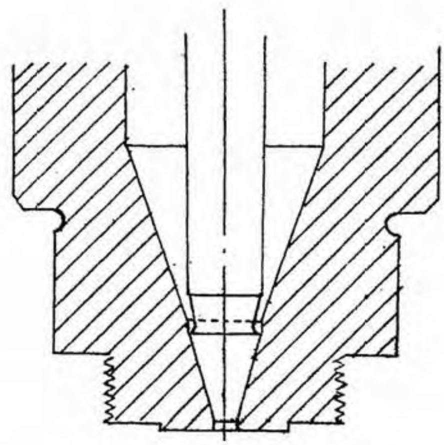


AFTER REPEATED GRINDING IN

FIG. 3.

VALVE SPINDLE GROOVED

FIG. 4.



GROOVED SPINDLE
SHEWING CLEAR PASSAGE FOR FUEL
NO RESTRICTION OF OPENING.

in of the valve seat. The position of the seat in a remote place at the lower end of a long casing makes access difficult and accurate examination impossible. Generally a small mirror is used for examination purposes, but the extent of the fault cannot be measured by that means. The author was faced with this problem and decided to try another method which has proved most effective, viz. :—

Carefully clean out the fuel casing; take a stout wax candle and warm the pointed end until it reaches a plastic condition for about 1 inch up of its length. Next pass the wax candle down into the fuel casing and press it firmly on the seating at the lower end; hold there until the wax has set firmly, turn the casing upside down and knock out the wax impression. If it has been treated in a proper manner, a perfect model of the worn seating will have been obtained. From this the exact extent of the wearing in can be measured and the necessary steps taken to remove the trouble.

It is usual when the seats have been found to be worn in to reamer out the seating, but this is not always possible and the following method will be found to be equally effective :

From the wax impression, measure the exact amount of the recess which has been worn into the seating. Take the needle valve and mark off from the top edge of valve face, this amount, plus, say, $\frac{3}{16}$th inch. Then take a $\frac{3}{16}$th inch rat-tail file and file a semi-circular groove about $\frac{1}{16}$th inch deep round the valve spindle, letting the edge of the groove coincide with the top edge of the valve face. Then file a chamfer from the groove to the point marked higher up on the spindle : let the chamfer at the lower end be filed until it coincides with the bottom of the groove (*see* Figures 3 and 4). This should produce an elongated tapered recess immediately above the valve face, which will form a passage or port behind the parallel recess in the valve seat and permit the fuel oil to pass freely directly the valve is lifted from its seat. No other alteration should be necessary.

It is recommended that all fuel casings should be periodically examined by the wax impression method, and if this is done the author believes that the number of cracked pistons will be materially reduced.

Packing of Fuel Valves.—It is essential that care should be exercised when adding to or replacing the packing in the stuffing box of the fuel valve. The following is recommended as the most convenient method of packing the stuffing box. Remove the gland casing and clamp it into a vice. See that the stuffing box is quite clean. Take a single ring of packing and press it into the stuffing box with a gunmetal distance piece provided for the purpose; screw the gland down on to the distance piece and squeeze the packing down hard. Insert the fuel valve and the tool provided for the purpose and work the valve to and fro by hand through the packing, gradually tightening the packing ring until it cannot be tightened any more. Remove the distance piece; insert another ring and a shorter distance piece; deal with it in the same manner as the first ring was dealt with and continue to do this until the stuffing box is full. To obtain the best results it is important to observe :—

(*a*) That each packing ring be dealt with separately.

(*b*) That each packing ring be compressed as tightly as the tools provided for the purpose will permit.

(*c*) That the needle valve be worked to and fro until it moves through the packing quite freely.

Occasionally when the casing is removed to examine the pulverisers, the packing should be tightened up and the needle valve worked through the packing until free. If this practice is adopted very little trouble will be experienced and a sticking needle valve will be a remote possibility. It is most important to observe that tightening up the fuel valve packing gland when the engine is at work is a risky and unsatisfactory proceeding.

The packing used is generally white metal shred packing and is available in compressed rings of the correct size to fit the stuffing box.

The same material and method are used to pack the fuel pump glands. Some makers adopt compressed fibre packings or leather packings and issue special instructions how to deal with them.

Fuel Pumps.—These details require very little attention beyond cleaning out of the sump chamber every few months, and attention to the draining off of water before starting up and occasionally during running. This is particularly necessary where heavy fuel oils are used, as experience has indicated that the heavy oils hold water in suspension.

The valves should be rubbed in once a year and any ridges removed with a small smooth file. If the valves require re-seating, it is suggested that they should be treated in the same manner as was recommended for the conditioning of the fuel valve. The use of hard abrasives for grinding these valves is not recommended.

In passing, reference was made to the adjustment of the fuel pump mechanism which is provided to enable equal powers to be obtained in each cylinder. This mechanism on M.B.D. engines is enclosed with the fuel pump chamber with a view to preventing indiscriminate adjustments being carried out whilst the engine is running. It is, however, easy of access when the engine is shut down, but one little point has at times been overlooked when adjusting the clearance between the control tappet and the fuel pump suction valve. After a lengthy term of service it is possible for an indent to be worn in the hardened collar which is secured to the underside of the suction valve. If the collar is removed and rubbed on a carborundum stone until the recess is removed, a correct adjustment can be made with certainty.

Valve Adjustments.—On M.B.D. engines the mechanical clearances required between the rollers on the levers and their respective cams are clearly stamped on the levers, and a certain point is marked on the cam profile to indicate the position at which the clearance is to be taken. The adjustment should be made when the centre of the roller is over the mark. It is necessary that adjustments to valve tappets and their clearances should be carried out periodically, usually when the valves are being changed, but it is strongly recommended that these adjustments should not be made while the engine is hot. This warning refers in particular to the fuel valve adjustments. If adjustments are carried out while the engine is hot, it is possible for the clearances allowed to be reduced to zero after the engine cools down. Under such conditions difficulty will be experienced in starting up and in any case difficulty will be experienced in maintaining the air injection pressure if a start is made.

A case in point occurred where trouble in starting was repeatedly experienced and renewals of certain parts were excessive. On investigating the matter it was found that two out of the four fuel valves (four cylinder engines) were melted away at the ends and the pulveriser nut and fuel casing were badly burnt. The conditions of service were that each engine should run continuously at full load for a week and then be shut down for twenty-four hours. (No water was run through the engine after shutting down.) After stopping the engine and whilst it was hot the engineer immediately proceeded to adjust his valve clearances, change the exhaust valves, etc., At the end of the 24 hours the engine was again run up. Not always, but frequently, starting trouble occurred, but was eliminated when the adjustments were made after the engine had cooled down.

If circumstances require that the engine should be shut down for immediate valve adjustments, then cooling water should be allowed to pass through the engine jackets so as to cool the parts down as much as possible before the adjustments are made.

Exhaust Valve Covers.—Several cases have occurred where the exhaust valve guide and cover which hold this valve seating in place has been broken. Observations have shown that the fracture has invariably been due to unequal tightening down, *i.e.*, one side has been tightened down unduly, causing a very severe bending stress at the root of the flange. This stress, added to those produced by the expansion of the seating and by the load due to the compression pressure, may result in the fracture of the flange. This difficulty is easily overcome by tightening down the nuts evenly on each stud and finally nipping them up *by hand* with a spanner. The joint faces being metal to metal, it is quite impossible to tighten them any more by the use of a hammer. Further, excessive tightening up produces undue stresses on the valve seatings and distorts them.

Exhaust Valves and Casings.—When the exhaust valve casing is removed from its cylinder cover and before the spare is fitted care should be taken to remove the carbon which is deposited on the walls of the valve seating recess in the cover and also to see that the seating in the cover is clean. If the carbon is not removed it is liable to be scraped down on to the seating in the cover when placing the spare valve and casing into position, and some of this carbon may be trapped between the seating in the cover and the valve casing. This would cause loss of compression and in all probability the fuel oil admitted to this cylinder would fail to ignite. Although this appears so obvious, a case was brought to notice recently of an engine which was giving trouble at starting. Examination of the valve casings on this engine showed carbon trapped between the seats and the casings. This was removed and the valve casings and valves replaced; the engine then started up without any difficulty.

At least twice a year it is advisable to grind the valve casings (particularly those of the exhaust) on to their seatings in the cylinder cover. When this is to be carried out, the seating in the cylinder cover should be cleaned and lightly rubbed with rouge or red lead marking. The valve casing should then be rubbed on the seating and the *markings on the seating of the cylinder cover noted.* If not marking equally all the way round, the valve casings, including the working spare, should be ground into the cylinder cover until an equal seating is obtained. If the seating in the cylinder cover is out of round and the valve and casing be fitted to same, the valve casing will assume the same degree of ovality and will in turn distort the seating for the valve, and as the valve itself will remain round there will be a space between it and the casing for part of the way round on the valve facing. This will not only tend to cause faulty starting by loss of compression, but will permit the high temperature gases during the combustion period to escape through the interstice thus formed between the valve and its seat and will burn away the valve facing very quickly. In short, if not detected, it will cause quite a lot of trouble.

The author strongly recommends the more general use of pyrometers or thermometers for the recording of temperatures of the exhaust gases, as this will be found to be a ready and reliable means of detecting such leakages as are described in the foregoing notes on exhaust valves and casings. Further, the importance of using these instruments cannot be too strongly emphasized, as by means of them overloading, due either to excess load on the engine or individual overloading of any one cylinder, can be detected. Also, by this means it can be determined when the exhaust valves of an engine require changing.

Intercooler Coils.—This detail has formed the subject of much discussion. Without doubt the deterioration or wastage of these coils is largely due to acidity produced by the presence of lubricating oil in high pressure air. The author is of the opinion that the great improvement in the lubricating of compressors, the use of carefully selected lubricating oils, and the recommendation to renew the coils when the wastage by weight has reached 25 per cent. of the original weight of the coil, have all helped to prevent a recurrence of accidents due to the failure of this detail. Every coil should be weighed when first fitted and the weight stamped on one of the fittings attached to the coil. The weight should be recorded, and each time the coil is weighed the new amount should be entered in the records in red ink under the original weight, and the date appended.

The domes or casings covering these coils are usually protected by a rubber disc, which is intended to rupture at low pressure. It should be noted that pure rubber only should be used and not rubber fabric, as the latter will not rupture so readily and so completely as the pure material. Only recently, a disc failed to release the excess pressure produced by the failure of the coil and the casing or dome itself was ruptured. On examination, the disc fitted on the casing was found to be made from a thick, tough, rubber insertion which accounted for its failure to release the excess pressure in the casing.

Discussion.—The paper provoked an interesting discussion between prominent users and the author's views as to the importance of preventing deposits and maintaining the efficiency of the fuel valves were generally endorsed. The practice of circulating water through the jackets for a time after stopping was generally commended, although it was represented that it did not altogether prevent scale forming. It transpired that in shore practice it was not an uncommon method to remove scale from the jackets, &c., by the use of dilute hydrochloric acid, although it appeared that the method was only really effective in dealing with deposits consisting chiefly of carbonate of lime and was of little value in dealing with sulphate of lime; also that circulation of the dilute acid was required to produce effective results. This method has been frequently adopted for clearing condenser tubes of scale in shore and marine practice, but it was generally agreed that it was not altogether desirable and open to objection, and should not be necessary if the water is circulated for a time after the engine is shut down. The general concensus of opinion was, moreover, in favour of preventing the deposits occurring, by water softening devices for examples.

One case of marine Diesel practice was referred to in which fresh water was used for jackets and where engine trouble arose as a result of the stored fresh water becoming contaminated by oil leaking from an adjacent compartment.

One speaker referred to the desirability of increasing the pressure in the circulating water system with the object of increasing the velocity of flow in places where the tendency would be for the water to stagnate and for steam pockets to form.

The liner distortion theory advanced was questioned by one speaker who ascribed the decrease of bore in parts of the liner (which feature was agreed to be not uncommon) to "growth" of the cast iron under the influence of repeated heating. In this case it had been generally observed in the way of the belt, which restrained the liner when attempting to grow, and thus led to the diminution of diameter.

In this connection a device was described which served the dual purpose of affording easy ingress of the rings into the liner when entering the piston and assuring that the gap in the rings would be suitable for the smallest diameter of the liner. It consisted of a shallow pilot ring which rested on the top of the cylinder and through which the piston was passed in to the liner. The lower part of the bore of the ring was made equal to the smallest bore of the liner, thus permitting the gap of each ring to be noted as the piston passed down through the ring. The upper part of the ring bore was tapered to permit the ring to enter readily and finally close down to the liner bore diameter.

Mention was made of the necessity of providing sufficient clearance at the butts when the ring is in the smallest part of the liner to provide for the lesser diameter of the ring when in action due to the presence of an oil film and to provide for the differential expansion of the ring and liner due to the higher temperature of the ring.

Several speakers emphasized the desirability of providing two sets of gauges for cam clearances, one set for use when the engine is cold and the other for use when hot; this course has saved much time in making adjustments when the engine could only be stopped for a short time.

Disagreement was expressed in several instances with the author as to the use of a file for touching up the needle valve, and it transpired that many users employ, with success, a speck of the finest carborundum powder for grinding in, finishing off with clean oil. The latter precaution was generally agreed to be essential.

A repair to a crank shaft in which one of the pins cracked is of special interest for the oil engine. A new pin and new webs were made which were shrunk and pinned together and to the shaft in the same manner as is adopted in the merchant service for reciprocating engine crank shafts. This made a sound repair and the engine has run for over 6,000 hours since. The diameter of the pins was 6½ inches.

One user had experienced considerable trouble from crank head bearings which were finally traced to porous bearing shells. These were of cast iron and the presence of the oil had led to only partial adhesion of the white metal, which permitted the oil pressure to get behind the white metal and so to the overheating of the bearing. (An analogous case is mentioned in Papers No. 1, page 37). Such cases emphasize the necessity for adequate tinning of all white metal bearings to ensure efficient adhesion.

Trouble has occurred in certain cases due to the engines working in a dusty atmosphere, *e.g.*, flour mills and cement mills, and it has been necessary in large plants to fit a closed air chamber through which the air to the engine passes viâ baffle plates and fine mesh wire netting over which water was allowed to pass in a fine film. Cases were also mentioned of the stoppage of oil holes by an accumulation of fluff from waste or rags left when wiping the open sight feed oil holes.

The difficulty in getting operators to realise the importance of keeping clean the slits for the air suction pipes was referred to. and many complaints of engines being unable to carry their load have been found to be due to choking of the slots. Sometimes the difficulty has occurred when the engine has been newly painted.

Several speakers, while approving the use of a pyrometer for measuring the exhaust gas temperature, stated that it did not yield the same conclusive results as were afforded by an indicator diagram, and on these grounds urged that it should be regarded as a supplementary to the information given by the diagram rather than that it should replace its use. For example, an engine cannot be said to be running perfectly because the exhaust temperatures do not vary, and it is quite possible for pre-ignition to be taking place with excessive initial pressures, and this condition might, in their opinion, decrease the exhaust temperature rather than increase it. So that if indicator cards are not taken an inexperienced operator might increase the fuel supply on the strength of the pyrometer reading with the result that the engine would be overloaded. Pre-ignition can easily be detected on the examination of an indicator diagram and the height of the diagram will show a considerable increase of pressure when compared with a compression card taken from the same cylinder. The desirability of taking of compression cards was urged.

Enquiry was made as to experience with other materials for exhaust valves. The author replied that stainless steel valves had been tested thoroughly but did not show any advantage over nickel steel valves. The cost of the forgings was very high. Valves and casings had also been treated by the calorizing process, but this process distorted the finished parts so much that they could not be used. The process appeared to produce an exceedingly hard surface.

Concerning renewable cast iron valve faces, these details have a fair area of contact surface with the valve head to which they are attached, the parts become distorted, and it is difficult to refit a new part. This type of loose face now fitted seems to be quite good, and no complaints have been received. It is now possible to renovate a valve face by welding cast iron on it.