DIESEL ENGINE OPERATION

INTENDED FOR ERECTORS, INSTALLATION AND PLANT ENGINEERS, AND ALL INTERESTED IN THE PRACTICAL ASPECT OF DIESEL ENGINE OPERATION

Prepared by a Staff of Technical Experts under the direction of

E. MOLLOY

SECOND EDITION
(*Revised*)

WITH ONE HUNDRED AND TWENTY-FOUR ILLUSTRATIONS

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PREFACE

THIS book is intended for erectors, installation and plant engineers, and in fact for all who are concerned with the practical side of diesel engine operation.

After the two-stroke and the four-stroke cycles have been described briefly in the first chapter, practical considerations involved in the installation and maintenance of cold-start oil engines are fully dealt with. The fuel pump is a vital part of engines of this type. Particular attention has therefore been devoted to a description of the operation and adjustment of the principal types of pumps, with notes on the tracing and remedying of faults.

The chapter dealing with oil-engine installation includes reference to both diesel and semi-diesel types, the subject being dealt with from the preparation of the engine-room and site, and the laying of foundations, to the final starting-up. Much useful information is included on the layout and construction of exhaust systems, as this has an important bearing upon the efficient and quiet running of engines of this kind.

Not every plant engineer is entirely familiar with the use of engine indicators and the interpretation of indicator diagrams produced from these ingenious instruments. A separate chapter has been devoted to describing the use of these instruments, with and without a planimeter, or the measurement of horse-power.

In addition to installation and plant engineers, the book will be of interest to marine engineers, as it also covers the erection, operation, and maintenance of oil engines used on board ship. The illustrations have all been carefully chosen to show clearly how the various operations referred to are performed in actual practice.

E. M.

PREFACE TO SECOND EDITION

In this edition the opportunity has been taken to amplify considerably the original text, by including details of several specialised types of engines, such as the Fullagar and the Superscavenge.

The section on Fuel-injection Equipment has been improved by the addition of information relating to the Simms, Belliss and Morcom, Ruston, and Robey fuel pumps and atomisers. The original information relating to C.A.V. fuel-injection equipment has also been amplified and brought up to date.

E. M.

CONTENTS

DIESEL ENGINE OPERATION

Chapter I

BASIC PRINCIPLES OF THE COMPRESSION-IGNITION ENGINE

THE compression-ignition engine may be regarded as a development of the petrol engine. As most readers will be aware, the petrol engine depends for its operation upon the following sequence :—

Induction Stroke.—A mixture of air and petrol vapour is drawn into the cylinder.

Compression Stroke.—The charge is compressed as the piston moves back towards the cylinder head.

Firing Stroke.—The compressed charge is now ignited by a spark and the expanding gas forces the piston outwards again, doing external work.

Exhaust Stroke.—Near the end of the firing stroke, the exhaust valve opens and the inertia of the moving parts carries the piston back towards the cylinder head, expelling the burnt gases.

The above is known as the four-stroke cycle because four strokes of the piston are necessary for each firing stroke.

By a special arrangement of valve ports and deflectors and by using the crankcase as a compression chamber, the above sequence can be modified to give the two-stroke petrol engine, which has one useful stroke for every two strokes of the piston.

In the compression-ignition or diesel engine no sparking plug is used; the ignition being obtained by the heat of compression. A second point of difference is that the fuel is not vaporised by being injected at the top of the compression stroke. It is injected through an atomiser spray or nozzle.

The full sequence of the four-stroke compression-ignition is as follows :—

Suction Stroke.—As the piston moves outwards, air is drawn into the cylinder. Air-inlet valve then closes.

Compression and Injection Stroke.—The piston now moves inwards, compressing the enclosed air to about 33 atmospheres and raising the temperature above the flash point of the fuel. Near the top of the compression stroke the fuel injection valve opens and a fine spray of fuel oil is injected into the heated air.

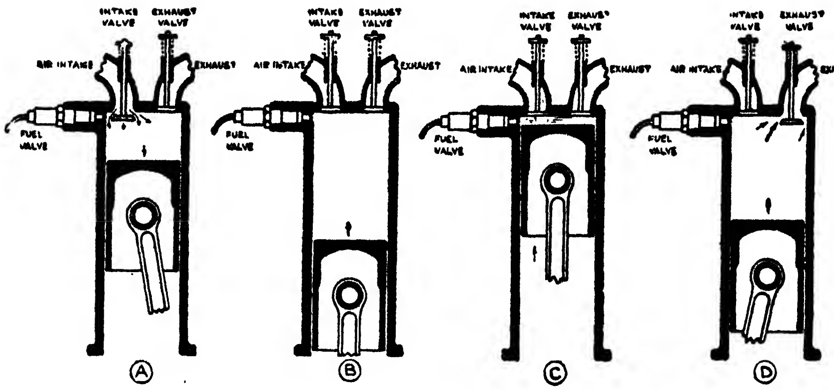


Fig. 1.—Showing principle of four-cycle Diesel engine

The four diagrams show the induction, compression, combustion and expansion, and exhaust strokes, respectively.

Firing Stroke.—The high temperature due to the rapid compression of the air in the cylinder ignites the fuel. This causes a sudden rise of pressure and the piston is driven outwards whilst the combustion of the fuel continues. Near the end of the stroke the exhaust valve opens.

Exhaust Stroke.—The momentum which the moving parts have acquired during the firing stroke causes the piston to travel back towards the cylinder head, expelling the products of combustion. Near the top of this stroke the exhaust valve closes and the inlet valve opens ready for the recommencement of the cycle.

Before passing on to describe the corresponding sequence which occurs in the two-stroke compression-ignition engines, we would draw attention to one or two points of special interest which apply equally to four-stroke and two-stroke types.

The first point to note is that much higher compression ratios are used in compression-ignition engines then in petrol engines. Whereas the latter may have compression ratios of about 5 : 1, the compression-ignition engine is designed for compression ratios of from 13 : 1 to 15 : 1.

Anyone who has used a bicycle pump is aware that a sudden compression of air causes its temperature to rise. It is this simple fact which forms the basis of the compression-ignition engine.

The second point to note is that as a high compression ratio enables high internal cylinder temperatures to be attained, fuels having a high flash point can be used. Such fuels, i.e., heavy oils, are considerably cheaper than the highly refined petrol or aviation fuel. Also, these oils have a high calorific value and can be stored with greater safety.

A third point which in many cases is the most important factor, is that the high compression ratio conduces to greater thermal efficiency than can be attained with the lower compressions which are used in petrol engines. In this connection it may be remarked that if the compression ratio of a petrol engine is increased beyond a certain limit, pinking or pre-ignition of the charge occurs, due to the high temperature engendered.

The final point to be borne in mind with regard to the compression-ignition engine is that the high compression ratios involve very high internal cylinder pressures, both immediately preceding and after ignition. This, in turn, calls for a much sturdier construction than was necessary with the earlier type of internal-combustion engine.

Having described the basic principles upon which all compression-ignition engines depend, we now give below some particulars regarding two-stroke and other modifications of the basic systems.

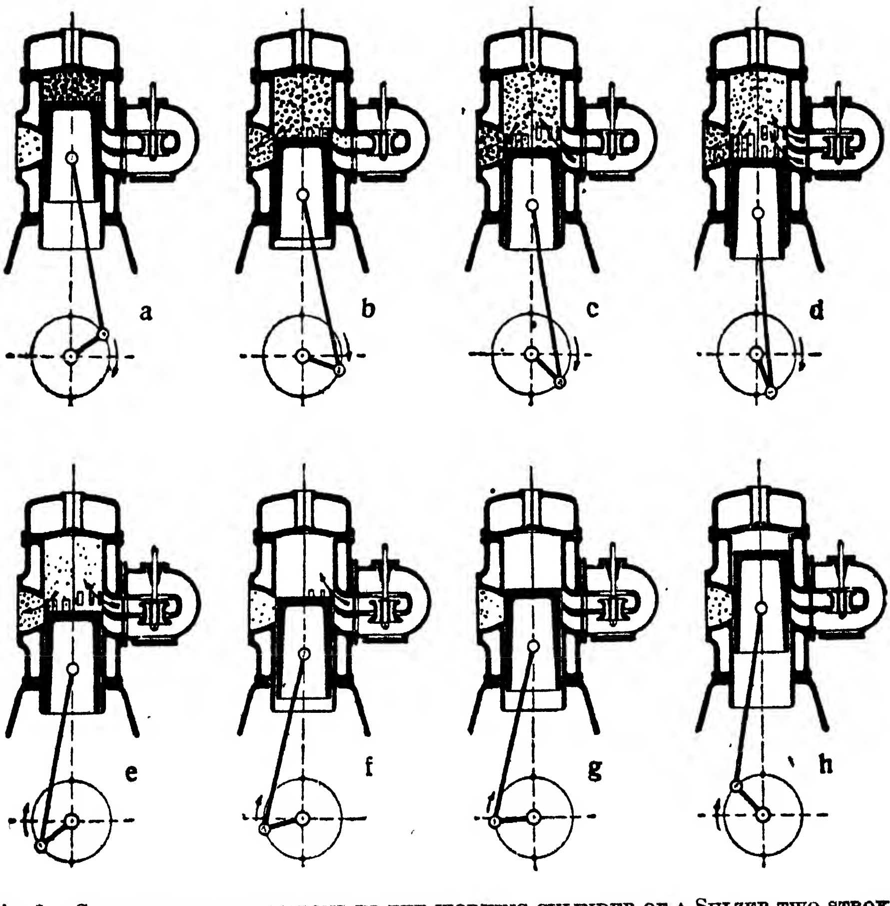


Fig. 2.—SEQUENCE OF OPERATIONS IN THE WORKING CYLINDER OF A SULZER TWO-STROKE DIESEL ENGINE

[*Sulzer Bros.* (*London*) *Ltd.*

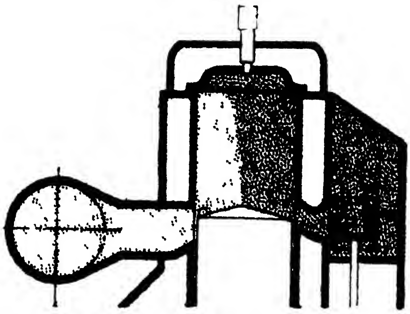


Fig 3A —THE EVACUATING AND RECHARGING SYSTEM OF AN ORDINARY TWO-STROKE CYCLE ENGINE

Left-hand dots represent outgoing exhaust gas and right hand incoming fresh air. Showing cylinder at a moment when exhaust and inlet are opening

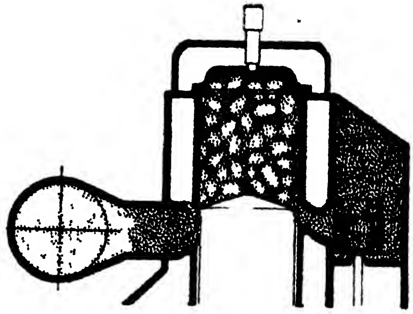


Fig 3B —THE EVACUATING AND RECHARGING SYSTEM OF AN ORDINARY TWO STROKE CYCLE ENGINE

Left hand dots represent outgoing exhaust gas and right-hand incoming fresh air. The same cylinder at moment when exhaust and air ports are closed

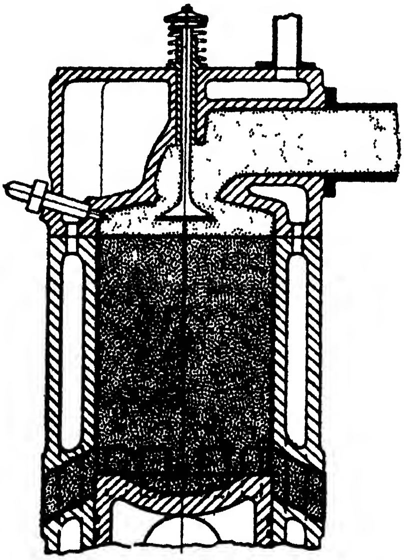


Fig 3C —THE "SUPERSCAVENGE" SYSTEM OF EVACUATING AND RECHARGING AN ORDINARY TWO-STROKE CYCLE ENGINE

Top dots represent outgoing exhaust gas and bottom incoming fresh air. At same instant as depicted in Fig. 3a, i.e., when exhaust and inlet are opening.

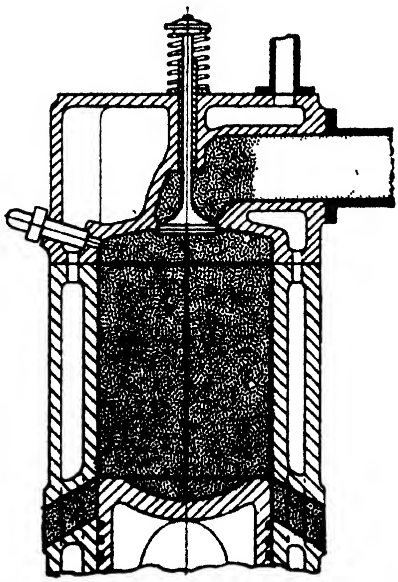


Fig. 3D —THE "SUPERSCAVENGE" SYSTEM OF EVACUATING AND RECHARGING AN ORDINARY TWO-STROKE CYCLE ENGINE

Top right-hand dots represent outgoing exhaust gas and bottom incoming fresh air. At same instant as depicted in Fig. 3b, i.e., at moment when exhaust valve and air port are closed.

THE TWO-STROKE SYSTEM

It will be remembered that in the two-stroke petrol engine, the crank-case is used as a reservoir from which air is forced through the inlet ports in the cylinder walls, when the piston is near the end of the firing stroke. This air also serving the purpose of expelling the residue of burnt gases through the exhaust ports.

In the case of a two-stroke diesel engine, a separate air reservoir is used, the necessary air pressure being maintained in the reservoir by means of a scavenge pump. The sequence of operations is illustrated in detail in Fig. 2A–H.

It will be seen from Fig. 2B that the exhaust port opens an appreciable time before the piston reaches the bottom of its stroke. The main scavenging ports do not open until most of the exhaust gases have been expelled (see Fig. 2C). At a later stage (Fig. 2D) a valve in the scavenge system admitting scavenging air also through the auxiliary or upper scavenging ports is again closed by the returning piston (see Fig. 2F–H). The compression stroke is now completed and the operation recommences.

The particular system just described is that used in the well-known Sulzer two-stroke engine. Other typical arrangements are shown in Figs. 3 and 4.

Fig. 3A–D shows the Petter Superscavenge system as compared with ordinary two-stroke, and Fig. 4 shows the arrangement of exhaust and scavenging ports as used on the Atlas Polar two-stroke engines. It will be appreciated that there are many possible alternative methods, all of which enable the cycle of operations to be completed in two strokes.

Another interesting variation is the Fullagar type, which is a double-acting two-stroke engine with vertically opposed pistons and a special arrangement of cross heads and tie rods designed to enable four pistons to operate on a two-throw crankshaft, or eight pistons on a four-throw crankshaft

It is of the vertical, totally enclosed, opposed-piston type, operating on the two-stroke cycle and employing mechanical injection of fuel. The special feature of the Fullagar engine consists in its having only one crank and connecting rod per cylinder, so that it is, in effect, a double-acting, two-stroke-cycle engine without cylinder covers.

The construction is shown in Figs. 5 and 6. Fig. 5 shows a pair of cylinders, each having two pistons working in it ; Fig. 6 shows a pair of connected pistons with the forces as actually applying.

Operation of the Fullagar Engine

Referring to Fig. 5, combustion takes place between the opposed pistons *A* and *B* and causes *B* to move downwards and *A* upwards. Piston *A* acts on the right-hand crank through the tie-rods and also draws up piston *D* in the adjacent cylinder. Piston *B* acts directly on

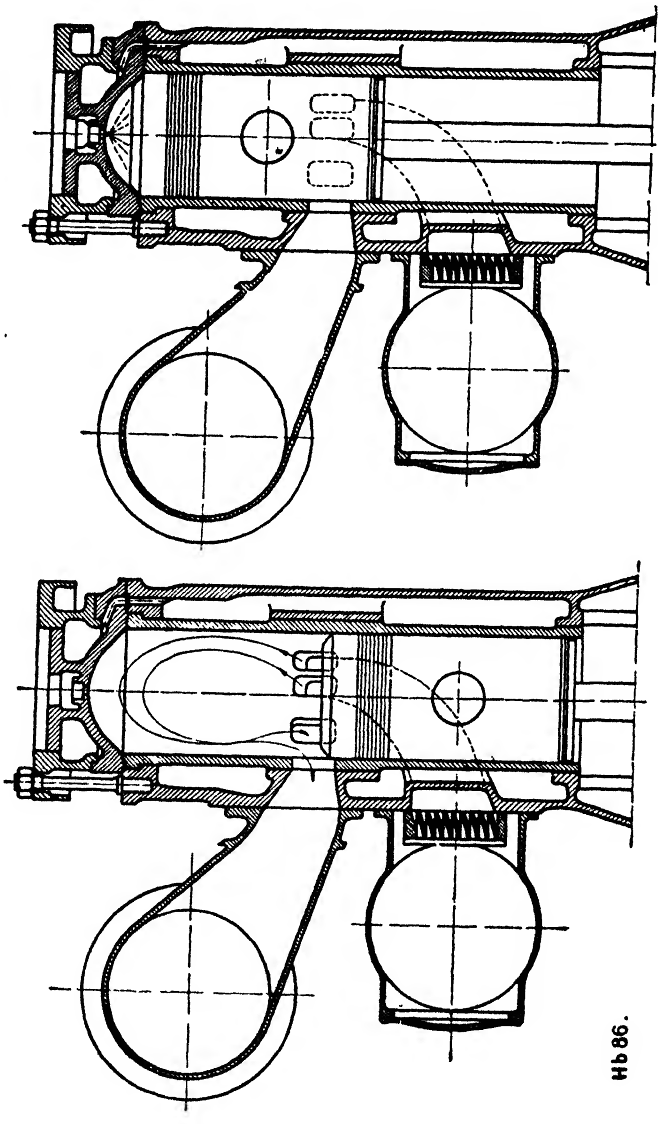


Fig. 4.—THE WORKING CYCLE OF A TWO-STROKE ENGINE

[*Atlas Diesel Co. Ltd.*

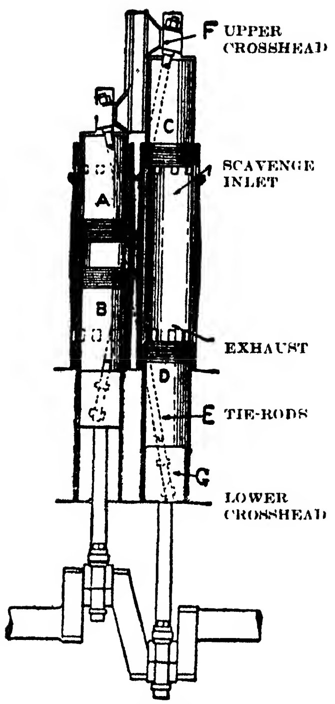


Fig. 5.—DIAGRAMMATIC SECTION OF A PAIR OF CYLINDERS

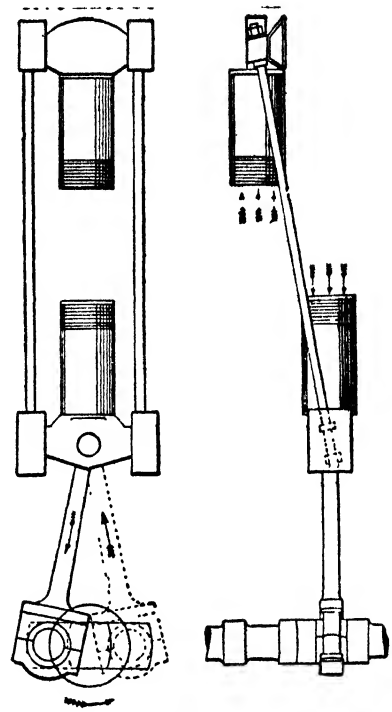


Fig. 6.—ARRANGEMENT OF PAIR OF PISTONS AND CROSS-HEAD TIE-RODS

the left-hand crank, and draws downwards the piston *C* in the adjacent cylinder. The power required for compressing the air in the combustion chamber is thus obtained directly from the pistons in the adjoining cylinder, instead of having to be transmitted through the crankshaft, as in all other types of engines. The crankshaft receives two equal and opposite impulses and the side-thrust produced by the tie-rods is taken by the cross-heads *F* and *G*.

Since the pressure in the cylinders acts equally on the upper and lower pistons, the forces upon a pair of cranks are equal and opposite at all times, and the main bearings are, in consequence, relieved of load.

The reciprocating parts are cushioned at each end of the stroke; for example, in Fig. 5 the pair of connected pistons, *A* and *D*, are cushioned upon the down stroke by the pressure under piston *A* and on the up stroke by the pressure above piston *D*. Thus, exceedingly smooth running is obtained.

With the construction described, each connecting rod is double-acting and the effort of each crank is uniformly in one direction. A four-crank engine therefore receives four pairs of balanced impulses during each revolution of the crankshaft.

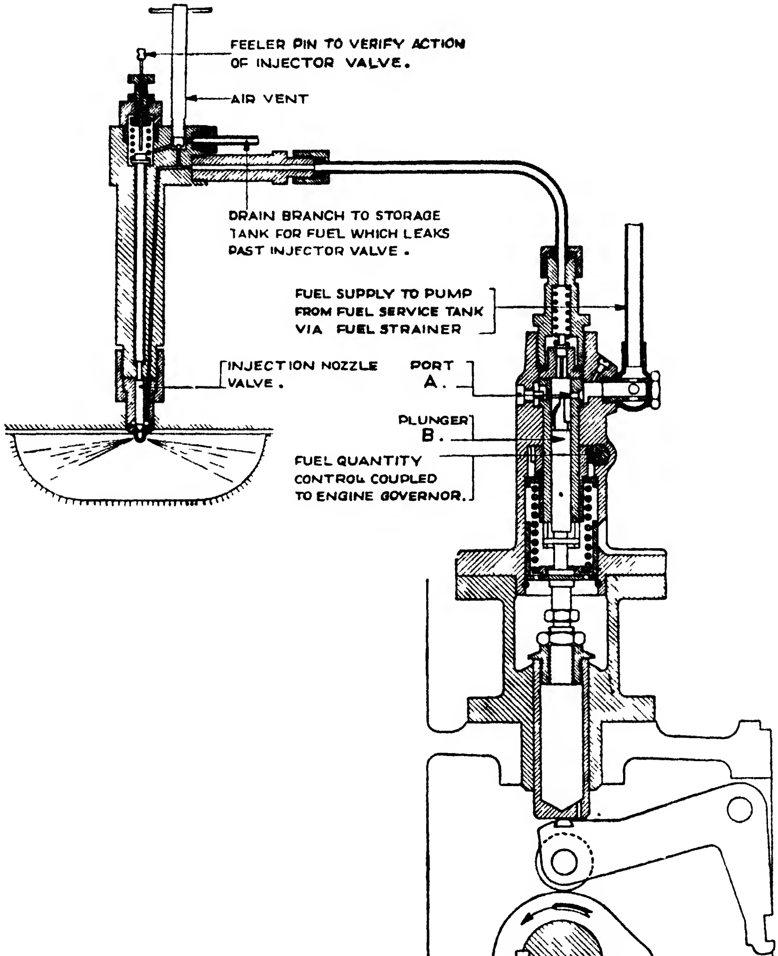


Fig. 7.—Typical arrangement of fuel pump and injection valve

FUEL INJECTION

It has already been pointed out that the modern compression-ignition engine depends for its effective operation upon a spray, or jet, of atomised fuel being injected into the cylinder when the piston is near the top of the compression stroke.

A little thought will show that many factors are involved in ascertaining the optimum conditions under which fuel should be injected. For example, the compression ratio of the engine, the design of the cylinder head and the engine speed are three important factors which will obviously have their influence upon the amount and timing of the injection. These, however, are matters which are of more direct interest to the designer, and it may be reasonably assumed that, when an engine has passed its type tests and efficiency tests, the injection system finally adopted is that likely to give the most satisfactory performance under actual working conditions.

Fig. 7 illustrates the essential features of a typical injection system for one cylinder of a multi-cylinder engine.

The sequence of events in the actual injection of the fuel is, briefly :—

With closure of the port *A* by the upward moving plunger *B*, the fuel in the system up to the nozzle valve is under compression. Further movement of the plunger increases the pressure in the system to the point where the nozzle valve lifts. Injection now begins and the pressure in the system is controlled from this point until the end of the injection period, by the cross-sectional area of the holes in the nozzle tip and the velocity of the moving pump plunger.

It is necessary, in order to regulate the amount of fuel delivered to the cylinder, to have some means of varying the effective stroke of the pump plunger. Various courses have been followed to achieve the same object, but the best known and simplest is the system whereby a constant plunger stroke is used, with by-pass or " spill " controlled by the engine governor.

One of the most widely used types of fuel pumps is the C.A.V. (see Fig. 2, page 68). This has been adopted as standard by many makers of compression-ignition engines. Another type of proprietary fuel pump, which is coming into extended use, is the Simms (see Fig. 10, page 77).

Certain engine builders, notably Messrs. Ruston & Hornsby, and Robey of Lincoln, have also developed fuel pumps of their own design. The internal construction of the Ruston fuel pump is shown in Fig. 18, page 84.

Associated with the fuel injection pump is :—

(*a*) The injection nozzle which delivers the atomised oil into the combustion chamber, or cylinder head ; and

(*b*) The governor mechanism which controls the oil delivery in accordance with the requirements of the engine.

Typical injection nozzles, namely, C.A.V., Simms, Ruston & Hornsby, and Robey, are shown in Figs. 8, 14, 19, 20 and 22 in Chapter III. It may be mentioned that there are no fewer than six different types of C.A.V. nozzles. Thus an engine builder is enabled to select the type of nozzle which is found by experience to give the best results with his particular design of engine.

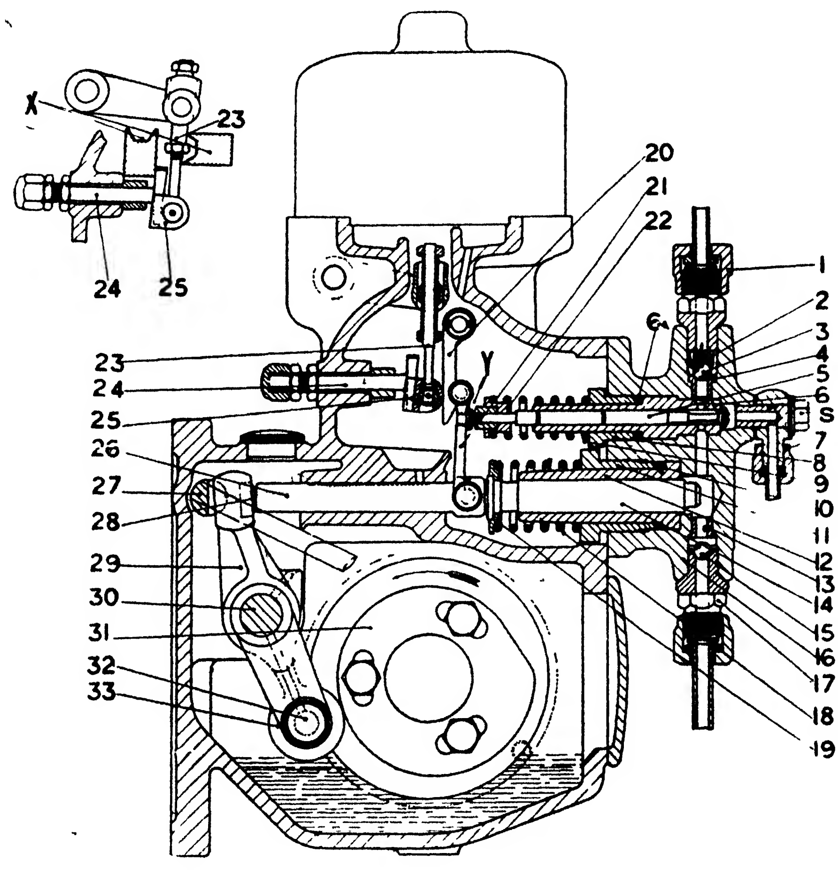


Fig. 8.—ARRANGEMENT OF RUSTON FUEL PUMP AND GOVERNOR

1. Fuel pump delivery connection and valve stop.
2. Fuel pump delivery valve spring.
3. Fuel pump delivery valve.
4. Fuel pump delivery valve seating.
5. Fuel pump spill valve.
6. Fuel pump spill valve bush.
6A. Fuel pump spill valve bush joint ring.
7. Fuel pump spill valve overflow connection.
8. Fuel pump spill valve bush gland nut.
9. Fuel pump spill valve spring.
10. Fuel pump plunger bush joint ring.
11. Fuel pump plunger bush gland nut.
12. Fuel pump plunger bush.
13. Fuel pump suction valve stop.
14. Fuel pump plunger.
15. Fuel pump suction valve.
16. Fuel pump body.
17. Fuel pump suction valve seating.
18. Fuel pump plunger spring.
19. Fuel pump plunger spring cap.
20. Governor swing lever.
21. Fuel pump swing lever.
22. Fuel pump spill valve spring cap.
23. Governor vertical rod.
24. Governor incline support.
25. Governor incline shoe.
26. Fuel pump plunger tappet.
27. Fuel pump stopping and starting lever.
28. Fuel pump lever pad.
29. Fuel pump operating lever.
30. Fuel pump operating lever fulcrum pin.
31. Fuel pump cam.
32. Fuel pump operating lever roller fulcrum.
33. Fuel pump operating lever roller.

GOVERNORS

Compression-ignition engine governors are of two main types, namely, the centrifugally controlled type and the vacuum, or pneumatically operated, type.

The Ruston & Hornsby Governor

Fig. 8 shows the governor used on Ruston & Hornsby engines. This is of the centrifugal type, in which the movement of the governor elements controls the opening of the fuel pump spill valve, thus by-passing more or less of the fuel oil according to the power requirements of the engine.

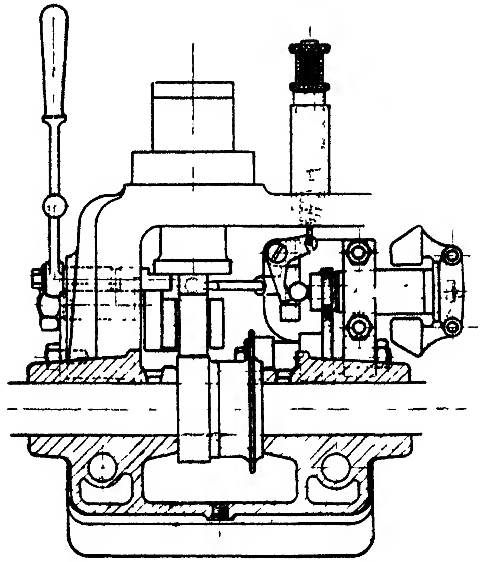


Fig 9.—The Robey governor

The Robey Governor

Another good modern example of a diesel engine governing system is the Robey. The essentials of the Robey governor are as follows :—

Figs. 9 and 10 show side and end elevations of the governor. This is positively driven through a spring (or, in other words, an elastic) coupling. This protects it from the torsional spring of the layshaft at the moment of operating of the fuel pump and valve gear.

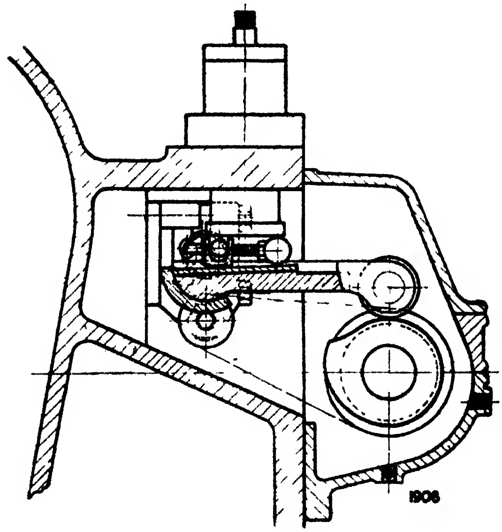


Fig. 10. The Robey governor

Governing is achieved by means of a lever having a pivot at one end and a roller fixed at the other, which runs on a cam that always gives the same movement to the lever. Between this lever and the fuel-pump plunger guide is a roller which is moved towards or away from the point of pivot of the lever.

The roller is controlled by the governor and gives a varying lift to the pump plunger according to the load on the engine. This variable lift pump, operated in such a manner, ensures that the period of opening

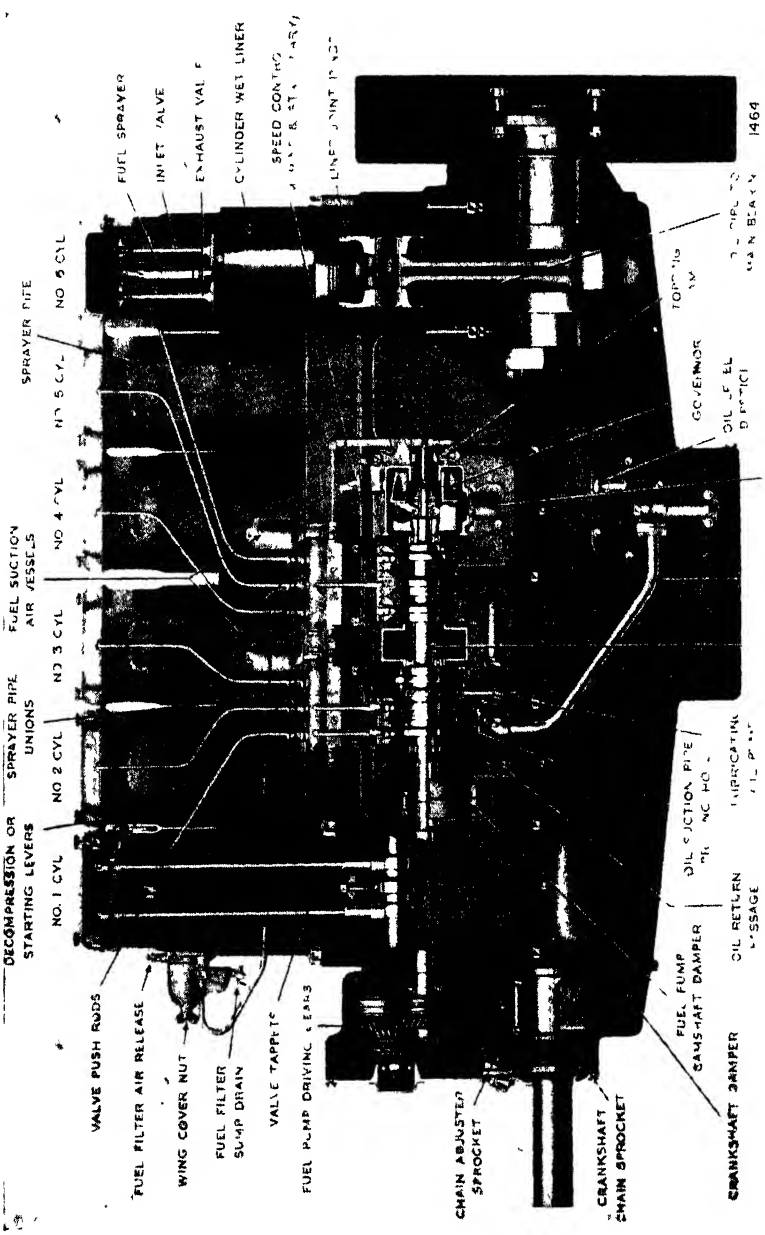


Fig. 11.—Part Section of Gardner 6L3 Oil Engine and closing, and also the time of opening and closing are the same at all loads. Complete combustion is thus maintained, even on the lightest load. Owing to the length of the lever, the work on the fuel lever roller is considerably reduced, thus ensuring long life to the cam toe piece.

The cam-operated lever has an adjustable pivot which allows the roller to be moved backwards and forwards over the cam face, allowing for the advancing or retarding of the fuel injection, an adjustment which can be made while the engine is running.

The engine can thus easily be regulated to use any grade of fuel oil.

Speed Variation

The governor is designed so as to give a momentary speed variation from full to no load of less than 7 per cent. and a permanent variation of less than 3 per cent. By means of a special speeder gear, which is situated in a convenient position on the top of the bedplate, a considerable change of speed can be made while the engine is running.

The vacuum-operated governor is used chiefly on vehicle engines.

A MODERN EXAMPLE

In the foregoing pages we have outlined the main principles upon which modern compression-ignition engines operate, and the reader should now have a clear idea as to the functions and relative importance of various components.

Before proceeding to study detailed notes relating to installation, operation and maintenance, the reader may be interested to examine the typical example of a modern 6-cylinder compression-ignition engine as illustrated in Fig. 11. All the essential portions of the engine have been shown in sectional view and the drawing is very fully annotated, so that little further description is necessary.

The six oil-sprayer pipes can be clearly seen leading from the fuel pumps to the respective cylinders. The drive for the camshaft, fuel pumps and governor will be observed above the left-hand end of the crankshaft. It will be seen that the governor is of the centrifugal type, being fitted with a speed-control lever for marine or stationary engines.

Chapter II

INSTALLATION OF OIL ENGINES

With Operation and Maintenance Notes

BOTH the four-stroke and the two-stroke engines are made horizontal or vertical. In comparing the vertical and horizontal engines the detail most discussed is the piston. Vertical-engine builders call attention to the disadvantage of the weight of the piston, and the side pressure thereby produced on the cylinder bore in the case of the horizontal engine, and claim floor space saved by the vertical engine ; while the horizontal-engine builders claim easy overhaul, more convenience for attention, better lubrication of bearings and pistons, and especially the renewal of pistons without disturbing the cylinder head and valve gear, reduced height of engine-room, as all pipes can be under the floor in trenches, and do not obstruct the room.

Vertical or Horizontal Engines ?

The horizontal class of engine is still very popular and generally employs the mechanical system of fuel injection. For layouts embodying a drive from engine to mill shaft, either direct or indirect, this class of engine is favoured, owing to the lower head room required and the slower engine speed which generally enables a satisfactory drive to be obtained.

The vertical engine is eminently suitable for coupling direct on to electric generators, compressors, pumps, etc., for which it has many special advantages.

THE ENGINE-ROOM

The buildings or engine-rooms for oil-engine installations will depend naturally on the size of plant being installed and the amount of capital available for this item. Generally speaking, money spent on a substantial, dry, and clean engine-house will not be wasted and will result in more efficient and economical running, and longer life from the engine. No hard-and-fast rule can be laid down on the matter of buildings, for all considerations will obviously be governed by the degree of permanency required and the factors mentioned previously.

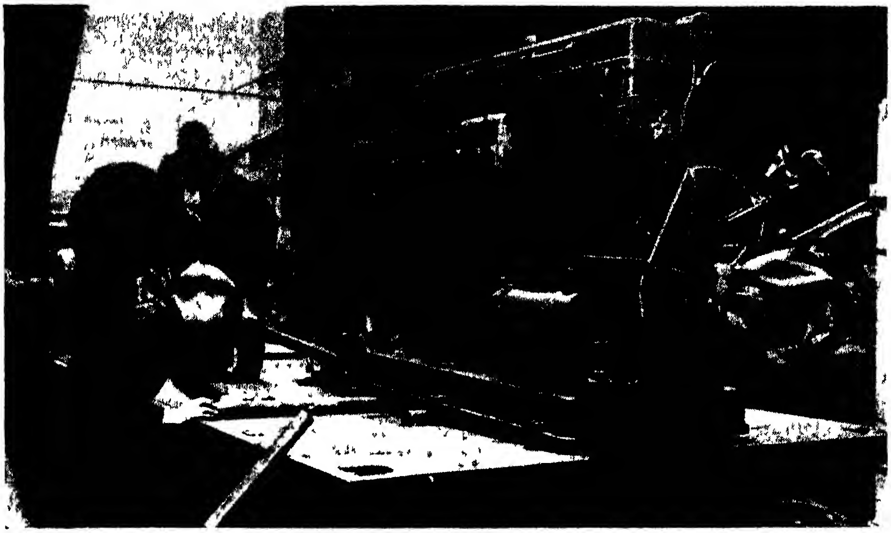


Fig. 1A.—UNLOADING COMPRESSION-IGNITION ENGINE FROM LORRY ON TO SITE

Here we see an engine being lifted by crowbar from the lorry platform where rollers are slid into position underneath. The engine is thus raised sufficiently to allow room for placing the tackle in position.

Fig. 1B.—UNLOADING ENGINE FROM LORRY ON TO SITE

This shows the tackle in position. Note the necessary wood packing between the ropes and the engine to prevent damage to pipes, etc.

Fig. 1C.—UNLOADING ENGINE FROM LORRY ON TO SITE

The lorry has now been driven clear, leaving the engine suspended and enabling it to be lowered to the ground and moved into position.

(*By courtesy of Messrs. Kessel Power Plant*)

Fig 1D.—Moving Engine to Site
Note method of sliding and tackle as aid

Fig 1F.—Moving Engine to Site
Tackle used horizontally for sliding engine

Fig. 1F.—Moving Engine to Site
The site, with generator in temporary position. Note the shifting tackle hitched up to stake in bolt hole

(*By courtesy of Messrs Kessel Power Plant*)

Modifying an Existing Structure

For waterworks and similar installations, stone and brick-built structures are usual, whereas in some cases it might be found desirable to use an existing building to house the plant.

In this case it may be necessary to modify or improve the old structure to suit its new purpose. For instance, buttresses may have to be added to carry crane supports, windows may have to be increased or enlarged if the house is poorly ventilated or lighted, and doors and roof may have to be improved to exclude dust and damp. A good floor may also have to be laid which should be free from anything that is likely to make dust or grit in the course of time.

Heating the Building

Large plants, those which include electrical gear, which are in particularly cold or damp situations, or which are likely to be shut down for any length of time, may require heating arrangements to maintain a reasonable temperature and to keep the place dry. These usually take the form of a hot-water boiler and circulating pipes or radiators, and the boiler is, as a rule, either coal, coke, or oil fired. If the latter, it may, if necessary, be placed in the engine-room, but if coal or coke fired, it is almost imperative that the boiler shall be in a separate compartment on account of the dust and dirt entailed.

A Cheap and Satisfactory Building

From the foregoing it might seem that elaborate engine-houses are essential for oil-engine plant, and although a good building is desirable and should be provided where possible, it must be mentioned that extremely good results have been and are being obtained from engines with a very meagre covering. A cheap and quite satisfactory building for average use consists of a steel-frame skeleton with galvanised corrugated-iron covering.

If financial considerations will allow, it is an advantage to line the inside with asbestos sheeting or with suitable light boarding, as this will assist in preventing extreme cold and the ingress of damp and moisture during bad weather.

Arranging for Lifting Tackle

The four main stanchions of the building can be arranged to carry the crane rails. If there is only one engine, however, and parts to be lifted do not exceed, say, 15 cwt., it is often a simple matter to support a girder along the centre of the room and arrange lifting tackle from this. Overhauling is sometimes provided for in this way when the plant comprises more than one engine, but in these cases it is not much more expensive to fit a crane of the hand travelling type, which will be generally more

Fig 1G.—MOVING ENGINE TO SITE
Swinging plant into temporary position over bed Note temporary supports

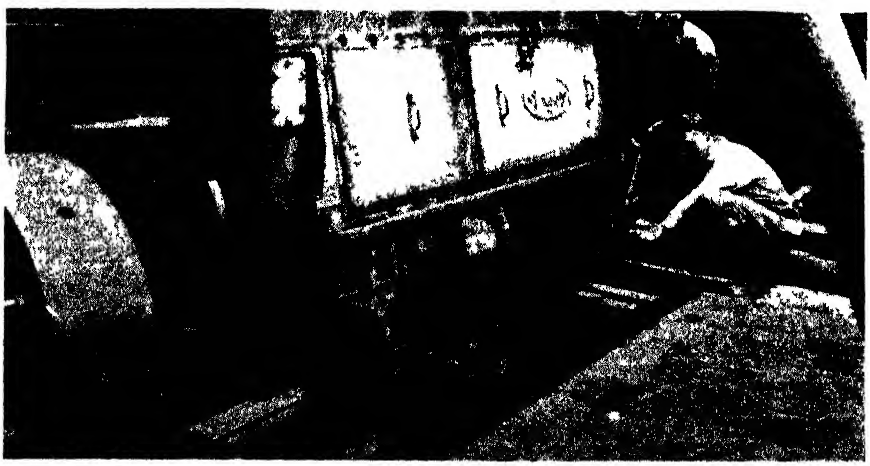


Fig 1H.—PLANT IN ALIGNMENT WITH BED
Note method of rolling into position until lugs overhang base holes.

Fig. 1J.—CHECKING DISTANCE BETWEEN PLANT AND GENERATOR

Fig. 1K.—PREPARATION FOR FINAL BOLTING DOWN

Note attachment of depth irons.

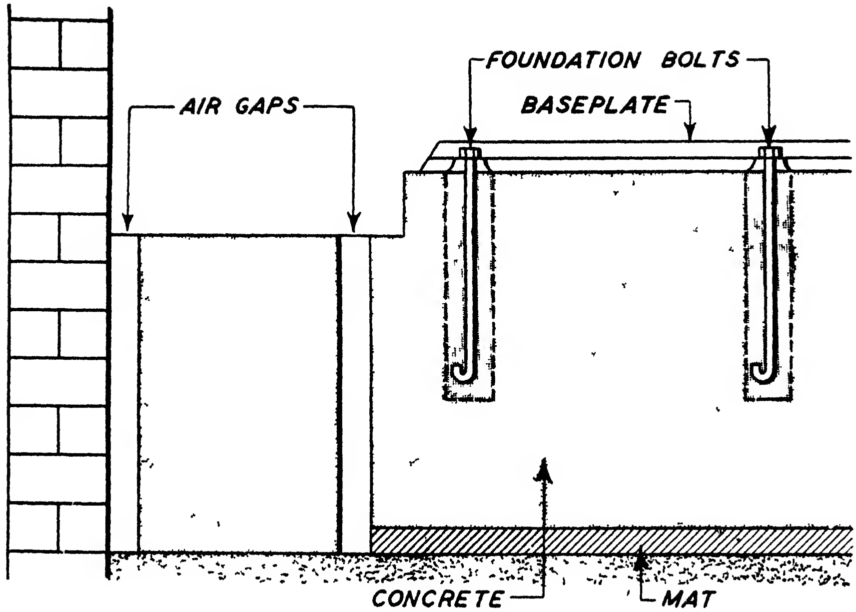


Fig. 2.—Special anti-vibration engine bed

satisfactory in use. If tackle is rigged from a single girder, two men are usually required for the removal of pistons, etc., whereas a crane can be operated with ease by one mechanic. This point is worthy of consideration when deciding on the initial outlay of such an accessory.

LAYING THE FOUNDATIONS

The foundations for the plant should be put in carefully to the maker's special foundation drawing.

The Foundation Block

Assuming that the position in which to place the engine has been decided upon, the makers' foundation drawing should be carefully studied. The engine centre lines should then be marked out, and the necessary excavation made in the engine-room floor to receive the foundation block.

In the case of most makes of vertical engines, the concrete foundation finishes at, or a few inches above, ground level. In larger types of horizontal engines, the foundation is carried up to bring the centre line of the crankshaft to a suitable height. Boarding or shuttering is then built round the pit to bring the foundation up to the sizes given on the

Fig 3.—ENGINE ROOM WITH LISTER $2\frac{1}{2}$ KW DIESEL GENERATOR SET

Cooling water tank and fuel storage tanks shown on right. Fuel tanks hold oil supply for approximately one year's average running. Switchboard on left. The photographs on the following pages showing this set being installed are by courtesy of R. A. Lister & Co., Ltd.

drawing to keep the concrete in position until it has set. Deep pockets are usually left in this block to receive the engine foundation bolts, the former being made by pieces of square timber, tapering towards one end, and well greased, so that they can be withdrawn when the concrete has set. It is most important that these bolt holes match those on the engine bed, so that when the concrete has set, and the engine bed is lifted on, there is no doubt that the foundation bolts will drop into their respective pockets.

Another point is to leave the top of the foundation rough and about 1 in. lower than the drawing dimension ; this enables the engine to be correctly levelled and lined up by means of steel wedges.

If the engine is of a type having an outer crankshaft bearing, the plinth for this outer bearing should be left about 1 in. low, as it is far easier to raise it by means of packings than to chip off a layer of concrete.

Local Conditions Affecting Foundations

If the person installing the engine has not previous knowledge of local conditions affecting foundations, it is as well either to get advice on this point, or else to make the engine-builders fully responsible for the adequacy of the foundations shown on their drawings.

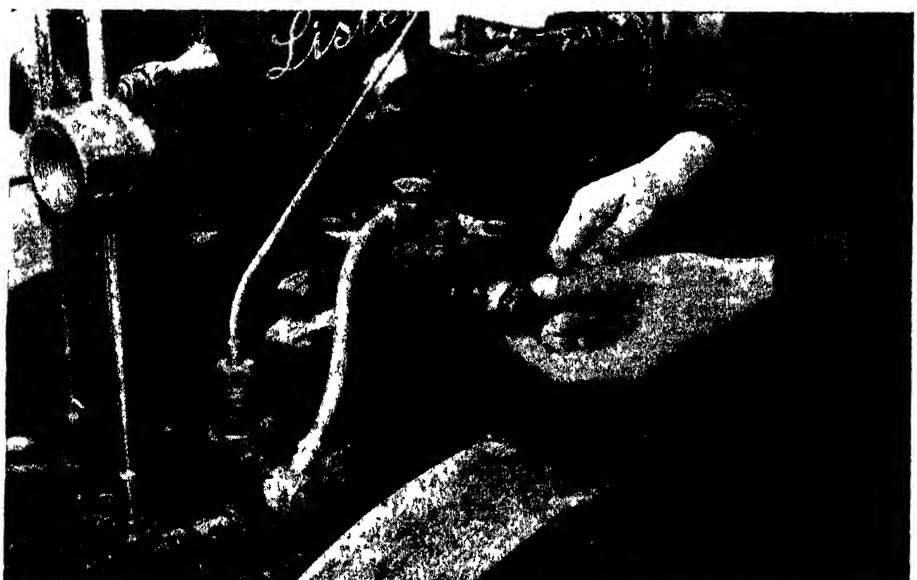


Fig. 4.—Coupling fuel pipe to filter on engine

The work of laying the foundations is usually easier if the building is first completed.

A Note on Installing Overhead Tanks

Before the builder removes his scaffolding, his services should be enlisted to place in position any overhead water or fuel tanks, etc. It may be found an advantage to have these fixed before the roof is finished, and this work should then form part of the builder's contract, and delivery of the tanks, etc., arranged accordingly.

Fig. 5.—Testing level of engine with spirit level

Any necessary adjustments for level are made by placing steel packing strips under engine.

Concrete Work to do at the Same Time

In proceeding with the work of excavating the foundations, it should be remembered that concrete supports for fuel and water tanks, exhaust pits, and pipe trenches should be made at the same time. It may be that the men doing this part of the work have had previous experience of such work, but in any case the makers' notes and instructions, contained either in book form or on the drawings, should be followed carefully. These notes contain the knowledge of long experience, and if ignored an unnecessary waste of time and expense may easily result.

Excavating the Ground

The ground should be taken out as indicated in the drawings, and the sides of the excavation timbered if necessary in soft ground. If the subsoil is not solid at the depth indicated on the drawing for the foundation

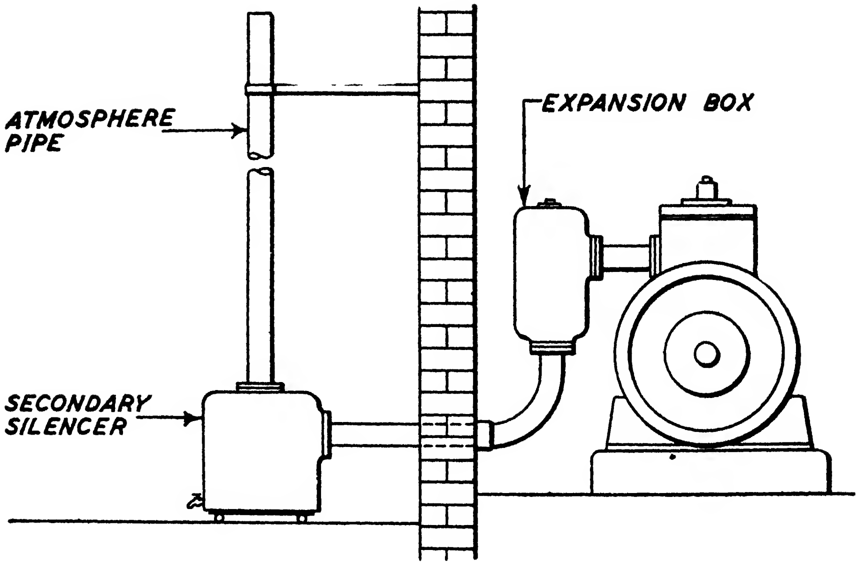


Fig. 6.—Exhaust system with secondary silencer

in question, the depth must be increased until a good firm bottom is obtained. In the case of water being encountered, pumping and close boarding may have to be resorted to.

Making and Placing Wood Boxes for Concrete

Make an open box representing the engine bed or pedestal. Check the centre lines to the drawing. Now fix the box or template in the correct position relative to the building or other machinery. This can be done by nailing it to two long planks resting on pegs or on the ground. The underneath side of these pieces of wood should represent the top of the foundation proper.

If the engine is to be direct-coupled to a pump or electric generator the foundations for the complete set should be cast in one piece. In any case, the outer bearing pedestal and such projections as the air-compressor or water-pump blocks must be cast at the same time as the rest. The boxes for these pedestals are also supported at floor-level in the same way as the engine bed.

Providing for Bolt Holes in Concrete

Holes in the concrete for foundation bolts should extend below the bottom of the bolts. The boxes for these holes should be made of about $\frac{1}{2}$-in. wood lightly nailed together, so as to be easily collapsible after the concrete has set. Wooden blocks must on no account be used. It is

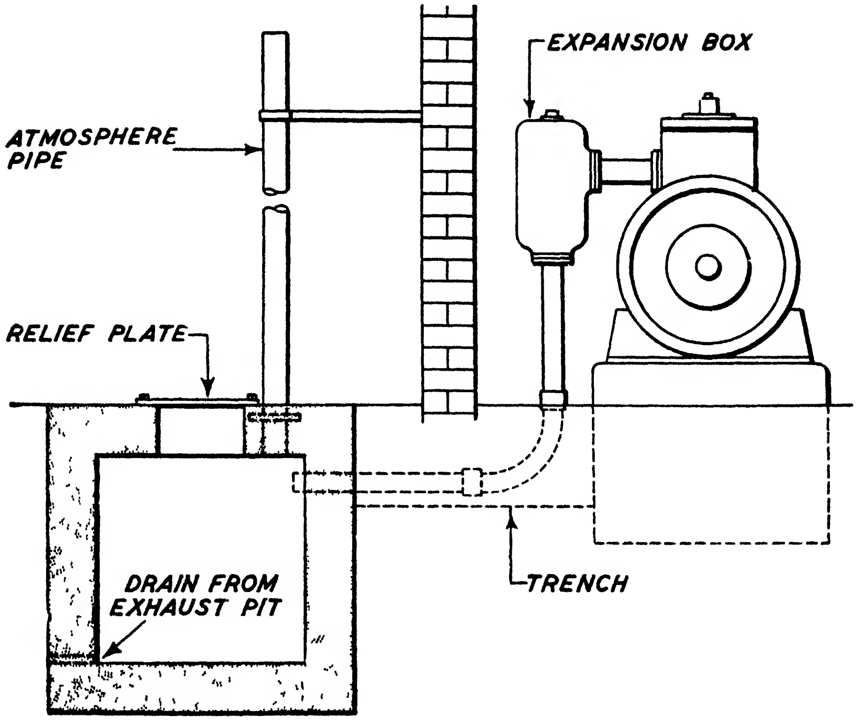


Fig. 7.—EXHAUST SYSTEM WITH PIT SILENCER

a good plan to move the boxes slightly before the concrete has thoroughly set so as to give a small clearance.

Check the Position of Boxes before Concreting

Before commencing the actual concreting work, the positions of the various boxes should be carefully checked to drawing and existing plant, and care should be taken to see that there is available sufficient material to complete the work in one continuous operation.

Mixing the Concrete

The concrete may now be mixed and should consist of roughly four parts of good clean ballast or equal, not larger than 1½ in., two parts of sharp sand, and one part of best Portland cement. Quick-setting cement may be used if desired, but should be placed in position with as little delay as possible.

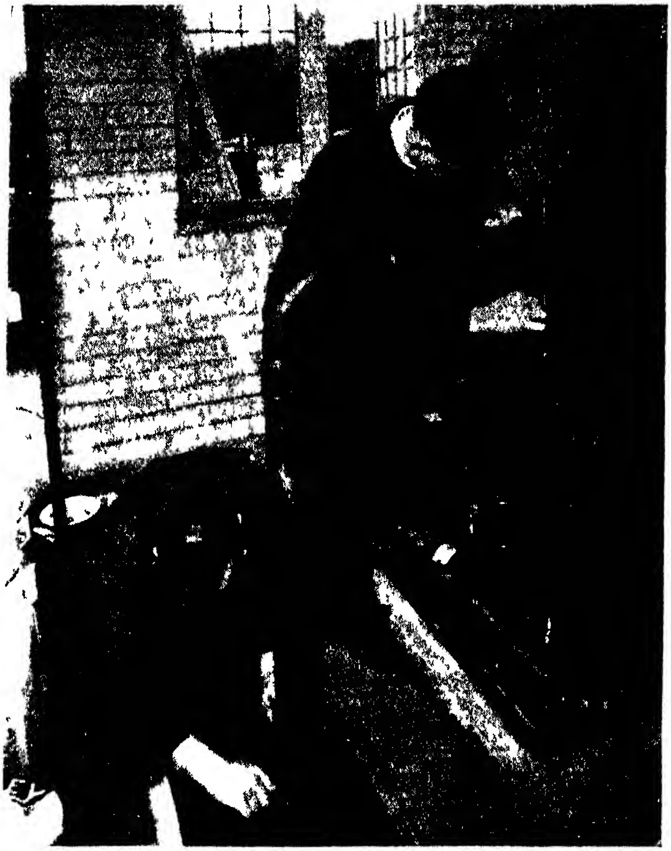


Fig. 8.—FITTING EXHAUST SYSTEM
This shows exhaust pipe being connected between engine and expansion box

Filling in the Concrete

The whole of the concrete should be filled in carefully. Take care to see that the boxes are not disturbed and that the work proceeds continuously, so that one solid homogeneous block of concrete is formed. The top surface should be left rough about ¾ in. below finished level for grouting up. Concreting should not be done in frosty weather.

Providing Clearances in Concrete

The foundations should be about 3 in. clear of wall footings. Flywheel races, clearances for pulleys, etc., and the recesses under the engine bed can be formed by light boxes placed in position as the foundation work proceeds.

Drainage

Drainage for the flywheel race and the pipe trenches can be provided by earthenware pipes fixed in the concrete.

Trench Covers

Kerbing for the trench covers should be grouted in and care taken to see that the top is flush with the finished floor-level.

ERECTION OF ENGINES

When the foundation work has been finished and all bricks, dust and dirt, etc., such as are usually connected with a building job, have been removed and the concrete has had a few days to harden, erection may commence.

Keep Engine Clean during Erection

At this stage it will, perhaps, be as well to give a few words on the subject of cleanliness. It is most important that any oil engine, or for that matter an engine of any sort, should be kept scrupulously clean whilst it is being erected, and care should be taken that no bearings or wearing parts go together with foreign matter between them. Given a clean engine, clean fuel oil, clean lubricating oil, and clean cooling water, sterling service can be expected from an oil engine, whereas dirt accumulated during erection may take years off the ultimate life of the engine.

Fig 9.—SHOWING LAYOUT OF EXHAUST SYSTEM

Note pipe going through wall into exhaust pit shown in the next photograph

Conveying Parts to the Site

It is usual for one door of the engine-house to be made sufficiently wide to allow for the machinery in its various parts to be either carried or rolled in. Where an extra wide doorway is provided, it may be possible to run the lorry close up to the foundation and slide such a part as the bedplate direct on to its base, thus saving a good deal of time. In some cases it may be advisable to leave part of the wall adjoining the doorway unfinished, so as to allow the lorry or trailer to enter.

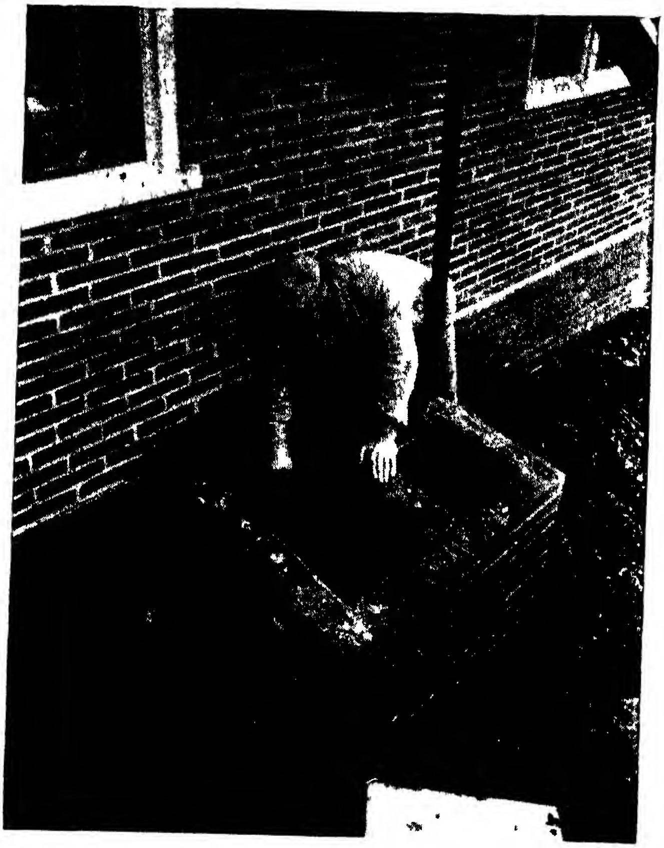


Fig 10.—THE EXHAUST PIT

Walls of pit being rendered End of exhaust pipe can be seen, also atmosphere pipe. Note that pit is divided into three sections.

Lowering Bedplate on to Foundation

If the lorry should happen to be higher than the foundation, timbers should be packed on the latter until the respective levels are the same, and the part can then be rolled on to the wood packing and gradually lowered by removing the packing piece by piece. Before the final packing is removed and the bed finally dropped on to the concrete, the wires which are fastened to the foundation or holding-down bolts should be drawn through the bolt holes in the bedplate.

Placing Bolts in Position

When all packing has been removed, the bolts may be drawn up through the bolt holes by means of the wires, and the nuts screwed on until about one thread short of a full nut. In this way, when the nuts are finally drawn down tight, the bolts will not project through the nuts.

Now Check Position of Engine, etc.

The distance from the centre line of the crankshaft to the finished floor-level is now checked with the drawing, and the bedplate raised by means of steel wedges until this dimension is correct. At the same time dimensions from the centre line of the crankshaft to the wall, and from No. 1 cylinder to the wall, should be checked, likewise leading dimensions relative to other plant or machinery, and the position of the bedplate altered as may be necessary.

Fig. 11.—Section through Burgess silencer (*Burgess Products, Ltd.*)

Fig. 12.—Connecting rubber hose to thermal valve on water-cooling system

Fig. 13.—Method of adjusting thermal valve to keep cooling water at correct temperature

Belt or Chain-drive Alignment

Where the engine has a belt or chain drive to existing machinery, the crankshaft should be placed in its bearings with pulley, etc., fitted and a line taken to ensure that the belt will run true on both pulleys.

Checking Direct-coupling Alignment

For checking alignment relative to existing plant to which the engine is to be direct-coupled, the respective half-couplings should be fitted and the faces brought to coincide. Feeler gauges will show whether alignment is correct.

Connecting Shafts by Flexible Coupling

Fig. 14 shows a method of connecting two shafts together by means of a flexible coupling, and on most types of coupling there are machined faces intended for use by the erector, which greatly facilitate the work of lining up. There is a tendency for erectors to be somewhat careless over this operation and to rely on the flexibility of the coupling itself to prevent trouble. Whilst most good flexible couplings are capable of dealing with reasonable errors in alignment, the shafts should be set in line as shown, and should be adjusted in line as far as practicable, in order to avoid undue wear of the belt and possible bearing troubles.

The actual procedure to be followed in lining up a flexible coupling will vary with different types and makes, but the question of correct alignment will always be important, and a method of checking can easily be devised to suit the particular make of coupling in question.

Grouting Bolts into Foundation Block

Flat steel packing pieces of varying thickness and of a length and width to suit the particular size of engine should be provided by the makers and a set put next to each holding-down bolt. The steel levelling wedges are then removed, and the bolts are then grouted into the foundation block to within, say, 6 in. of the top. The grout should consist of equal parts of sharp sand and Portland cement, mixed with water so that it flows freely.

Proceed with Erection of Tanks, etc.

Whilst the grout is hardening—and quick-setting cement will hasten this process—the erection of tanks and other accessories can proceed. There should be several days' work coupling up piping, etc., but the final position of the tanks, etc., is best left until the pipes are completely finished, thus avoiding any difficulties in mating flanges, which is sometimes apt to be difficult if working between two fixed points.

Next Step—Making Bedplate Level

As soon as the foundation bolts are fast, work on the engine must proceed, and other work must be left until the engine is properly grouted

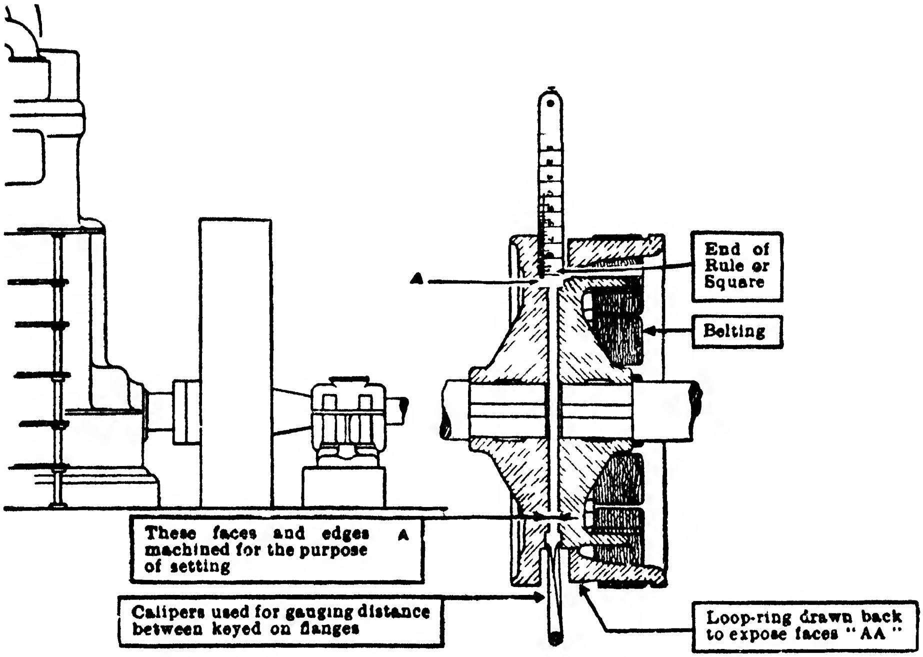


Fig 14 —METHOD OF LINING UP FLEXIBLE COUPLING (*Ruston & Hornsby, Ltd*)

in. All the nuts can now be tightened up and a spirit level used in conjunction with a straightedge both longitudinally and across the bedplate.

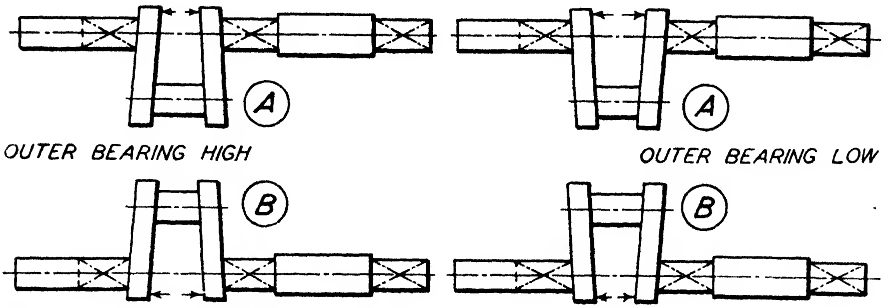
Lining Up the Engine

After the engine bed is in position on the foundation block, which must be given as long as possible to set, the foundation bolts can be dropped into their respective holes, and the next thing to do is to get the engine lined up correctly with the line shaft or whatever shaft is to take the drive. This is best done by putting the crank into position first, and lining up from it, as the bed, being only a casting, is not sufficiently accurate to serve as a datum line.

When this operation has been completed, the foundation bolts are grouted in by pouring liquid cement in all the holes and under the space left by the wedges between the bottom of engine bed and foundation block. If the flywheel is keyed to the crankshaft it must be put on *before* the crankshaft is lifted into position.

Alignment and Adjustment of Crankshaft Bearings

If the maker's services are not obtainable to check over the alignment of the crankshaft and bearings, then this should be carried out with the aid of a clock micrometer or a pin gauge made to suit, as follows :—



Figs. 15 and 16.—DETAILS FOR ALIGNMENT AND ADJUSTMENT OF CRANKSHAFT BEARINGS

(1) Rotate crankshaft until crankpin is in its lowest position (Fig. 15 A), then with a clock micrometer measure the distance between the crank webs at a point nearest their upper edges.

(2) Now turn the crankshaft until the crankpin is uppermost (Fig. 15B), and again measure the distance between the webs, making sure by having previously marked the spots that the micrometer is located at the same point on the webs.

(3) If the second measurement is greater than the first (see Figs. 15 A and 15 B), then the outer bearing is high and must be lowered ; but if this measurement is less than the first (see Figs. 16 A and 16 B), then the outer bearing is low and must be raised. This is done by inserting or removing one or more shims interposed between the outer-bearing pedestal and sole-plate.

(4) Shaft alignment in the horizontal plane should be tested in both backward and forward positions, and if any discrepancy is found, the outer bearing must be moved backwards or forwards as required.

Note.—The tests should be made with the main bearing caps on and tight. The outer-bearing cap should be off, because if there was considerable misalignment and all the caps were tightened down a permanent set in the shaft might be caused. When the micrometer tests have shown that the bearings are in alignment, marking such as prussian blue or ruddle should be thinly and evenly applied to the journal and the shaft revolved. The shaft is then lifted to see whether the journal is bearing evenly over its whole length. The caps can now be put on and tightened down.

The bedplate nuts should all be tightened equally, that is, from corner to corner and across, as shown in Fig. 17.

Testing for Loose Crank-journal Bearings

It is as well to go over the crank journals with a spirit-level and to try tapping the bottom halves of the bearings to find the loose ones which are not taking their share of the weight of the crankshaft. The bearing shells

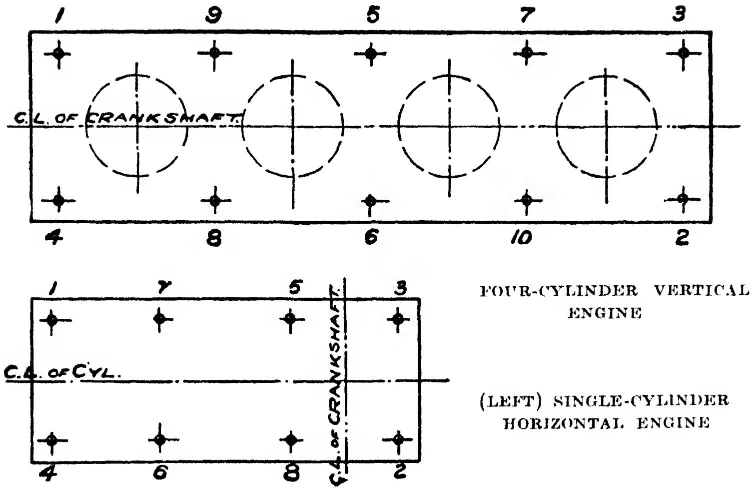


Fig. 17.—CORRECT ORDER FOR TIGHTENING HOLDING-DOWN BOLTS

Bedplate nuts should all be tightened equally from corner to corner and across as shown above. This method avoids springing and assists in lining up bearings correctly.

should have been bedded into their respective housings at the works and each numbered, and care should therefore be taken to see that the bearings have not become misplaced from their correct positions.

Now Turn Crankshaft by Hand

With the top halves of the bearings tightened down evenly, the crankshaft, when lined up, should turn easily by hand.

If Crankshaft Runs Stiffly

If stiff, each top half should be inspected and scraped, if necessary, until free, and to give a running clearance as recommended by the makers, and determined by feeler gauges.

The bottom halves of the bearings should not be bedded to the crankshaft until all is done that can be done by levelling the bedplate proper. The makers will have previously run the engine on test and very little work should be required in this respect.

PLACING FLYWHEEL ON SHAFT

A Useful Tool for Erection and Maintenance

An easily made tool which is useful both in the erection and in the subsequent maintenance of the engine consists of a flat steel bar which can be secured to the crank web by two setscrews. This tool can be clearly seen in Fig. 18, and it is a good plan to have a fitment of this sort provided by the engine-makers.

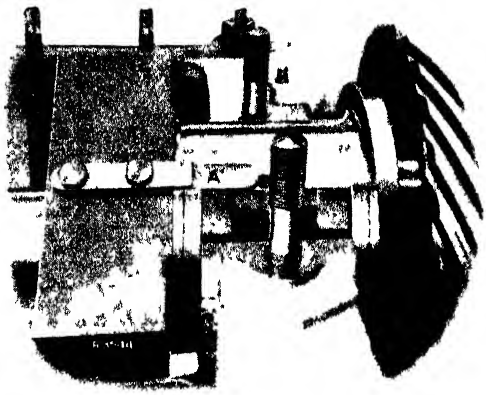


Fig 18 Tool for removing and replacing crankshaft bearings

The tool consists of a flat bar 1, shown in position for removing bottom half-bearing It is screwed to the crank web by two setscrews To remove bearing, the crankshaft is turned slowly and the bar pushes the half-bearing to the top This saves lifting the crankshaft and obviates any possible damage being done. (*Ruston & Hornsby, Ltd*)

To Remove a Bottom Half-bearing

Should it be necessary to remove a bottom half-bearing at any time, the tool should be fitted as shown, and the crankshaft turned slowly with the bar in position, thus bringing the half-bearing to the top, whence it is easily removable for attention. This saves lifting the crankshaft and obviates the possibility of damage to crankshaft or bearing. Care must, however, be taken to see that the width of the bar is less than that of the bearing section, so that the shaft may be turned without jamming

The flywheel should next be lowered into the flywheel race of the foundation and supported on timber packings whilst the extension shaft is brought close up and the bolts fitted.

Fitting Wheel to Crankshaft Coupling Face

When the wheel is being fitted to the crankshaft coupling face, care should be taken to prevent straining of the shaft by overhanging the weight of the wheel. The extension shaft should be supported by the outer bearing as soon as possible, so that the packing under the wheel can be removed. The same procedure applies if there is a dynamo shaft bolting up to the flywheel face, and in each case there should be shims, or liners, fitted to a total thickness of $\frac{1}{32}$ in. to $\frac{1}{8}$ in. between the outboard bearing and its sole-plate, in case future adjustment should be required.

Fitting Keyed-on Flywheel

If the flywheel is in halves or otherwise keyed on the crankshaft, extending in one piece to the outer bearing, then the latter can be fitted in position and its foundation bolts grouted in as soon as the bedplate and bearings are lined up. Generally, the quickest way of doing this is to place the sole-plate on the concrete pedestal, and to hang the bearing on the crankshaft. The sole-plate is then packed up to the bearing, with packing pieces similar to those used under the engine bed, until the bearing is properly supporting the shaft; the shims will, of course, have been fitted between the bearing and the sole-plate before placing in position.

The holding-down bolts can then be grouted in, in a similar manner to those for the main bedplate.

After allowing sufficient time to set, the nuts may be tightened down and the crankshaft alignment checked and corrected if necessary.

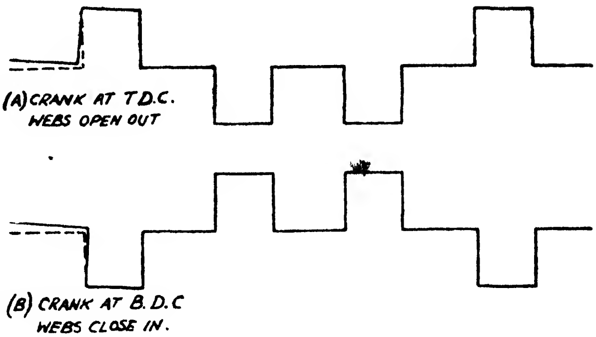


Fig. 19. —CRANKSHAFT WITH EXAGGERATED ALIGNMENT FAULT

Showing "breathing" of webs adjacent to a high bearing.

The flywheel should then be fitted, and if this is in one piece it will be necessary to remove the crankshaft from the bedplate. This usually has to be done with the horizontal type of engine.

To Check Alignment of Complete Crankshaft

To check the alignment of the complete crankshaft is now necessary, and for this purpose a stick gauge is inserted between the crank webs and on rotating the shaft it is noted whether the webs open or close. A telescopic gauge can easily be made if not supplied with the engine, and will, in any case, be extremely useful for periodically checking over the crankshaft alignment.

Fig. 19 shows a line drawing of a multi-cylinder engine crankshaft, with exaggerated alignment fault. One can see from this that the crank webs of the throw, adjacent to a high bearing, will close when the throw in question approaches the bottom position.

Rectifying Non-alignment

The cylinder nearest the flywheel should be the first to have attention, and when the crank is on top dead centre, the gauge should be placed between the webs in the plane of the centre line of the crankshaft and adjusted to fit. The shaft is then given half a turn and the gauge tried between the webs. If slack, then the outer bearing is low, and it must be packed up slightly. If the gauge will not enter, then the packing of the bearing should be adjusted until the gauge is an exact fit in top and bottom positions. The horizontal alignment of the outer bearing should be checked in two positions, with the crank midway between top and bottom centres, and the bearing moved sideways until no breathing of the webs takes place.

On multi-cylinder engines the cranks should all be dealt with in turn and, when apparently correct, the whole shaft should be checked over to make certain that the adjustment to one throw has not interfered with that for the other cylinders.

Using Micrometer Dial Gauge

A spring-loaded gauge can be obtained which incorporates a micrometer clock. This gauge should be left between the webs and the plus or minus readings taken as the shaft is revolved. This type of instrument is sensitive and is easily used, and it is invaluable for showing at a glance the condition of the main bearings. The micrometer can also be adapted for measuring the clearances of the connecting-rod large- and small-end bearings.

The method of applying the dial gauge is shown in Fig. 20, which illustrates the method of testing clearances of both large- and small-end bearings.

Testing Shaft with Spirit Level

The crankshaft can also be tested for alignment with a sensitive spirit level, but it must be borne in mind that a slight allowance will have to be made for a deflection due to the weight of the flywheel. The level will read downwards towards the wheel both from the engine bearing and the outer bearing, the amount varying somewhat according to the distance of the centre of gravity of the wheel from the respective bearings.

Now Grout in the Bed

The bed can now be grouted in, and the space left when grouting the bolts will serve to form a key. A wall of clay or of wood of uniform height should be placed around the bed, to retain the grout, and this should form the finished level of the grouting. The grout must be stirred well underneath with a flat rod, and in the case of large engines the main grouting should extend over two or three days to give time for settling.

The outer bearing is similarly grouted in, but not until the grout in the bolt holes has finished settling. The finished level of the grout should be above the bottom of the bedplate and sole-plate, thus helping to make a good solid job.

Fitting Large-end Bearings to Crankshaft

The erection of accessories can now proceed once more. When the grout has sufficiently hardened to permit further work on the engine, the large-end bearings can be fitted to the crankshaft, after first making sure that all parts are absolutely clean and that no foreign matter is contained in the oil holes of the crankshaft, etc. The crank journals should be well oiled and the oil wiped round by hand before the bearing halves are bolted together. The compression plates should have been stamped for each cylinder at the makers' works, and these should now be checked over and placed in position.

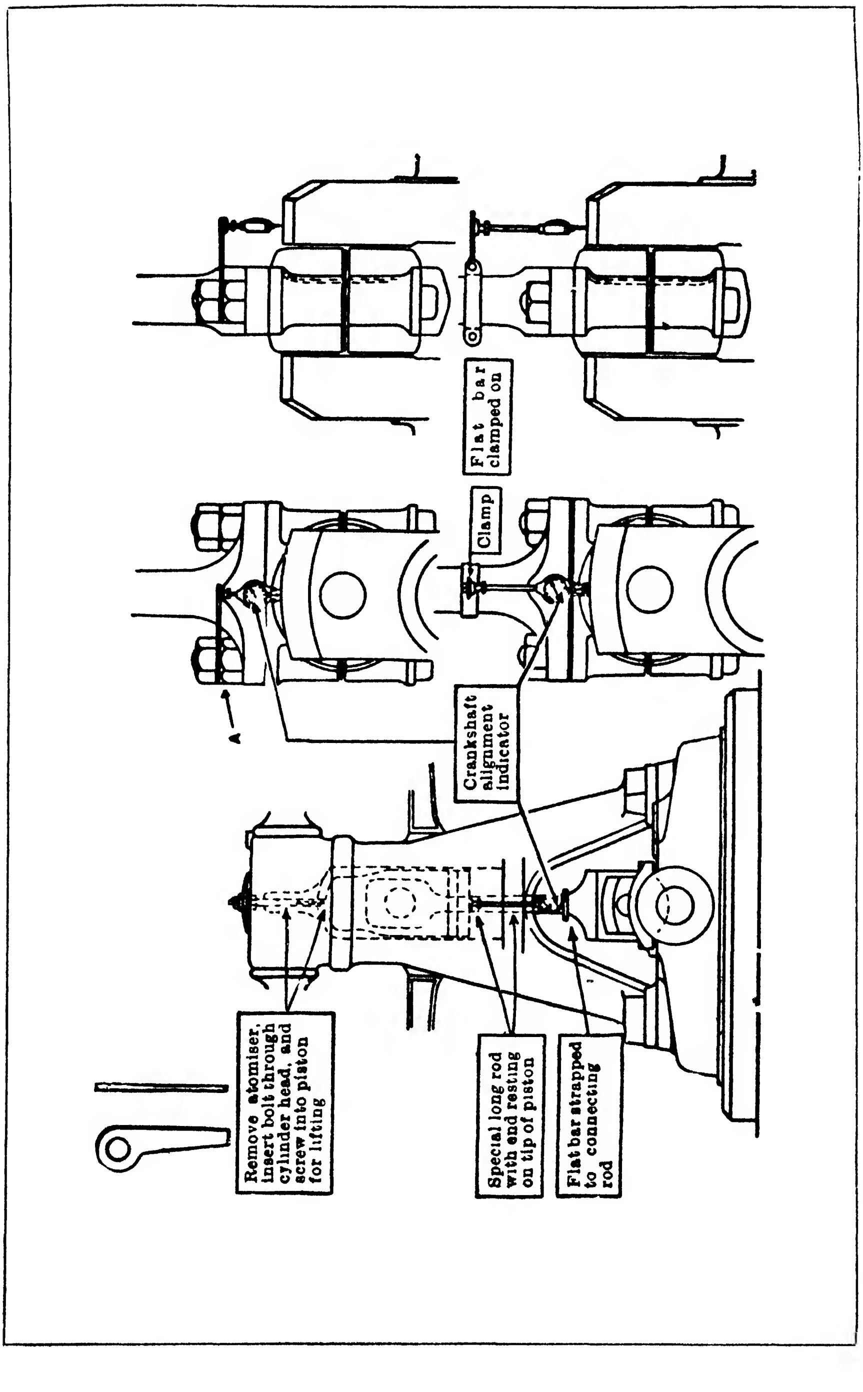


Fig. 20.—METHOD OF TESTING BEARING CLEARANCES WITH DIAL INDICATOR (*Ruston & Hornsby, Ltd.*)

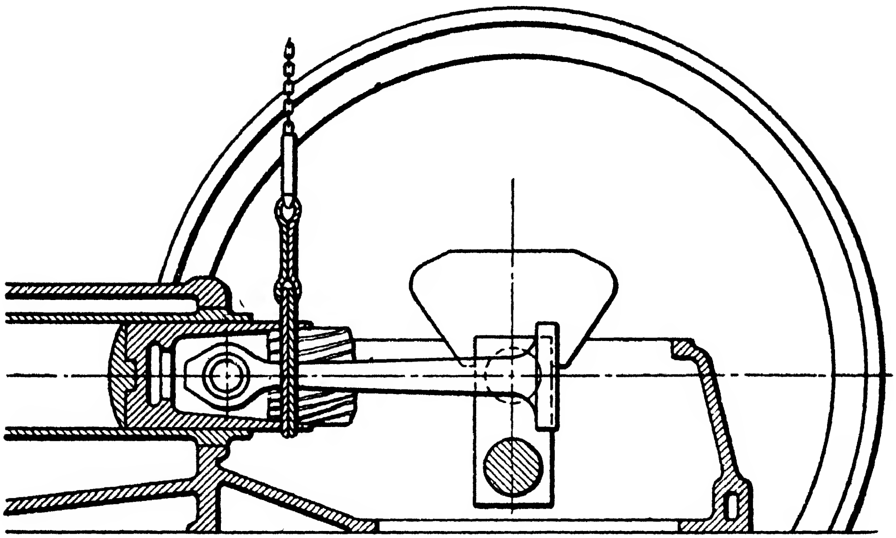


Fig. 21.—Connecting rod of crankshaft in horizontal position to facilitate slinging by means of hardwood wedges

Fitting Connecting Rod

The housing and gear can now be assembled, and, in the case of a horizontal engine, the piston and connecting rod. To fit the latter, the rod is fitted to the piston and then slung as near to the skirt of the piston as possible and the piston pushed into the cylinder liner by means of the large end of the connecting rod. It will be necessary to adjust the height of the piston very carefully to permit entry to the cylinder skirt.

Fitting the Piston

With the crankshaft correctly aligned, the piston (or pistons in the case of a multi-cylinder engine) is fitted, complete with its connecting rod.

If the engine is of the horizontal type the crankpin should be located at the bottom, so that when the piston and connecting rod are lowered into position the piston may be pushed into the cylinder without the tee end of the connecting rod fouling the crankpin.

The connecting rod can be wedged into a horizontal position for convenience of slinging by means of hardwood wedges, as shown in Fig. 21.

After the piston has been pushed in about two-thirds of its length, the wood blocks should be removed and the connecting rod raised to about 30° from the horizontal, and in this position it is possible with most horizontal engines to put a bar underneath the connecting rod, thus supporting it while the large-end bearing is being fitted.

Arrangement of Piston Rings

All the rings should be well oiled and the gaps arranged so that they do not come in line, for this would cause loss of compression. The liner should be well oiled and oil wiped round the piston before assembling. When closing the rings so that they enter the liner, care should be taken that the edges are not damaged, which would cause scoring of the piston or liner.

Take Care to Prevent Breaking Skirt of Piston

Before lifting the pistons of vertical or horizontal engines, a block of wood should be wedged between the under side of the connecting rod and the piston skirt. If this is not done, the piston may fall back with the gudgeon pin as fulcrum and thus break the skirt. In the case of vertical engines the packing is taken out as soon as the piston is in the vertical plane.

With horizontal engines the packing is kept in position until ready to connect up to the large-end bearing. A piece of wood should be placed under the rod and rested on each side of the engine bedplate to take the weight of the rod. A length of pipe may be used for this, but there is a danger of it slipping forward towards the main bearings.

The back half of the large-end bearing is next mated up to the connecting rod and the bolts pushed through until the bearing half is held in position. The crankshaft is now turned so that the large-end journal is close up to the large-end bearing, the packing under the rod being adjusted so that the bearing half is in the path of the journal. The crankshaft can then be turned steadily until the journal touches the bearing, and the front half of this can then be bolted up and tightened. This procedure is reversed for removing pistons or large-end bearings and it is soon learned and quickly executed.

The same operation for a vertical engine is usually assisted by an eye bolt screwed into the piston crown, the cylinder-head being, of course, removed, so that the piston and rod can be lowered into position from the top. For maintenance work it is generally possible to hold the piston in place by means of a bolt through the cylinder-head whilst the large-end bearing is being removed.

To remove the piston and rod, the cylinder-head is taken off and a bolt fastened in the piston; the large-end bearing is then disconnected and the piston and rod lifted out.

Care must be taken to see that the crankshaft is not turned whilst any bolts are fastened to the pistons, and it will also be necessary to see that the fronts of all rods are pointing to the front of the engine, for when the large-end connecting-rod bearings are bedded to the crankshaft journals they have to be lined up to the pistons, and to the small-end bearings, and this alignment may be lost if the bearings are reversed.

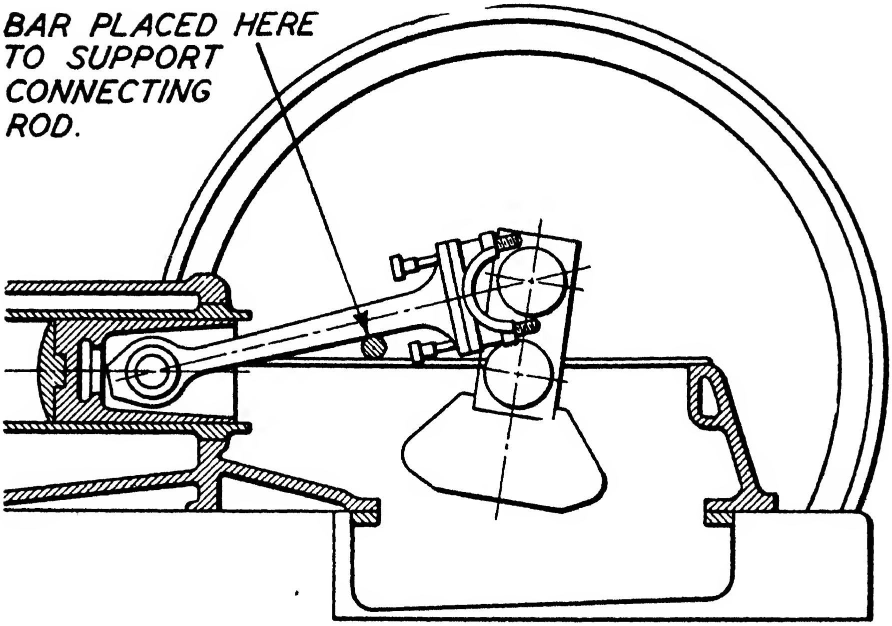


Fig. 22.—Back half of large-end bearing in position with bolt ends just showing through

Fitting the Bearings

All engine makers mark the halves of bearings, so that when these are placed together the numbers, letters, or symbols match. This is a point that should be most carefully watched, as the bearings must be put in exactly as they were intended to be fitted by the makers.

The large-end bearing should now be fitted, and will usually be found to have either one thick shim or several thin ones placed between the two halves. This is to allow for wear to be taken up by removing a thin shim or filing down a thick one.

While the crankshaft is still at the bottom, place the back half of the large-end bearing in position and put in the bolts so that the ends just show through (see Fig. 22). The crankshaft is then slowly turned in the reverse direction until the pin comes round and engages in the back half of the connecting-rod bearing.

Next the front half is put in position, care being taken to fit the shims between each half, and the bolts being tapped through. The nuts should now be fitted and screwed up *tight.* The bar is now removed from under the connecting rod, and the engine turned slowly by hand. The effort required should not be unduly great. It must be stressed here that the split-pins or locking screws for the large - end bolts must not be omitted, as many an engine has been completely wrecked by the connecting - rod bolts coming loose.

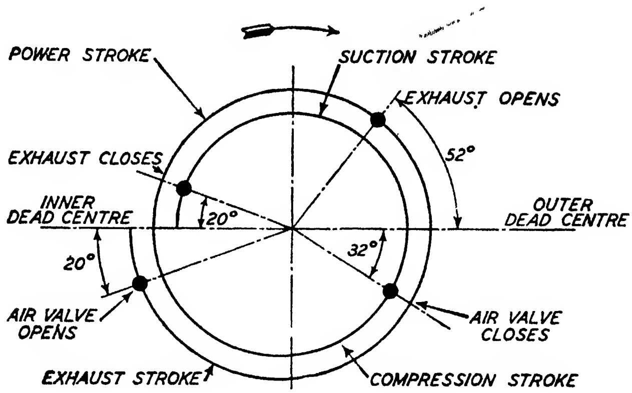


Fig. 23.—Ignition timing diagram

Erection of Valve Gear

The erection of the valve gear and camshaft, etc., can now proceed, and all brackets should have locating pegs, or else fitted studs or bolts to ensure correct alignment. Gear wheels which mesh will have the teeth stamped so that they can be meshed in the correct positions, and no mistake must be made here, otherwise the cam settings will be upset accordingly.

It cannot be emphasised too much that absolute cleanliness is essential in all stages of erecting and fitting major and minor parts. If the engine-house is not quite completed, all windows, doors, and openings likely to allow the ingress of dust and dirt should be blocked up with tarpaulins and sheets.

Camshaft

The camshaft, whether it be driven by a chain, skew-gears, or spiral bevels, must be in correct relation to the crankshaft to give the proper timing to the valves and fuel pump.

Wheels

The wheels are generally marked by the makers, so that one mark on the one gear falls into position between two marks on the other ; or, if a chain drive, the wheels are marked and a pointer fitted inside the chain case. Should this not be the case the timing is set as indicated in Fig. 23.

Timing for the two-stroke engine is only a matter of the fuel-injection cam being set to deliver the charge of fuel at the correct moment, i.e., just before inner dead centre.

After all the parts have been tightened up in position the engine should be pulled round by hand, to make sure that nothing is fouling.

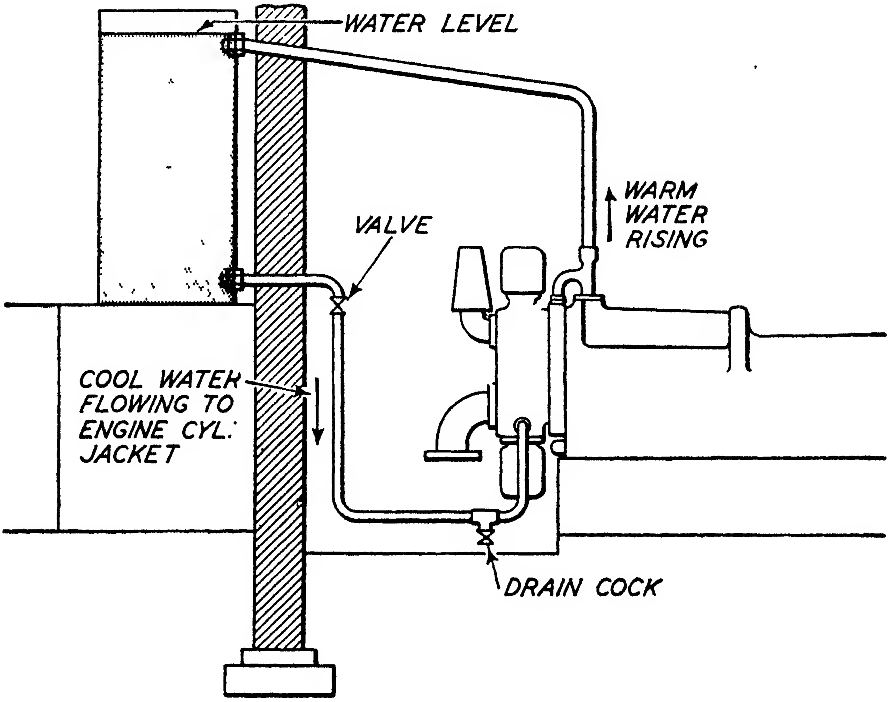


Fig. 24.—THERMO-SYPHON COOLING SYSTEM
This method of cooling is not suitable for large engines.

The Cooling-water System

There are two systems of cooling:

(1) *Thermo-syphon*, which perhaps is the more simple and gives the least trouble, but, owing to the large quantity of water required, is not suitable for large engines.

A single tank, or a number of tanks carried on a concrete or brick foundation, generally 3–6 ft. above the engine foundation, may be used for this system. The essential point is that the water-level in the tanks should always cover the outlet pipe from the engine or the system will fail.

(2) *The Run-through System.* Here water is pumped from a sump, pond, or stream and lifted into a comparatively small tank, from which it is gravity fed through the engine and then allowed to run to waste or return to the sump.

Whichever system is adopted, be quite certain that there are no air locks and that the cylinder and combustion-head water jackets are full of water before starting up.

PIPEWORK AND TANK INSTALLATION

Pipework can now be permanently coupled up, screwed oil and water joints being made tight with hemp and a good jointing compouud.

Cleaning Out Pipes

Pipes, other than oil pipes, should all be blown out with compressed air, if available, and during the erection of the engine they should have their ends protected from dirt and damage. Oil pipes should be cleaned out with paraffin before fitting.

Bend Pipes before Connecting Up

Pipes generally should be bent correctly before connecting up, in order to avoid strains on joints and flanges, etc., when the engine is running.

All pipes liable to expansion must be free to move.

How to Pack Exhaust Pipes Passing Through Wall

The exhaust pipes should be from 12 to 18 in. from any woodwork where they pass through the wall. It is advisable to pack the exhaust pipe in the wall with asbestos. To make a good job of this, bricks should be cut away to make a hole about 3 in. larger than the outside diameter of the pipe. Asbestos rope is then wrapped round the pipe to a thickness of about 1 in. and the remaining space grouted up with cement. This will permit expansion of the pipe, but the weight of the exhaust pipe and that of the exhaust manifold should be taken by means of roller supports.

Making Joints of Vertical Pipes

Very special precautions are necessary with the joints of vertical pipes, since these are liable to transmit vibration. Makers' drawings and instructions should be rigidly adhered to in such cases ; for instance, in the case of a vertical pipe connecting on to the flat bottom of an overhead water tank, or any pipe requiring a water joint where it passes through a roof.

Carry Pipes Outside Engine-room where Possible

Wherever possible, pipes should be carried outside the engine-room in a horizontal plane and should be amply supported.

Water Pipes—Drain Taps

Drain taps should be fitted at the lowest points of all water pipes and provision made for emptying the pipe trenches of oil or water, as previously mentioned, whilst dealing with foundations.

Lagging Oil Line Exposed to Frost

If there should be a length of fuel-oil line from the storage tank above the ground and exposed to frost, it is a good plan to lag this with straw or other suitable material.

Except when the fuel storage is overhead, it is advisable to install a semi-rotary or other suitable type of pump to assist the flow of viscous oil and to remove air locks from the system.

Fuel-oil Tank—Its Position

A usual position for the fuel-oil tank is immediately outside the engine-room, supported by brick or concrete piers, the bottom of the tank being about 1 ft. 6 in. to 2 ft. 6 in. above ground-level.

Oil-level Indicator

An oil-level indicator should be fitted inside the engine-room, and whilst this can be arranged for almost any position of the tank, it is as well to keep the arrangement of pulleys and gear as simple as possible.

When Tank is Underground

To economise in space above ground the tank or tanks can be buried underground, or else arranged in a pit with a suitably designed cover, fitted with a manhole so that a filling pipe from the wagon to the tank can be easily connected. Drainage of the pit should be provided for, likewise accessibility to pipe connections. The tanks should be well painted, and if to be buried and not enclosed in a pit they should be painted with special bitumastic paint. A fuel pump will be necessary in either of these cases.

Fuel Tank in Roof

The fuel tank can be arranged in the roof of the building, if this is suitably designed and sufficient space is available, but this is, as a rule, found more expensive than an outside tank. If, however, an overhead storage is decided on, then care should be taken that it is not so high that the fuel supplier's wagons cannot pump to it.

Water-cooling Tanks—Test for Leakage before Installation

When several water tanks are supplied, as for the thermo-syphon system of cooling, each tank should be tested for possible leakage at the seams owing to damage received during transit. If each tank is tested separately this saves loss of time and the trouble involved in disconnecting gear to rectify faults afterwards.

Piping Water from Pond or Sump to Jackets

With some systems of water cooling a pump draws water from a pond or sump and delivers it to the jackets. In these cases the suction pipe should have a gradual rise to the pump, otherwise air locks may result if the pipe slopes towards the pump in any part of its length.

Piping to Cooler

If pumping hot water for delivery into a cooler, the length of suction pipe and the number of bends in it should be kept to a minimum, so that the total suction head, including friction, does not amount to more than about 10 ft. for a water temperature of, say, 150° F. Ten feet is not the maximum suction head allowable, but if exceeded it is possible that trouble may be experienced due to air bubbles, etc.; furthermore, the pump efficiency will be greater if the suction head is kept low.

A foot valve and strainer of approved type should be inserted at the end of the suction pipe.

Installing Fuel-service Tank

The fuel-service tank in the engine-room should not be lower than the dimension given on the maker's drawing, whilst a little extra height will not do any harm. Cocks and valves in the various pipes should be easily accessible.

Water Drain from Compressed-air Receiver

There should be a water drain in the compressed-air receiver, which is usually included in oil-engine installations for starting purposes. If not possible or convenient for this drain to be taken from the bottom of the vessel, then a simple arrangement is sometimes obtained by fitting the drain valve or cock at the top of the receiver and leading an internal pipe from this almost to the bottom of the vessel. In this way, when the valve is opened, any accumulation of water is forced out by the air pressure, and when such a valve is used a bent pipe should also be fitted to deflect the stream of water and air downwards, thus avoiding the possibility of this being sprayed about the engine-room.

Air Receiver

Most engines above 20 h.p. are fitted with automatic air starters, and will have an air receiver, a small air compressor which can be driven by a belt from a pulley on the main engine crankshaft, or, in the case of a large engine, the starting compressor is usually independently driven by a small petrol engine or an electric motor.

The piping from the compressor to the air receiver, and from the receiver to the engine, should be fitted in accordance with the makers' drawing.

The next thing is to fill up the fuel tank, and prime the fuel pump by the hand-lever. It is best to disconnect the fuel-oil pipe at the sprayer

Fig. 25.—Checking valve-tappet clearances before running

This shows a Lister oil engine with inlet clearance of 0·017 in. and exhaust clearance of 0·032 in.

end, and pump until the oil is flowing freely, in order to remove all air from the pipe-line.

Position of Air Receiver

The air receiver should be placed as near to the compressor as possible, at the same time in a convenient position for the attendant and close to the engine, with a valve easily accessible for starting-up purposes.

Fuel-oil pipes should, where possible, be run in the same trenches as the exhaust pipes and close to them, thus assisting the flow of oil.

Lubrication

All moving parts must be well lubricated. If the engine is of the forced-lubrication type (that is, the oil is circulated to the bearings by a pump), the oil sump or container should be filled with a reliable diesel-engine lubricating oil. The pump should then be worked by hand to ensure that all the air is driven from the pipes and that the oil has actually arrived at its various points. This priming operation is of great importance.

PUTTING AN ENGINE INTO COMMISSION

Filling the Tanks and Pipelines

When all erection of pipework, etc., is complete, the various tanks and pipelines may be filled.

Preliminary Precautions

Care should be taken to see that fuel-oil and lubricating-oil tanks are thoroughly clean and dry before any oil is put into them.

Before opening up on any of the lines connected direct to the engine an inspection should be made to see that all connections have been made correctly and that everything is clear away from the engine and that there are no packings, etc., left behind. These elementary precautions may seem futile, but they are well worth while for the sake of the short time that they take.

See that Lubrication is Satisfactory

A final precaution is necessary before attempting to start the engine, and this is to see that all lubrication services are thoroughly primed and that they are clear and the oil is actually reaching the place intended. It is not merely sufficient to see that the sight-feed lubricators are working; the point to verify is that the oil is going where it is wanted.

Is the Foundation Well Set ?

Provided that the foundation is sufficiently well set, and in the majority of cases this will be so, the engine is now ready for starting. It should be borne in mind that the foundation should be about four weeks old if made with Portland cement, although this will depend a little on the quality of cement used and the size of the foundation. Obviously, if rapid-setting cement is used this will reduce the time required.

Ready to Start

The engine may now be started, as directed by the makers in their instructions. Some typical starting up instructions will be found on page 58. Here are a few hints which may be useful should the engine fail to start:

(1) The fuel system may have air locks. This can be remedied by taking off the fuel pipe to the sprayer, removing the sprayer from the cylinder-head, and coupling it on to the pipe so that it will spray outwards instead of into the cylinder. Work the pump again by hand, and it can be seen at once if the sprayer is functioning. Should the sprayer not be working the cause of the trouble must be further traced, as follows;

(2) Fuel-pump plunger sticking. Dismantle, examine, and clean the plunger. Never use emery cloth.

(3) Fuel-pump suction or delivery valve leaking, due to particles of foreign matter between the valve and its seat. In handling fuel-pump parts, do not use any cloth other than clean linen wipers, as the use of dirty cleaning material invariably causes trouble owing to lint, grit, etc., getting into the oilways.

(4) Exhaust valve sticking. In a new engine a few drops of paraffin injected into the guide will usually remedy.

(5) Valve timing incorrect. Check up from Fig. 23.

The First Run

This first test should be made without any load on the engine, and it should not last for more than a few minutes at the most. At the end of this time the engine should be stopped and all bearings felt for signs of undue warmth, and an inspection made to see that they are getting adequate lubrication.

The Second Run

Next run for, say, ten minutes, and again inspect.

Running Under Load

If satisfactory, the engine may then be run up on load, commencing with a short run of about a quarter of an hour on quarter-load and subsequently increasing this to half-load if satisfactory. After running for about a half-hour on half-load, if the engine seems to be going well and no symptoms of trouble have appeared, such as hot bearings, etc., the load may be increased to full load and a run of, say, two hours' duration carried out. Several hours should be completed on load before any fuel-consumption tests or endurance tests are attempted.

How to Tell what is Going On Inside the Engine

With a multi-cylindered engine tuning up and the distribution of load between the cylinders can be achieved with the aid of an indicator, but the same results can usually be obtained by a trained man using his physical senses alone.

Distribution of Load between Cylinders

If the exhaust branch from one cylinder is cooler than the others, this cylinder is not taking its fair share of the load. This also applies to the cooling-water outlets.

What Smoke from Cylinders can Tell You

The smoke from the cylinders is also a valuable indication of what is going on inside the engine, and the test cocks or plugs, usually provided on the exhaust manifold, enable the exhaust conditions to be observed. The loudest exhaust usually indicates the heaviest load, and is most often accompanied by heavier smoke. Dark-coloured smoke usually indicates overloading, whereas light-coloured smoke indicates underloading.

Indications of Over-lubrication

A pale blue smoke may indicate underloading, but it is also an index of lubricating oil in the cylinder over and above that normally necessary. It may be that the piston is being over-lubricated, or else that the scraper ring is not doing its work properly.

Smell of Exhaust Smoke

A different smell attends the various loads.

Blowing Past the Piston and its Causes

Light loading may be coincident with crank-case pressure, when a blowing past the piston will be noticed. This may be due to badly fitting piston rings or rings stuck in their grooves, neither of which is likely to be the case in a new engine. If a local blowing is noticed, this may be caused by the rings working round so that the gaps are all in line. On some types and sizes of engines where this trouble has occurred the makers peg the rings with the gaps staggered, thus permanently overcoming this trouble. If the pistons have been put in as instructed it is unlikely that the gaps are in line, and it is more likely that there is a slight distortion, which may disappear when the working parts bed down together.

How to Get an Accurately Tuned Engine

A clear exhaust should be the aim of the engine attendant. To assist in this the fuel injectors should all be made interchangeable and the springs and needle valves should be identical, whilst on some makes the lift, or spring pressure, can be adjusted to correspond with that of other cylinders.

Fuel-oil pipes from fuel pumps or distributors should all be of the same length, and for a neat arrangement of these pipes, coils can be made of the surplus length of those nearest the pump.

Valve clearances must be uniform and to the makers' recommendation.

Air filters must be clean to prevent obstruction to the air charge upon the opening of the inlet valves.

Checking Fuel Consumption

Finally the fuel consumption should be checked, and this is the ultimate proof of an accurately tuned engine. The fuel consumption guaranteed by the makers should at least be obtained, for these figures are mostly covered by a margin.

Causes of Heavy Fuel Consumption – Remedies

If the consumption is heavy, then the cam settings should be checked over, the governor inspected for steadiness, and the atomisers or fuel injectors tested for a correct spray without "dribble."

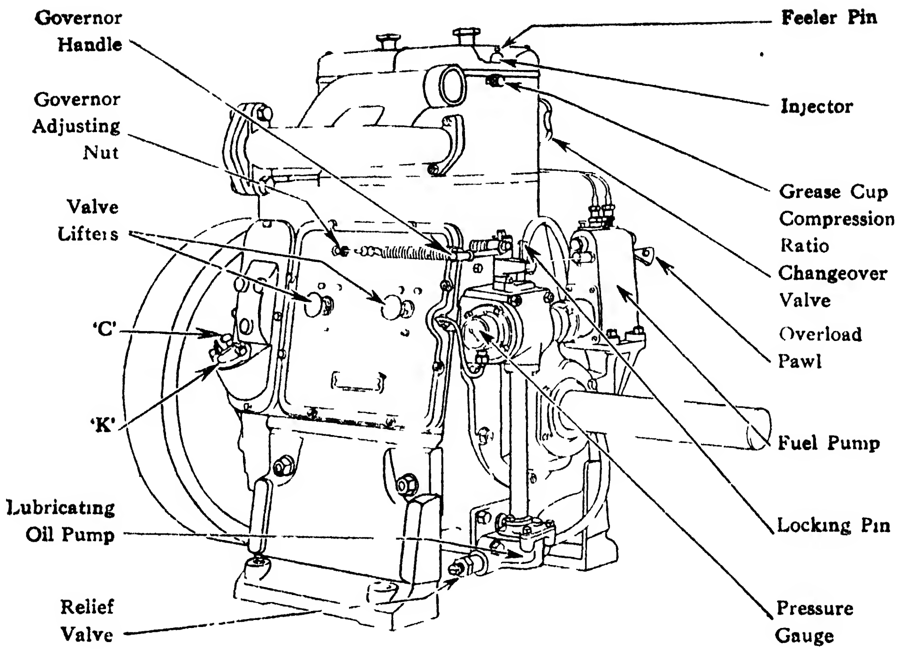


Fig 26 —A TYPICAL SOLID INJECTION DIESEL ENGINE
Showing various controls required for starting up (*R A Lister & Co , Ltd*)

Dirty Exhaust

A dirty exhaust may be caused by a fuel injector not working properly, late timing of the fuel injection, or by a choked air filter.

The needle valves of the injectors or atomisers should be an easy running fit in their sleeves or in the body, and should seat correctly.

STARTING UP A TYPICAL SOLID INJECTION DIESEL ENGINE

The following notes on starting up and stopping a solid injection diesel engine apply to a typical hand-controlled engine of this type. The engine, as illustrated in Fig. 26, is fitted with a compression change-over valve, which ensures a very high compression for starting, thus giving greater heat of compression for the ignition of the fuel.

Preparing to Start

Before actually starting the engine, the following procedure should be adopted :

(1) Open the oil filler *K* (Fig. 26) and pour in lubricating oil of the correct quality, until the level in the sump reaches the mark on the dipstick *C*. Close the oil filler after filling.

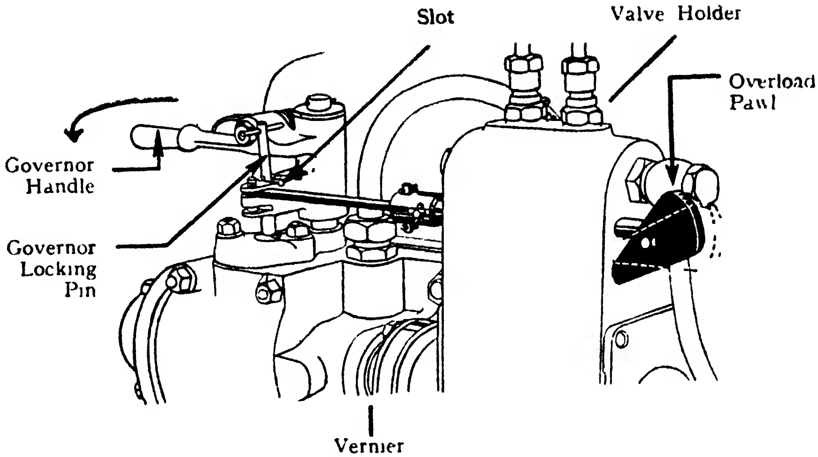


Fig. 27.—FUEL PUMP, OVERLOAD, PAWL AND GOVERNOR HANDLE (*R A Lister & Co , Ltd*)

(2) Fill the water-cooling system with water, avoiding "hard" water whenever possible. In the case of tank cooling, open the three-way tap in the bottom water-tank connection so that water can flow freely from the tank into the cylinder jacket. The water should be kept above the top connection in the tank.

(3) Now fill the fuel tank, using a fine gauze strainer. The fuel tank should be fitted so that the bottom of the tank is approximately 1½ ft. above the fuel pump. To collect the sludge, etc., deposited by the fuel, a good method is for the fuel tank to be fitted with a sloping bottom leading to a drain tap, which should be used to flush out the sludge from time to time, as found necessary. To prevent sludge from entering the

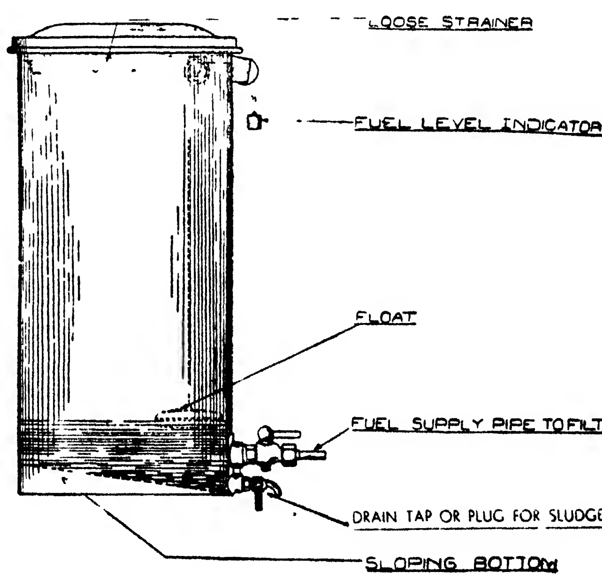


Fig. 28.—FUEL TANK

Showing drain tap and sloping bottom with level indicator and float. (*R. A. Lister & Co., Ltd*) fuel pipe, the fuel outlet connection should be placed at least 2 in. above the bottom of the fuel tank and the drain tap at the lowest point.

(4) After filling the fuel tank, turn on the fuel tap on the tank.

Priming the Fuel System

(5) Next prime the fuel system. To do this, prime the filter by unscrewing the vent screw on top of the filter with a spanner until the oil flows freely through. Then retighten the screw.

As it is highly important that all air should be removed from the fuel pump and fuel valve, in order to prime the fuel system, disconnect the fuel-injection pipe from the delivery valveholder on the fuel pump by unscrewing the union. It is necessary to see that the governor lever handle is in the " Stop " position.

Then remove the delivery valveholder and spring, and with the fingers slightly raise the delivery valve from its seating ; as soon as this is done fuel should appear. The delivery valve should be held off its seat until all air bubbles are out of the system and until a solid column of fuel oil appears. Then replace the delivery valveholder and spring and tighten down the holder carefully and not too vigorously, so that the body of the fuel pump is not distorted.

The fuel-injection pipe should now be connected again to the fuel pump, but in order to see that no air is present in the fuel pipe loosen the fuel-pipe union at the injector. Then place the governor lever handle in the " Start " position by withdrawing the release pin. Put the starting handle on the crankshaft and push in the compression release knob on the crankcase door, in order to lift the exhaust valve. Then turn the crankshaft until fuel free from air bubbles appears at the fuel-pipe injector union. Tighten the fuel-pipe union.

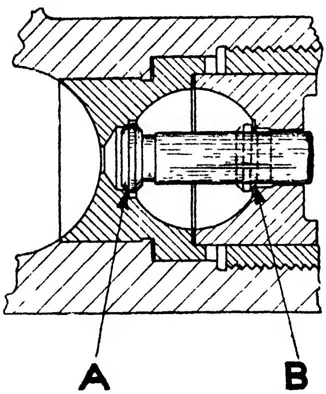


Fig. 29.—CHANGE-OVER VALVE

Finally, in order to make absolutely certain that a solid column of fuel is reaching the fuel valve, and that no air is present, place a finger on the feeling pin in the top of the injector, and if fuel is present without air, a definite creak will be heard in the fuel valve, and the lift of the valve will be felt by the finger.

On multi-cylinder engines this procedure must be carried out with each pump element.

(6) After priming the fuel system, see that the compression release knobs are pushed in.

(7) Set the governor handle to " Start."

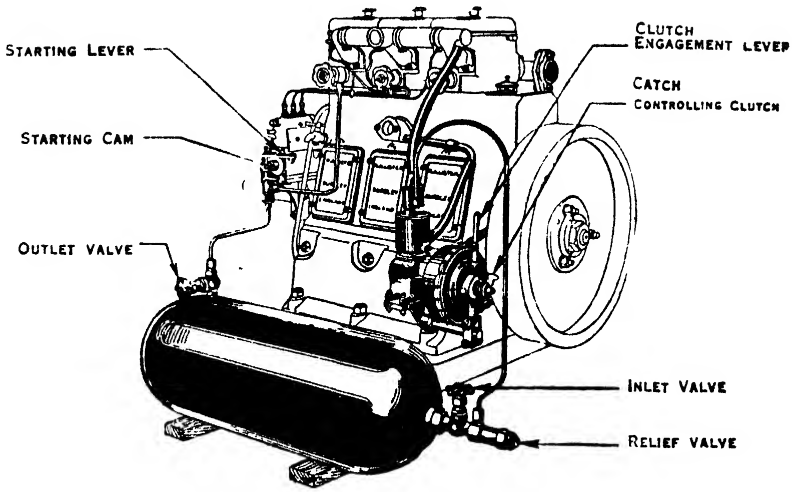


Fig. 30.—ENGINE FITTED FOR COMPRESSED-AIR STARTING—SEPARATE AIR-COMPRESSOR TYPE (*R. A. Lister & Co., Ltd.*)

(8) Lift the overload pawl to allow governor lever to move to its maximum position. This pawl will return to normal as soon as the engine starts.

(9) Screw the compression ratio change-over valves inwards tight on to their seats.

To Start

(1) Grip the starting handle firmly, ensuring that it is fully engaged with the crankshaft end, and turn smartly. When a good speed has been attained on the flywheel, pull out the valve lifters, when the engine should immediately fire. On multi-cylinder engines the other valve lifters should be pulled out immediately after.

(2) As soon as the engine has attained its normal speed, open the compression ratio change-over valve by screwing the handwheels outwards until they come to a stop.

(3) When the change-over valve is screwed in, it beds against the seating at *A*, Fig. 29, and when screwed out against seating at *B*. These seatings should be kept free from carbon. This can be done by turning the valve handwheel backwards and forwards once or twice before leaving in the final position, tight up.

Speed Regulation

Should a slight adjustment in speed be required, this can be made by screwing the adjusting screw inwards to increase the tension on the governor spring. This increases the speed, and by screwing out the adjusting screw the tension on the spring is eased and so the speed is dropped slightly.

To Stop Engine

Turn the governor locking pin until it falls into the slot. Pull back the governor handle in the direction of the curved arrow (Fig. 27) and the engine will stop.

Do not turn off fuel-supply tap except in case of emergency. The turning " Off " of this tap may lead to air locks in the fuel-supply system and the necessity for repriming it. Never try to stop the engine by lifting the exhaust valve.

Compressed-air Starting

If the plant is fitted with air receiver and air compressor for compressed-air starting (Fig. 30), to start the engine carry out the instructions already given with regard to filling up with fuel, oil and water, etc., and set the governor lever handle in the starting position. Screw in the handwheels of the compression change-over valves, except that fitted with the starting air valve, and put the engine on top dead centre of No. 1 cylinder, as marked on the flywheel. In this position the ball pad on the starting lever should be on the top of the starting cam. Put the engine on full compression by pulling out the exhaust-valve lifters. Open the outlet valve and press the starting lever, when the engine should start immediately. Screw out the handwheels, close the outlet valve, and proceed to charge the air receiver.

MAINTENANCE NOTES

The notes below relate to the engine proper and cover the routine operations which are required in connection with all types of stationary compression-ignition engines. Maintenance notes on fuel-injection equipment will be found in the next chapter.

Attention to Valves

The exhaust valves should be given attention and cleaned, and here the running period may be extended up to, say, about 1,000 hours, given reasonable conditions, and the inlet valves should be inspected and cleaned after about the same interval has elapsed.

When and How to Overhaul Pistons

The pistons may be withdrawn after, say, every nine months to a year, and thoroughly cleaned, and all carbon deposit removed, both from the inside and the outside of the piston. The rings should then be removed, and should be labelled so that they can be returned to the same grooves as previously, provided that they are in good condition. The grooves in the pistons can now be cleaned, and the rings also, and these can then be taken one by one, and the labels removed, and tried in the liner to see that they are a good fit. If satisfactory, they should be returned to their respective places in the pistons, whereas, if they are not satisfactory, and have lost their spring, they should be replaced by new rings.

Fig 31.—FITTING UP CRUDE OIL-ENGINE CYLINDER-HEADS

The cylinder-head carries the fuel, air inlet, and exhaust valves. The operator is seen grinding in the fuel valve, whilst to the left is the rocker shaft which carries the respective cam-operating gear.

Decarbonising

While the pistons are removed, see that there is no leakage past the water joints in the cylinder-head and remove any carbon deposit.

Cleaning Out Water Deposits

Under normal circumstances the liners may be withdrawn, and the water jackets of the cylinders and cylinder-heads cleaned of scale and other deposits from the cooling water, at about yearly intervals. If the cooling water is very hard, it may be necessary to install a water softener to treat it, or else to clean and scrape the jackets more frequently. A lime softener may help and may be used in the cooling water.

Trouble Due to Silt

Silt can be a source of trouble and is inclined to be more troublesome than a lime deposit, for whilst lime forms a scale of regular thickness, silting up may occur fairly quickly in certain places and may therefore cause overheating and distortion. It is more easily removed than scale, provided that its presence is suspected. It must not be inferred from this that lime scale is not dangerous—it is; but its formation is slower and can be counteracted by a boiler composition as mentioned below.

Adding Boiler Composition to Water

The practice of adding a quantity of composition to the cooling water at regular intervals has much to commend it, and every two or three days will be a suitable period, except in extreme cases. The necessary quantity will, of course, vary with the degree of hardness of the water, the quantity in circulation in the system, and the amount of make-up due to evaporation losses. The only remedy for deposits of silt and sludge is naturally to purify or filter the water, but fortunately this trouble is not often met with.

The Annual Overhaul

It is, of course, wise to have a regular annual overhaul wherever possible for this to be arranged.

Gauging Liners for Wear

When the pistons are out for cleaning, the liners should be gauged for wear and the particulars carefully noted and kept for reference purposes. Readings should be taken from front to back and from side to side, at the top, centre and bottom of the piston travel. Three further intermediate sets of readings should be taken, spaced equally between the top and the centre of the piston travel. These readings are, of course, repeated for each cylinder on the engine, and carefully identified with the respective cylinder numbers. The actual measurement can be made with a good stick gauge and feelers, the gauge being made to the original cylinder bore and kept permanently ; alternatively, an inside micrometer may be used.

How Long Should Liner Last ?

The rate of wear will, as a rule, be found to decrease after the first two or three thousand hours' running, but the actual rate will vary with the type and make of engine. The permissible wear in a liner bore will also vary according to the engine, and this should either be taken from the makers' instruction book, or else the matter should be referred to them. Assuming ten hours' running daily, a good liner should run, with care, for about five to seven years, depending mainly upon the quality of fuel used, the suitability and cleanliness of the lubricating oil, the lubricating arrangements generally, and the average load carried by the plant.

When to Replace Connecting-rod Bolts

Large-end connecting-rod bolts should be replaced every 12,000 hours' running and must not be merely heat treated and returned.

Running Clearances of Bearings and Journals

The engine makers mostly indicate suitable figures for the running clearances of bearings and journals. Great care should be taken when rebedding these bearings to ensure that a good wearing surface is obtained, owing to the high working pressures now employed.

Check Crankshaft Alignment Periodically

The crankshaft alignment should be checked periodically, especially in the case of belt or chain drives.

Check Compression Annually

Bad or insufficient compression will adversely affect combustion; the compression of the various cylinders should therefore be tested annually or whenever a new connecting-rod bearing is fitted. An indicator is generally used for this, but in some cases special gauges are supplied.

Loss of Compression—Causes and Remedies

Low compression may be caused by wear of piston, piston rings or liner, and if this is the trouble an overhaul of these parts is necessary. It may be due to nothing more than rings gumming up, but in any case an inspection will usually reveal what is wrong. It should *not* be forgotten that low compression may be caused by wear of bearings or by the fitting of a new bearing to the connecting rod. The remedy in this case is to fit liners between the connecting rod and the large-end bearing until the position of the piston relative to the cylinder is corrected.

The Lubricating System

The lubricating oil sump of vertical engines should be filled to normal level daily. It is preferable that some arrangement should be made for filtering and purifying the oil, either continuously or periodically. The sump should be drained periodically and thoroughly cleaned and refilled with the filtered oil.

Hints for Operators

DON'T—use dirty fuel oil.
use any but the best-quality lubricating oil.
try to economise with lubricating oil.
run with a smoky exhaust.
leave a mechanical knock unattended.
allow circulating water to get too hot.

DO— clean air filters periodically.
oil little and often.
keep everything tightened up.
attend to all leaks at once.
drain engine jackets in frosty weather.

Above all, keep engine clean; a dirty engine reflects upon its operator.

CHAPTER III

FUEL-INJECTION EQUIPMENT

With Special Notes on C.A.V., Simms and other widely used types

THE fuel pump of the diesel engine is a vital part. It is manufactured by precision methods and is a delicate piece of apparatus. There are quite a number of pumps on the market; some engine makers design and make their own, while others prefer to fit a standard type of pump made by firms specialising in them.

The fuel pump controls the time and amount of fuel supplied to the sprayer at each firing stroke of the engine. Now it is obvious that the load on any engine must vary, and therefore, to keep the speed constant, the amount of fuel must be varied accordingly. This is done either by varying the stroke of the pump plunger or by a sleeve having a helical groove. The engine governor is connected to the fuel pump, and as the speed tends to fluctuate the action of the governor increases or decreases the supply of fuel to compensate for the fluctuation.

When servicing fuel-injection equipment for high-speed C.I. engines it must be realised that as the function of the injection system is to provide small, accurately metered quantities of finely atomised fuel proportional to the amount of work the engine is required to do, and also to time each injection with the utmost precision, the highest quality of materials and workmanship must be used in its production.

This calls for something more than ordinary care when handling the equipment during periodical overhauls or when making repairs or replacements.

As the fuel-injection equipment made by the firm of C.A.V. Ltd. is probably the most widely known and used on the British engine market, it is proposed to deal with this make in some detail, but the care emphasised here applies equally to all fuel-injection equipment for C.I. engines.

Details relating to the Simms, Belliss and Morcom, Ruston and Hornsby, and Robey fuel pumps and atomisers are given later in this chapter. Before examining these in detail the reader is advised to study the typical fuel-injection diagram which is given in Fig. 1, as this shows the essential elements in a well-designed injection system. It will be seen that a fuel-feed pump is shown, this being used to ensure an adequate supply of fuel to the fuel-injector pump. Further details are as follows :

Fuel-injection Equipment Layout

In Fig. 1 will be seen a typical fuel-injection equipment layout : the fuel-injection pump is mounted in a convenient position on the engine casing, and its camshaft is driven at half crankshaft speed in the case of four-stroke engines and at crankshaft speed for two-stroke engines. The injection pump is provided with one pumping element per engine cylinder, and each outlet is connected by high-pressure steel piping to an injector, which is fitted in the engine cylinder head and consists of nozzle holder and nozzle. A fuel-feed pump is mounted on the side of the injection pump and is driven by one of the cams which operate the pumping elements. A preliminary filter is fitted to the suction side of the feed pump, to protect its suction and delivery valves, and a main filter is provided in the system between the feed pump and injection pump to prevent dirt, pipe scale, swarf or other foreign bodies in the fuel from damaging the pumping elements and nozzles.

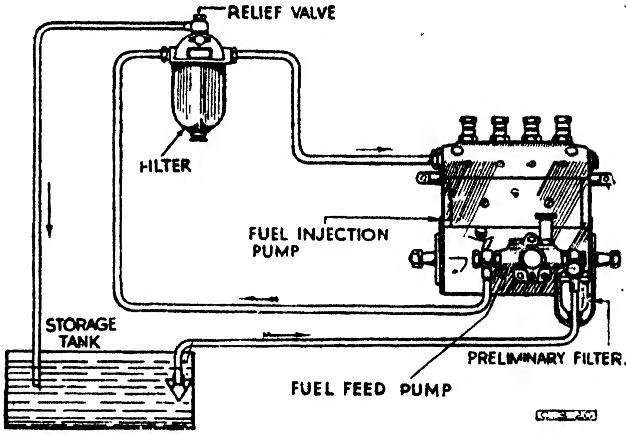


Fig. 1.—Typical fuel-injection equipment layout

Fuel is taken from the storage tank by means of the feed pump and is passed through the preliminary and main filters to the low-pressure side of the pumping elements in the injection pump. It is then pumped through the outlets to the injectors, which deliver it in a finely atomised condition to the combustion chambers in the engine cylinders.

As the fuel-feed pump is designed to deliver fuel in excess of the quantity normally required by the engine, a relief valve is arranged in the main filter to return the surplus to the storage tank. It will be observed that the relief valve is shown fitted at the highest point in the system, and this should always be arranged for, as it then ensures automatic air venting of the fuel system which eliminates air locks.

C.A.V. FUEL-INJECTION PUMPS

The C.A.V. injection pump is of the constant-stroke type, employing one pumping unit for each cylinder of the engine, and is available in two basic models :

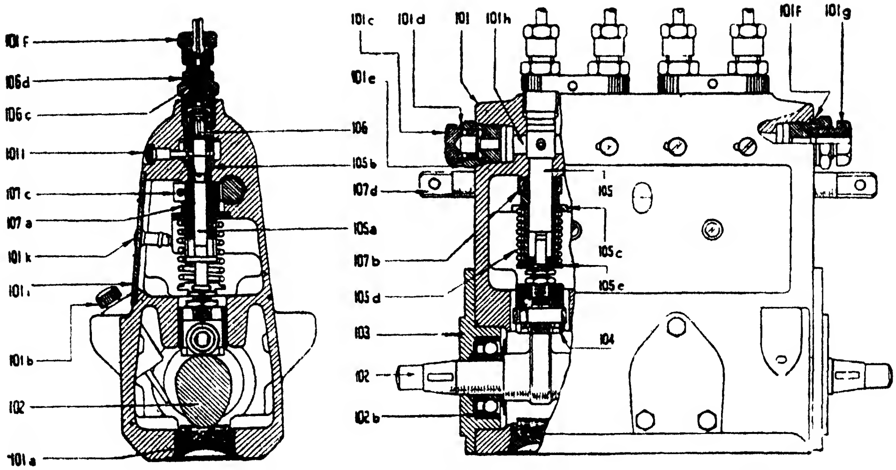


Fig 2.—Section through C.A.V. type BPE injection pump

101. Housing. 101*a*. Closing plug. 101*b*. Lubricating oil gauge rod. 101*c*. Inlet closing plug. 101*d*. Joint for inlet closing plug. 101*e*. Inlet connection stud. 101*f*. Joint for inlet connection stud. 101*g*. Fuel inlet nipple nut. 101*h*. Suction chamber. 101*i*. Inspection cover plate. 101*k*. Screw with spring ring for cover plate. 101*l*. Locking pin and joint. 102. Camshaft. 102*b*. Ball bearing. 103. Bearing end plate. 104. Plunger guide. 105. Pump element (plunger and barrel). 105*a* and *b*. Pump element (plunger and barrel). 105*c*. Spring plate, upper. 105*d*. Helical spring for plunger. 105*e*. Spring plate, lower. 106. Delivery valve and seating 106*c*. Delivery valve spring. 106*d*. Delivery valve holder. 106*f*. Delivery nipple nut. 107*a*. Regulating sleeve. 107*b*. Regulating toothed quadrant 107*c*. Clamp screw. 107*d*. Control rod.

(*a*) BPE, incorporating camshaft and tappet gear (see Fig. 1 and Fig. 2).

(*b*) BPF, without camshaft and arranged with base flange for mounting on a cambox built on the engine (see Fig. 3).

In both types the working principle is the same, and each pumping element comprises two essential components, namely :

Pumping element (plunger and barrel).
Delivery valve and seating.

The plunger is moved vertically in its barrel with a constant stroke by the tappet gear and cams (supplied in the pump with models BPE, see Fig. 2, or built into the engine with models BPF, see Fig. 3), and the output of fuel is determined by rotating the plunger in relation to its barrel by means of the control rod (107*d*) and regulating sleeve (107*a*).

Apart from the camshaft, the only other difference in design between the two basic types is that in order to make the BPF model a self-contained unit when it is removed from the engine, it is provided with special plunger guides (104*a*) and retaining rings (104*h*) ; this also entails the use of press bolt (105*f*) and special lower spring plates (105*e*).

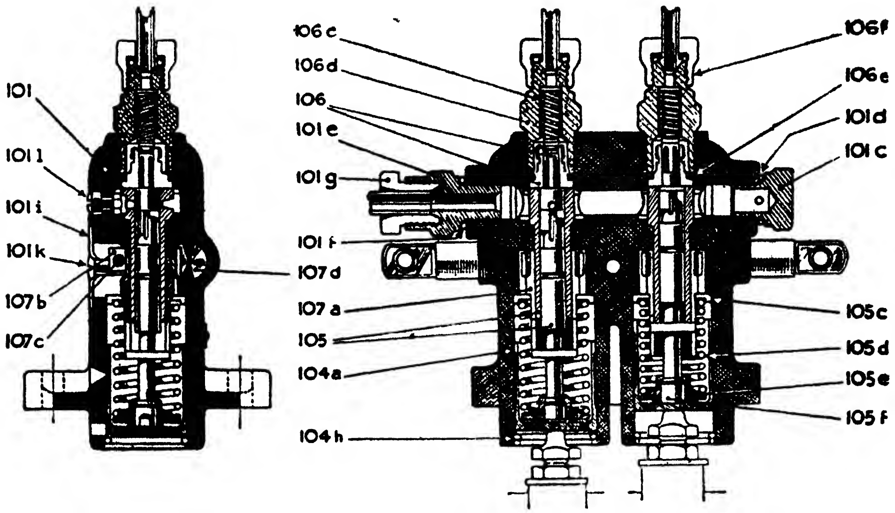


Fig. 3.—Section through C.A.V. type BPE injection pump

101. Housing. 101*c*. Inlet closing plug. 101*d*. Joint for inlet closing plug. 101*e*. Inlet connection stud. 101*f*. Joint for inlet connection stud. 101*g*. Fuel inlet nipple nut. 101*i*. Inspection cover plate. 101*k*. Screw with spring ring for cover plate. 101*l*. Locking pin and joint. 104*a*. Plunger guide. 104*h*. Spring ring. 105. Pump element (plunger and barrel). 105*c*. Spring plate, upper. 105*d*. Helical spring for plunger. 105*e*. Spring plate, lower. 105*f*. Press bolt. 106. Delivery valve and seating. 106*c*. Delivery valve spring. 106*d*. Delivery valve holder. 106*e*. Joint for delivery valve holder. 106*f*. Delivery nipple nut. 107*a*. Regulating sleeve. 107*b*. Regulating toothed quadrant. 107*c*. Clamp screw. 107*d*. Control rod.

Operation

The system of operation of the pump element, which is comprised of the plunger and barrel, is shown in Fig. 4. When the plunger is at b.d.c. as at (*a*), oil can enter through the barrel ports either by gravity flow from an overhead tank, or force feed from a fuel-feed pump, the latter being the most usual arrangement. In a primed system, of course, the barrel and the pipes leading from the pump to the injectors are full of oil. As the pump plunger rises, a certain amount of fuel is pushed back through the barrel ports, until the plunger reaches the position (*b*) where the top land of the plunger has closed both ports. The fuel above the plunger is then trapped, and its only outlet is *via* the delivery valve (part 106) which is mounted on top of the pump barrel (see Fig. 3). The pressure exerted by the rising plunger upon the oil causes this to lift the valve and to enter the pipe which connects the pump to the injector. As this is itself already full of oil, the extra oil which is being pumped in at the pump end causes a rise in pressure throughout the line and lifts the nozzle needle (or injector valve). This permits oil to be sprayed into the engine combustion chamber. Thus, at this moment we have oil

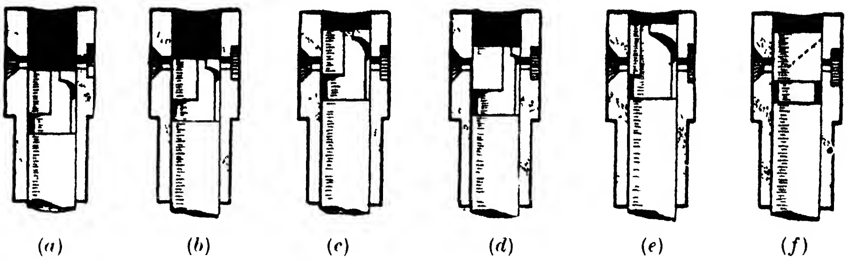


Fig. 4.—C.A.V. INJECTION PUMP BARREL WITH VARIOUS PLUNGER POSITIONS

being pumped into the line at the pump end, and an equal quantity being pushed out at the nozzle end. This continues until the plunger reaches the position shown at (*c*). Here the lower edge of the control helix has uncovered the barrel port, thus allowing fuel to be by-passed back to the suction chamber (which is under a very much lower pressure than the fuel oil above the plunger) by way of the vertical slot. This causes the delivery valve to shut under the action of its spring, and with the consequent collapse of pressure in the pipe line, the nozzle valve also shuts.

The plunger stroke is always constant, but that part of it which is actually pumping is variable. By means of the helical edge which runs around the plunger, which itself can be rotated within the barrel (see Fig. 3), it is possible to make this point of cut-off occur earlier, or later, in the stroke—compare positions shown at (*d*) and (*e*), which are full load and idling respectively. To stop the engine, the plunger is turned so that the vertical slot coincides with the barrel port (see *f*) during the whole of the plunger stroke; thus no fuel is delivered. The position of the plunger stroke at which the helical edge will uncover the port is adjustable by rotating the plunger axially by means of a toothed quadrant 107*b* (see Fig. 3) which is clamped to a sleeve 107*a*, having slots engaging the lugs of the plunger at its lower end.

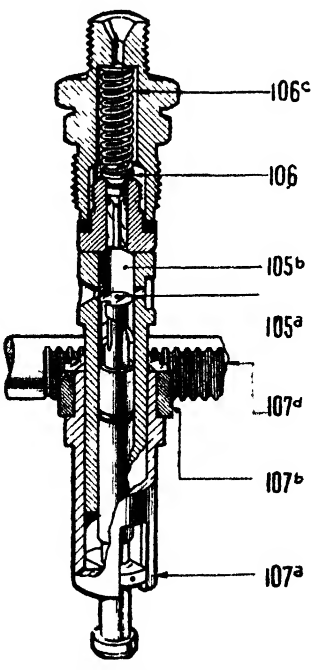


Fig. 5.—C.A.V. INJECTION PUMP ELEMENT IN SECTION

105*a*. Pump plunger.
105*b*. Pump barrel.
106. Delivery valve and seat.
106*c*. Valve spring.
107*a*. Control sleeve.
107*b*. Toothed quadrant.
107*d*. Control rod.

Troubles and Remedies

Fuel - injection difficulties may arise on engines from numerous causes, some of which may be traced to the injection pumps, and, therefore, before proceeding with particulars of servicing, it may be of interest to briefly review some of the possible causes and suggested cures.

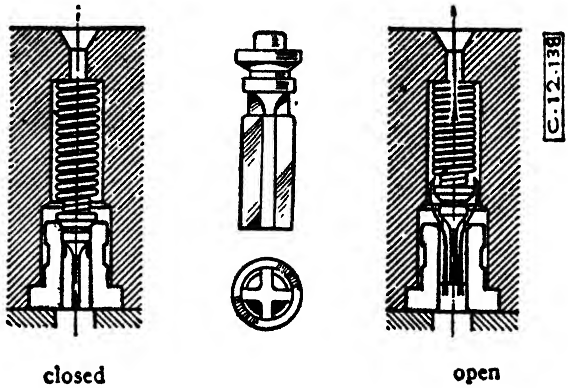


Fig. 6.—C.A.V. INJECTION PUMP DELIVERY VALVE

In the tables the word "pump" applies to the pump unit block as a whole or to individual elements.

FUEL-INJECTION PUMPS—FAULTS AND REMEDIES

I.—ENGINE WILL NOT START, OR STOPS AFTER A SHORT TIME

Possible cause	*Location*	*Condition or suggested remedy for correct working*
Pump does not deliver fuel.	(*a*) Fuel cock.	Must be open.
	(*b*) Fuel tank.	Must contain an adequate supply.
	(*c*) Fuel inlet pipe or filter elements.	Clean—examine, and if choked replace cloth or clean filter pad.
	(*d*) Air in pump.	Air-vent filter and pump.
	(*e*) Pump plunger 105*a*.	If worn, replace element 105. Inspect filter and if necessary insert new cloth of felt.
	(*f*) Delivery valve 106.	Clean and inspect. If worn or damaged replace both valve and seating.
Pump does not deliver fuel uniformly.	(*g*) Air in pump.	Air-vent filter and pump.
	(*h*) Delivery valve spring 106*c*.	If broken, replace.
	(*j*) Delivery valve 106.	If damaged on face or guide, replace complete.
	(*k*) Plunger spring 105*d*.	If broken, replace.
	(*l*) Pump plunger 105*a*.	If sticking, clean and refit. If trouble continues replace element 105 complete.
	(*m*) Fuel inlet pipes or filter elements.	Proceed as (*c*).
	(*n*) "Head" between tank and pump.	Increase if too small.
The moment of injection commencement has altered.	(*o*) Tappet adjusting screw.	If loose, readjust and well tighten nut.
	(*p*) Cam profiles.	If badly worn, replace cam.

II.—ENGINE DOES NOT PULL

Possible cause	*Location*	*Condition or suggested remedy for correct working*
Quantity of fuel delivered per stroke is insufficient.	(*a*) Delivery valve 106.	If leaking, scored, or damaged, replace both valve and seating.
	(*b*) Pressure system joints.	If leaking, clean joint faces and tighten.

III.—ENGINE "CARBONISED" BADLY

Possible cause	*Location*	*Condition or suggested remedy for correct working*
Quantity of fuel delivered per stroke is excessive.	Regulating quadrant 107*b*.	If moved, due to screw 107*c* being loose, adjust to mark and tighten screw thoroughly.

IV.—MAXIMUM SPEED OF ENGINE TOO HIGH

Possible cause	*Location*	*Condition or suggested remedy for correct working*
Control rod 107*d* has jammed.	(*a*) Pump plunger 105*a*.	If seized, dismantle and clean. If damaged, replace.
	(*b*) Control rod 107*d*.	Clean toothed rack if coated with dirt or other foreign matter.

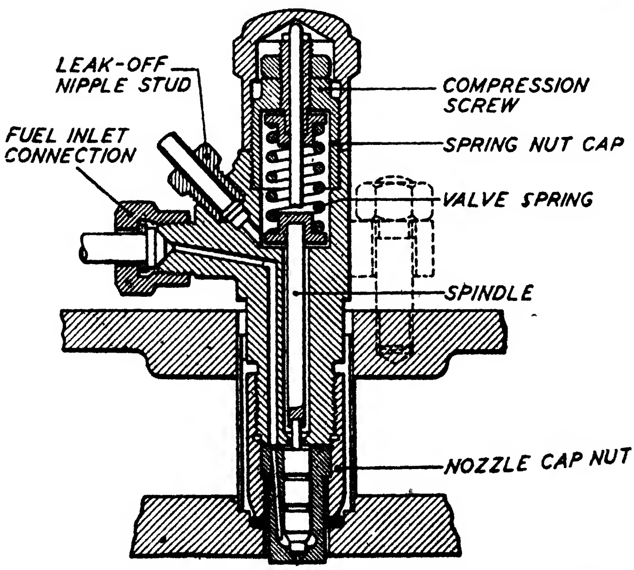


Fig. 7.—SECTION OF C.A.V. NOZZLE HOLDER, TYPE BKB

Sprayer Nozzles

Fig. 7 shows a sectional view of the C.A.V. nozzle holder. Sprayer nozzles are designed to suit the shape of the combustion chamber, and are made in many types, and vary in sizes of holes to suit the volume of the cylinder.

Fig. 8 shows six different types of nozzle made by C.A.V. The sprayer should always be kept clean.

and compared with the engine manufacturers' recommended value. The spray should now be observed for uniformity at a rate of pumping of not less than twenty strokes per minute—corresponding to minimum engine speed value.

The shape of the spray should also be examined for symmetry. There should be no semblance of a jet of fuel; the end face of the nozzle should remain dry and no drip should come from it.

HINTS ON MAINTENANCE

Lubrication.—This cannot be too strongly emphasised, as two or three minutes' running without any oil may be disastrous to a bearing which is white-metal lined. The bearing quickly heats up and melts the white metal, and the remedy is to fit a spare bearing, or to have the damaged one remetalled, in which case the engine must be shut down for some time. The oiling of the outer bearing must not be neglected.

NOZZLE FAULTS

Fault	*Possible Cause*	*Remedy*
Nozzle pressure too high.	1. Adjusting screw shifted. 2. Nozzle needle seized up corroded. 3. Nozzle needle seized up dirty and sticky. 4. Nozzle openings closed up with dirt or carbon.	Adjust for prescribed pressure. Replace nozzle and needle. Clean the nozzle. Clean the nozzle.
Nozzle pressure too low.	1. Adjusting screw shifted. 2. Nozzle needle seized up corroded. 3. Nozzle needle seized up dirty and sticky. 4. Nozzle spring broken.	Adjust for prescribed pressure. Replace nozzle and needle. Clean the nozzle. Replace the spring.
Nozzle drips.	Nozzle leaky due to carbon deposit.	Clean the nozzle. If this does not clear the fault, replace nozzle and needle.
Form of the spray distorted. Has a "fin."	1. Nozzle dirty, carbon deposit. 2. Nozzle needle damaged.	Clean the nozzle. Replace nozzle and needle.
Nozzle does not buzz while injecting.	Needle too tight, binding, or needle seating leaky.	Clean the nozzle. If this does not clear the fault, replace nozzle and needle.
Too much oil escaping at the leak-off oil pipe.	1. Nozzle has too much play. 2. Nozzle holding nut not tight. 3. Foreign matter present between contact faces of nozzle and nozzle holder.	Replace nozzle and needle. Tighten the nut. Clean the contact faces and the nozzle.
Nozzle blueing.	Faulty installing, bad tightening or bad cooling.	Replace nozzle and needle.

Cooling Water.—This must be carefully attended to, as failure to turn on the water before starting the engine, and then to hurriedly remedy this omission after the engine has run a few minutes, would in all probability crack the breach end or cylinder jacket. It is also important that the cooling water should be drained from the cylinder when shutting down for the week-end in frosty weather, as failure here would also result in a cracked water jacket.

Bearings.—The bearings must be kept in good order and the crankshaft well aligned, as a malaligned crankshaft, however strong, will ultimately break.

Bad Atomisation and its Consequences

After dismantling an atomiser, care should be taken that not only are the parts replaced as originally, but also that all metallic joints are seating, and if there are any signs of leakage, new joints should be used. Bad atomisation of the fuel may be the cause of local overheating and burning of the piston. This in turn may be the cause of overheating and cracks, but providing that the fuel pump and its timing are in order, and the atomisers are cleaned regularly, these troubles should not be experienced.

Clean Atomisers Regularly

Atomisers should be cleaned regularly with paraffin, after about 250 hours' running, but their condition will vary with the quality of fuel oil used and the load on the engine. By cleaning periodically as above it should not be necessary to have to grind-in the valve seats and sprays.

SIMMS 6 P A FUEL-INJECTION PUMP

The Simms P A Series Fuel-injection Pump is constructed for engines having from one to six cylinders.

Construction

The following are the chief constructional details of this type of fuel pump :

(1) The pumping element is illustrated in Fig. 10. The plunger has the comparatively short stroke of 7·5 mm., which reduces spill disturbance and the stress in the plunger spring. The plunger helix is designed to preserve the maximum wearing surface at the upper end of the plunger.

(2) The delivery valve is of the piston pressure-relief pattern.

(3) The tappets are provided with a screw adjustment and needle-roller bearings to the cam follower.

(4) The control rack and pinion mechanism is made as light as possible to give sensitive governing at idling speeds.

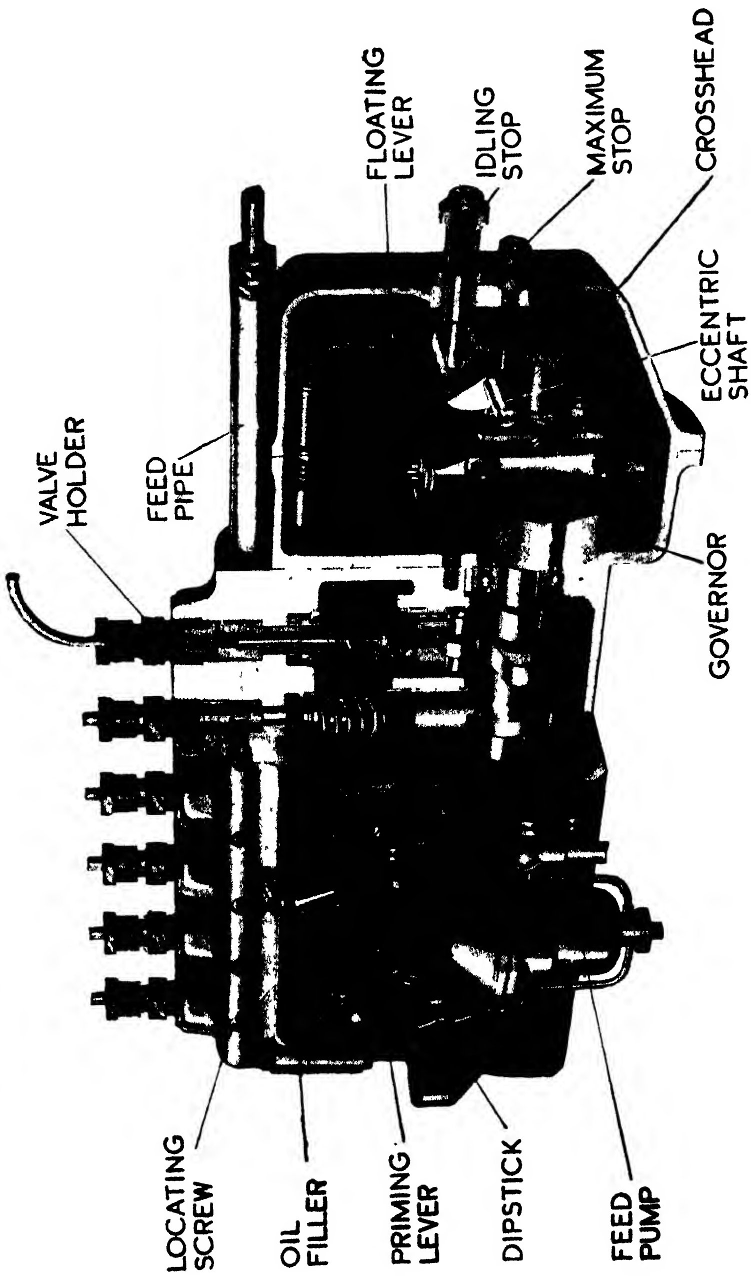


Fig. 10.—Simms 6 P A fuel-injection pump

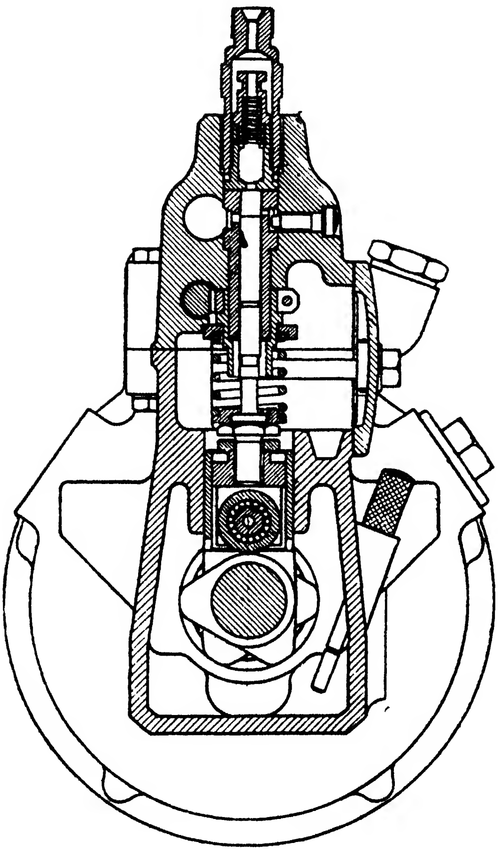


Fig. 11.—Section of Simms fuel-injection pump

(5) The pump body is split horizontally into two halves, the upper half containing the fuel passages and pump elements and the lower half the camshaft and tappets, the two halves being bolted together by six bolts.

This construction gives excellent accessibility, since it is possible to remove the upper half containing all the pumping elements, etc., without disturbing the camshaft and governor.

(6) The governor controls the maximum and idling speed of the engine only, intermediate speeds being controlled by the lever provided.

(7) A common lubricating oil level is used for the pump and governor, a dipstick being provided in the cambox for checking the level.

Operation

The method of operation is as follows :—

(1) When the plunger is at the bottom of its stroke fuel enters the barrel through inlet port *A*.

(2) The upstroke of the plunger cuts off this port and injection of the fuel then takes place.

(3) Injection ceases when the helical groove *C* in the plunger meets the spill port *B* in the barrel. The spilled fuel can then pass down the central hole *D* in the plunger and out through port *B*.

(4) The quantity of fuel delivered is controlled by rotation of the plunger in relation to the barrel.

(5) The pressure generated by the plunger lifts the delivery valve *E* against its spring until the fuel can flow past the valve through the grooves *F*.

At the close of injection the valve falls again on to its seat. Immediately the piston *G* re-enters the guide the fuel system above the valve

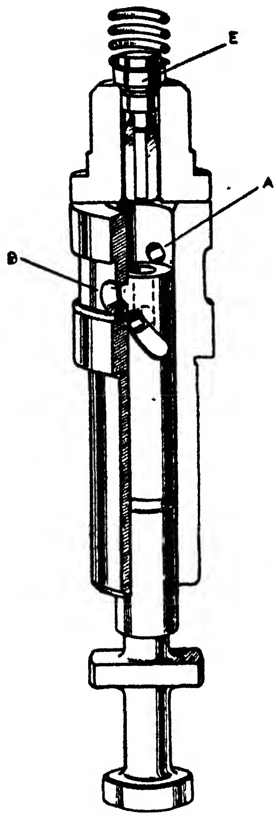


Fig. 12.—PUMP ELEMENT WITH PLUNGER AT BOTTOM OF STROKE

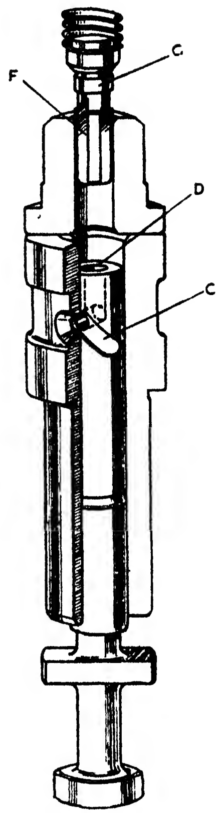


Fig. 13.—PUMP ELEMENT WITH PLUNGER AT COMMENCEMENT OF SPILL

is cut off from the pump. The remaining valve travel then increases the volume of this system and reduces or unloads the pressure in the pipe, thus preventing dribble from the nozzle.

Lubrication

(1) Twice weekly the lubricating oil level in the pump should be checked by the dipstick and light engine oil added if necessary to bring the oil level up to the mark on the dipstick. After filling, run the engine for a few minutes to circulate the oil through the pump and governor, and again check the level, adding more oil if necessary.

(2) Filters—Every two weeks clean filter and drain off any sediment from the filter bowl.

(3) Injectors—Every four weeks remove injectors and test on hand pump for correctness of spray and pressure setting. If a hand pump

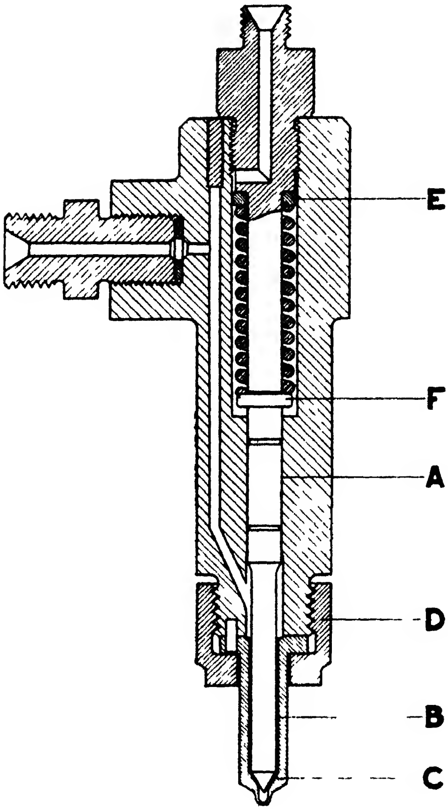


Fig. 14.—SECTIONAL VIEW OF SIMMS REMOTE SEAL ATOMISER, TYPE AB

A Needle guide.
B Clearance between needle and nozzle.
C Conical needle seat.
D Nozzle securing nut.
E Shim.
F Thickness of washer.

is not available the injectors may be tested by removing them one at a time from the engine to idle on the remaining cylinders.

(4) Pipe Unions — Once weekly inspect all pipe unions on the injection system when the engine is running and tighten any showing signs of oil leakage.

Simms Remote Seal Atomiser Type AB

Fig. 14 shows the construction of this atomiser. Note that whilst the nozzle is exposed to the heat of the combustion chamber, the seal in the atomiser body is located well outside the cylinder head, where cooler conditions prevail.

The spring pressure on the nozzle can be adjusted by varying the thickness of the shim "E."

The lift of the needle can be similarly adjusted by varying thicknesses of the washer "F."

Owing to the extremely accurate manufacturing methods employed it is possible to replace either the needle or the nozzle independently of each other. The needles are graded so that by selection it is possible to fit a new needle to the atomiser body.

BELLISS & MORCOM

Another interesting example of fuel-injection equipment is that manufactured by Messrs. Belliss & Morcom Ltd.

Belliss & Morcom Fuel-injection Pump

Figs. 15 and 16 show a sectional view of the B. & M. fuel pump.

It is a cam operated, spring return plunger pump of the constant stroke type.

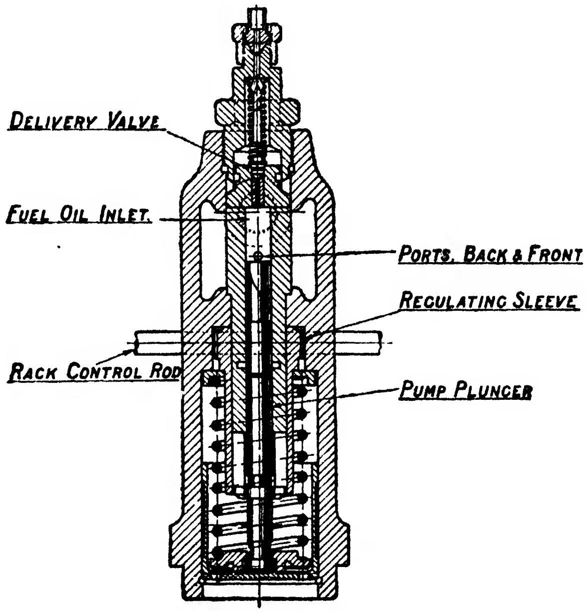


Fig. 15.—THE B. & M. FUEL-INJECTION PUMP

Operation

When the plunger is at its lowest position, the two ports in pump barrel are open and bore is full of fuel. On the next up or delivery stroke the plunger displaces fuel back through the ports until its top edge covers them, so that remaining fuel is pressed out through delivery valve *via* the connecting piping to the nozzle in the cylinder head. As long as the ports are kept covered by the plunger, the pump will continue to inject fuel at the nozzle, but before the plunger reaches the top of its stroke, the helical edge of the annular groove has uncovered the "suction" port, which enables the enclosed fuel to escape back through this port to the common suction chamber.

The position of the plunger stroke at which this helical edge will uncover the "suction" port is adjustable by rotating the plunger through a determined axial angle by moving the control rod. By moving control rod in direction of arrow engraved on control rod (and marked "stop") the output is reduced to zero, and by moving in the other direction increased, until maximum output is reached.

These control rod positions are regulated by the governor.

Belliss & Morcom Atomiser

The atomiser used in Belliss & Morcom engines is illustrated in Fig. 17. It is of very simple construction, and providing the fuel strainers are in operation and the engine is run with normal attention, does not require frequent cleaning, but it should be inspected after every 500 hours' running, according to the quality of fuel used. To dismantle or inspect an atomiser it is necessary to remove it from the cylinder head.

To Examine and Clean the Nozzle

(1) Unscrew the nozzle cap nut (1).

(2) Remove the nozzle complete (2) and lift out the nozzle valve, taking care not to touch the highly ground guide surface with the fingers or tools.

(3) The nozzle body and nozzle valve should then be washed in clean and strained fuel oil to ensure that they are entirely free from grease, grit or oil. The nozzle valve can now be returned to the nozzle body, after rinsing out in clean fuel oil, and must on no account be touched with a cloth, waste or dirty hands.

(4) The nozzle valve is a proper fit for the nozzle body if it can be rotated freely on its seat with the finger tips without "sticking" and without "rattle."

(5) Make sure that the flange of the nozzle body and the face of the nozzle holder are faultlessly clean and free from damage. Replace the nozzle complete on nozzle holder and tighten down cap nut with the special ring spanner.

RUSTON & HORNSBY FUEL-INJECTION EQUIPMENT

For the smaller range of their vertical engines, Messrs. Ruston & Hornsby Ltd. use C.A.V. pumps, which are referred to earlier in this section. For the larger ranges they use a fuel pump of their own design, which is illustrated in Fig. 18. It will be observed that though this varies somewhat from the C.A.V. pattern, the general principle upon which the pumps operate is similar.

The Ruston Atomiser

The atomiser is illustrated in Figs. 19 and 20. Fig. 20 shows the method of using the extractor for dismantling the nozzle. The procedure is as follows:

Remove the atomiser overflow connection 12 (Fig. 19) and screw out plug 9 (Fig. 19). Screw the extractor (Fig. 20) into the needle valve stop. Tighten the locknut **FN** (Fig. 20) on to the extractor washer, and the needle valve stop, together with the copper washer, can be withdrawn. Should the nozzle 2 (Fig. 19) stick, this can be easily removed by giving the nozzle a light tap, using a hollow soft-copper draft. Care must be taken not to damage the internal parts of the atomiser, and these parts should not be touched with a file or a coarse abrasive material. It is advisable, after the atomiser has been taken apart two or three times, to use a new copper-joint ring 8 (Fig. 19).

Nozzle holes should be cleaned with the wire broach supplied with each engine, and also included with the reconditioning tools.

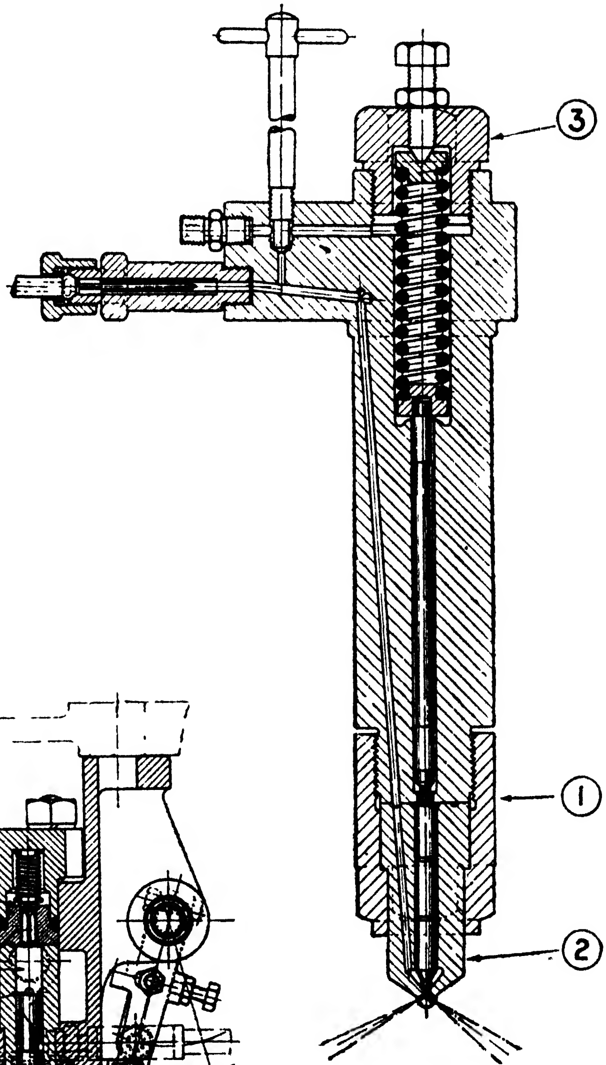


Fig. 17. — Sectional view of Belliss & Morcom atomiser

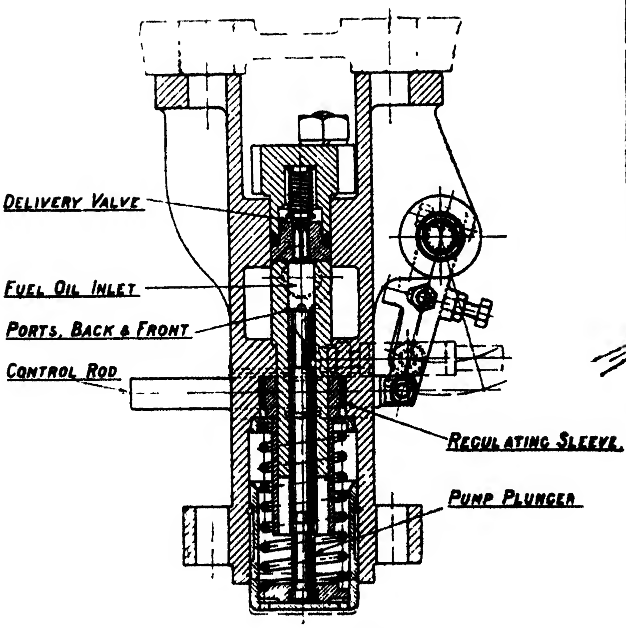


Fig. 16.—The B. & M. fuel pump

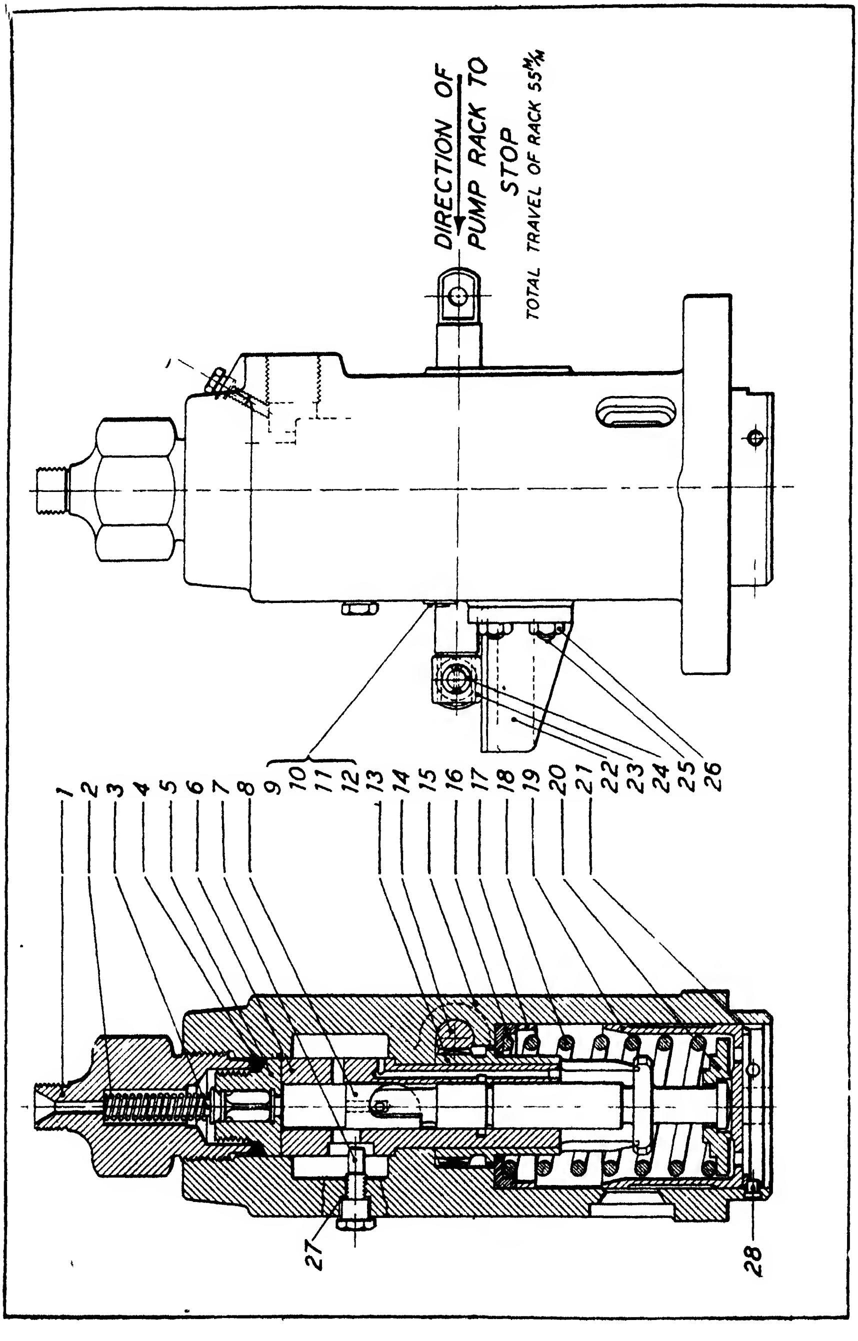
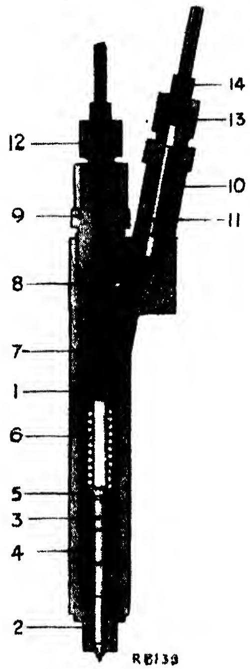
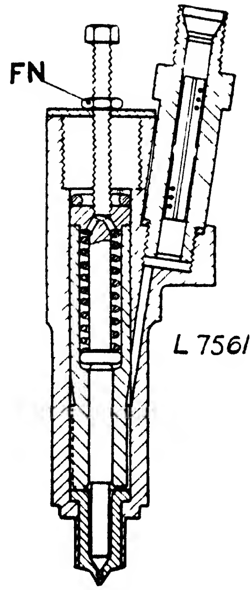


Fig. 18.—Arrangement of Ruston size "D" fuel pump with helix



1. Atomiser body.
2. Atomiser nozzle.
3. Atomiser needle valve.
4. Atomiser needle valve guide.
5. Atomiser spring pad.
6. Atomiser spring.
7. Atomiser needle valve stop.
8. Atomiser plug joint.
9. Atomiser plug.
10. Atomiser delivery connection and filter body.
11. Atomiser edge type filter.
12. Atomiser overflow connection.
13. Atomiser delivery pipe union nut.
14. Atomiser delivery pipe nipple.



Figs. 19 and 20.—Ruston atomiser, mark 37

KEY TO FIG. 18

1. Delivery valve connection.
2. Delivery valve spring
3. Delivery valve.
4. Delivery valve seat joint.
5. Delivery valve seat.
6. Plunger guide.
7. Plunger guide and rack-locating screw.
8. Plunger.
9. Setting pointer.
10. Setting pointer screw.
11. Setting pointer distance piece (thin).
12. Setting pointer distance piece (thick).
13. Plunger operating pinion.
14. Plunger operating rack.
15. Fuel pump body.
16. Plunger spring retaining collar (under).
17. Plunger spring ring.
18. Plunger spring.
19. Plunger tappet.
20. Plunger spring retaining collar (lower).
21. Fuel pump body plunger retaining collar.
22. Rack support.
23. Pump control rack-pin housing.
24. Pump control rack pin.
25. Stud.
26. Slide retaining nut.
27. Joint for fuel-pump plunger guide.
28. Fuel-pump body plunger tappet retaining screw.

Fig. 21. - RUSTON ATOMISER TESTING PUMP

Reassembling the Atomiser

To assemble proceed as follows:

(1) Drop the small spring pad 5 into the hole in the needle guide 4 and make sure that it lies flat (see Fig. 19).

(2) Place the spring 6 over its stop 7 and insert spring and stop into the needle guide (see Fig. 19).

(3) Fit the needle valve 3 into the guide and fit the nozzle 2 in the end of the needle and insert the full assembly into the atomiser body.

(4) For certain types of engines, such as Classes HR, VR and VQ, the nozzle must be located in the atomiser body so that the holes will spray between the air and exhaust valves. To ensure this the holes in the nozzle should be at right angles to the filter body. On more recent atomisers marks will be found cut in the nozzle and on the end of the atomiser body. These marks should be in line.

It will be seen that by assembling the internal parts in this order, the whole assemble can be inserted into the atomiser body, thus avoiding the likelihood of parts being misplaced, as may occur if they are dropped into the body separately.

(5) The atomiser should now be held in a vice.

(6) Drop the copper washer 8 (Fig. 19) into position, making sure that it is approximately in the centre.

(7) Smear a little lubricating oil on threads of the plug 9 and tighten down securely.

(8) The atomiser should now be tested, taking care that the spray is not allowed to impinge on to the hands, as the jets have been known to puncture the skin and cause skin trouble.

(For use of the pump see below.)

If the spray is still unsatisfactory, or leakage seen at the holes, the atomiser should be dismantled and reconditioned.

Ruston Atomiser Testing Pump

This pump, which is illustrated in Fig. 21, is designed for use in cleaning the atomiser, for checking the correct functioning at stated intervals, and for testing the atomiser after it has been reconditioned. The method is as follows:

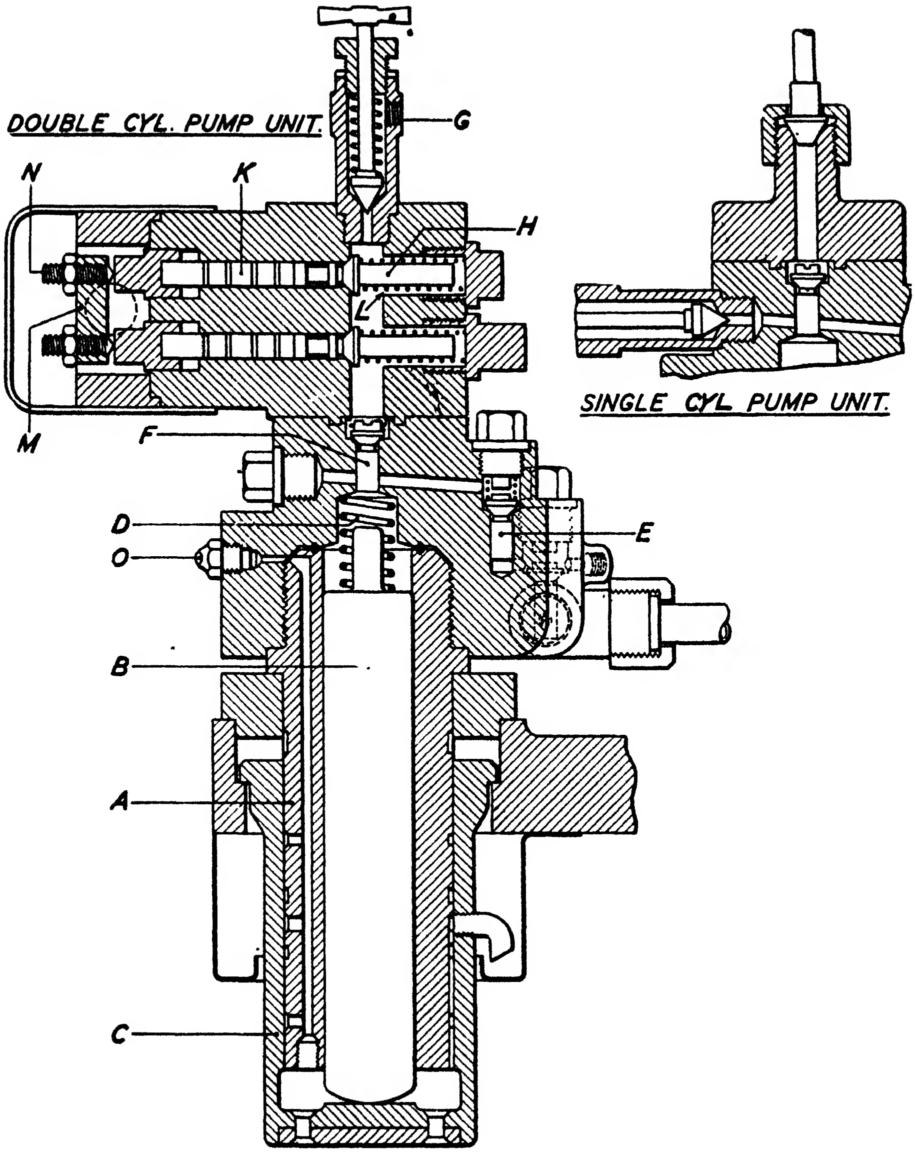


Fig. 22.—A SECTIONAL VIEW OF THE ROBEY FUEL PUMP, SHOWING BOTH SINGLE- AND DOUBLE-CYLINDER PUMP UNITS

Clean well-strained fuel oil is poured into the container, and the pump is freely operated until its discharge is free of air. The adaptor nut is then connected to the atomiser.

The necessity for using clean fuel oil, free from any foreign matter,

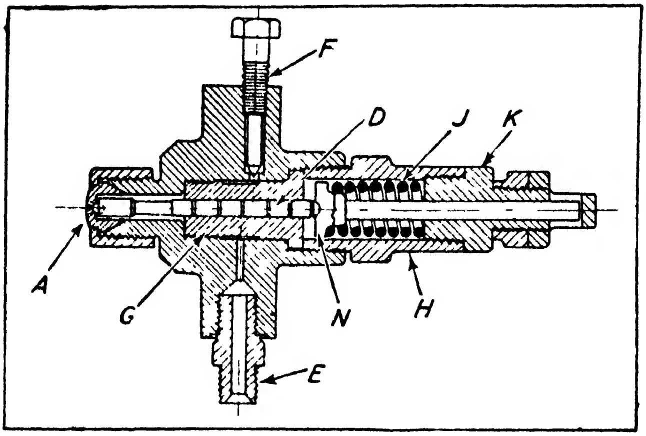


Fig. 23.—A SECTIONAL VIEW OF THE ROBEY SPRAYER

is particularly emphasised, as the greater part of atomiser wear and troubles are due to the use of unclean fuel oil.

At first, fuel oil should be forced through the atomiser for the purpose of cleansing, with the gauge valve closed. Then gradually open the gauge valve sufficiently for the operator to be able to read a steady pressure upon the gauge.

If the gauge continues to show a reading considerably above the correct atomising release pressure. further pumping should be done with the gauge valve closed, the aim being to clean the atomiser in this way by the force pump until a further trial shows the gauge to·read approximately the correct release pressure, as stamped on the plate attached to the atomiser.

A good spray should be cut off without a dribble at each pump stroke and the quantity of spray from each hole should be approximately the same.

Ruston Governor

Details of the Ruston Governor will be found in the introductory section, see page 19.

ROBEY PUMP AND ATOMISER

Robey Fuel Pump

Fig. 22 shows a sectional view of the Robey fuel pump. It will be seen that this pump has no variable cut-off, but the amount of fuel is varied by giving the plunger a variable stroke, which is controlled by the engine governor.

The double-cylinder pump unit has a distributor mounted on top of the pump, and worked by means of an eccentric from the camshaft. The distributor valves *K* have plenty of overlap, so that when the pump plunger has reached its maximum stroke the valve is still open and there is no chance of any damage being done.

The fuel-pump cam is fitted with two toes instead of a single toe, so that the pump plunger lifts each revolution of the crank, each cylinder in turn thus getting its supply of oil. This is a very robust pump and gives little trouble.

Robey Atomiser

The performance of the engine depends largely on the ability of the atomiser to convert the fuel into a condition suitable for combustion. The charge of fuel should be injected into the combustion chamber in the form of a very fine spray, which cuts off immediately without any dribbling. Fig. 23 shows a sectional view of the Robey sprayer. A steel atomiser nozzle *A* is fitted to the end of the atomiser body and forms a seating for the ball in the end of the plunger *D*, which is held to its seat by a strong spring *J* acting on part *N*, both of which are contained in the spring box *H*. The load on the spring and the plunger *D* is fixed by the hexagon cap *K*, and can be altered only by inserting washers.

This load is adjusted when the sprayer is tested by the makers, so that the ball valve opens with a fuel pressure of approximately 3,000 lb. per sq. in. The fuel enters the atomiser by way of the pipe connection *E*, and flows to an annular chamber surrounding the filter bush *G*, finally reaching the nozzle, and when the requisite pressure is obtained by operation of the fuel-pump plunger, the plunger *D* lifts, and the charge of oil is sprayed through the fine holes drilled radially in the nozzle itself, but instantly ceases when the pressure is cut off.

The needle valve *F* provides an air-release valve, so that the fuel-injection system may be primed before starting. It is important that the fine holes in the atomiser nozzle should be kept clean, otherwise the fuel cannot be atomised properly, and there will be difficulty in starting the engine and securing sufficient combustion.

Robey Governor

A description of the Robey Governor will be found in the introductory section, see page 19.

Chapter IV

INDICATOR TESTS ON DIESEL-TYPE ENGINES

NOW that compression-ignition engines are being used for motor vehicles, and are being made to run at very high speeds, it is important, so far as indicators are concerned, to distinguish between engines of this type and those running at comparatively slow speeds, such as ships' main engines and auxiliaries and engines used for driving large electric generators. Each type has its own indicator, and the following chapter relates to the low-speed model. We shall now consider indicating, say, a ship's main diesel engine, the apparatus required consisting of the indicator, indicator valve, and reducing gear, all of which differ from the corresponding units used for steam engines.

The Indicator

Fig. 1 shows a well-known type of diesel engine indicator, and although it operates on a similar principle to the steam engine indicator, it has a number of features to suit the exacting conditions met with in compression-ignition practice. Since cylinder pressures are much higher, the indicator is strengthened throughout, and while double—instead of single—coil springs are used to prevent the use of unnecessarily heavy spring wire, which would unduly stress the instrument, a piston of reduced area is fitted. This means that with the same engine pressure in the indicator cylinder, a spring of only half strength gives the same diagram height with a half-area piston and only half the force is felt by the piston rod. The piston, which is hardened and of heat-resisting steel, has grooves cut in its surface to collect carbon and other grit blown into the indicator cylinder by the engine gases. These channels also accommodate lubricating oil. The recording drum allows for a diagram 2 in. high and 4 in. long.

Other notable points include a double pulley for the cord, and a strong arch for protecting the parallel motion ; also the indicator is often fitted with spare cylinders and pistons of still smaller areas and a " detent " gear, so that the drum can be stopped for changing the diagram paper without unhooking the cord.

The Diesel Indicator Valve

When indicating a diesel engine, it is found that if an ordinary indicator cock is used, seizure of the cock plug takes place owing to the intense heat. Therefore a valve is used instead, and it is of special design, so that the indicator can be opened either to atmosphere for taking the atmospheric line or to the engine cylinder. A convenient type of valve is shown in Fig. 2. This has only one handle, is straight through (bends cause diagram inaccuracy), and is double-seated, so that when the engine is isolated, as shown in the illustration,

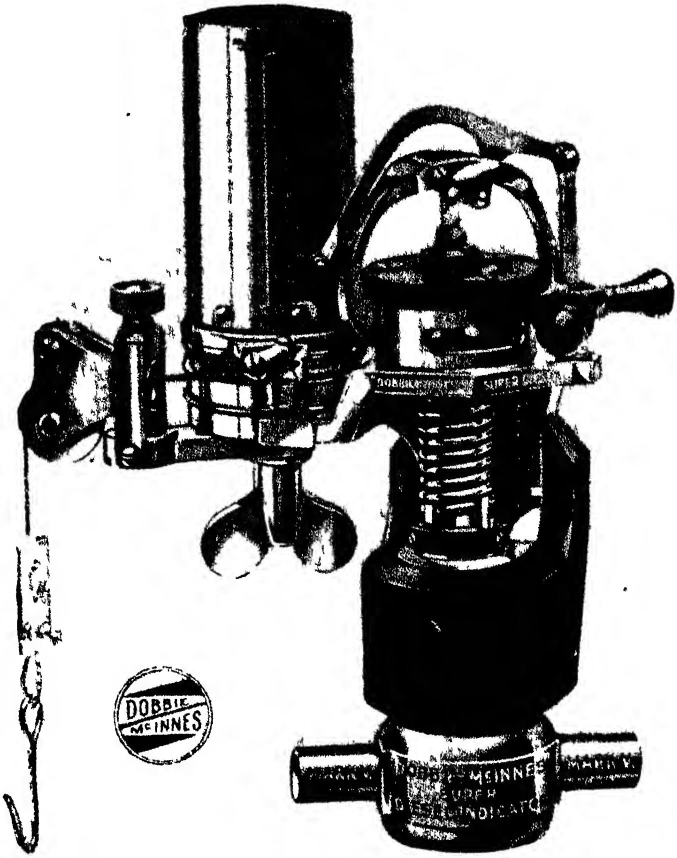


Fig. 1 —" DOBBIE-MCINNES " DIESEL ENGINE INDICATOR

the indicator is open to atmosphere, and when the spindle is screwed outwards the upper seat comes into play, closing the atmospheric hole and opening the indicator to the engine. No stuffing box is required with this valve, and as the spindle is screwed with a " quick " thread, the full movement can be accomplished in under two turns of the handle—more or less a flick of the wrist.

Reducing Gears

Unlike the steam engine, the diesel has a camshaft which is not far from the indicating points. This shaft is therefore conveniently used for the reducing gears—the contrivances used to actuate each indicator drum so that the movement of the latter shall be a reduced-scale copy of the

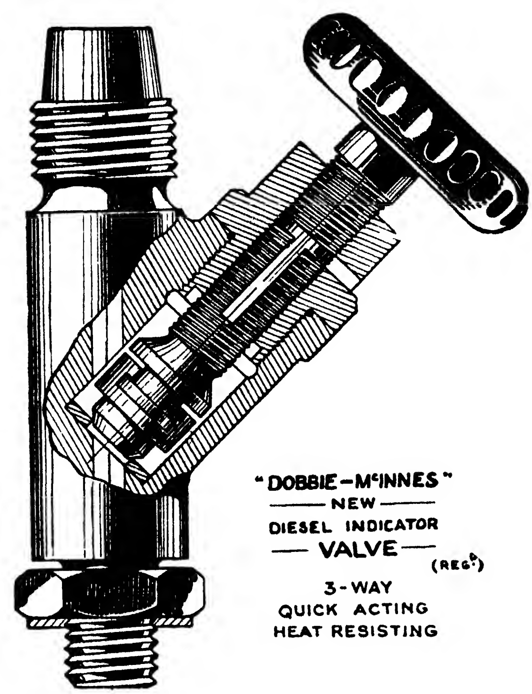


Fig. 2.—"Dobbie-McInnes" diesel indicator valve, shown closed to engine and indicator, opened to atmosphere

motion of the particular engine piston. Before the gears are fitted, it must be remembered that the drums must be pulled forward and backward once while the respective pistons move from top centre to bottom centre and back again; also that the two-cycle engine camshaft rotates once for every revolution of the crankshaft and the four-cycle camshaft only half a turn per crankshaft revolution.

Fig. 3 illustrates an eccentric type gear often fitted to the camshaft of a two-cycle engine; it will be noted that it is really a small reproduction of the connecting rod and crank of the engine, and to obtain a correct diagram it is important that:

$$\frac{\text{distance a}}{\text{distance b}} = \frac{\text{length of engine connecting rod}}{\text{length of engine crank}}$$

For a four-cycle engine a double-cam gear is frequently used (see Fig. 4).

When constructing this type of gear it is insufficient merely to fit two semicircular cam profiles on opposite sides of the shaft, even though they may be accurately set so that their peaks are under the rocker arm roller when the engine is on top dead centre; the cam profiles must be accurately designed to allow for what is known as the eccentricity of the connecting rod. No allowance need be made for this when fitting a reducing gear to

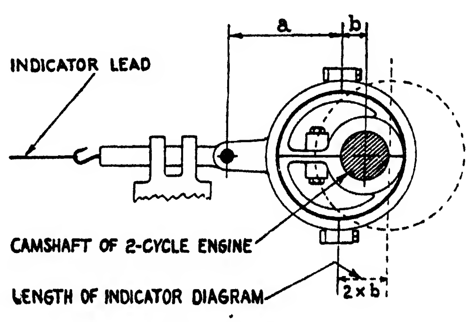


Fig. 3.—Eccentric type gear

a/b must equal engine connecting rod to crank ratio.

an engine cross head, but we are now dealing with a rotary part between which and the piston the connecting rod and crank intervene.

Connecting Up the Reducing Gear

If reducing gears have not been fitted by the engine builders, this must be done in accordance with the above, and the gears must be set so that the points to which the indicator leads are to be attached will move in phase with the respective pistons. Indicators and valves are then screwed into the cylinder tail pipes, which should be of large bore and as straight as possible. A lead made of indicator cord, steel tape, or wire is stretched between the hook or ring on each gear by a strong spring to a fixed pin on the engine, the spring being used to keep the lead taut—see Fig. 5—and the lead should be taken as near to the indicator as possible, with the pin preferably beyond it. A loop is made in the lead or attached to it for the indicator cord hook.

Setting the Drum Cord

Any one piston is put on top centre, at which point the indicator lead will be at the end of its stroke. The drum cord is lengthened or shortened until, when hooked to the loop, the drum is clear of the stop. On slowly turning the engine one revolution, the drum should

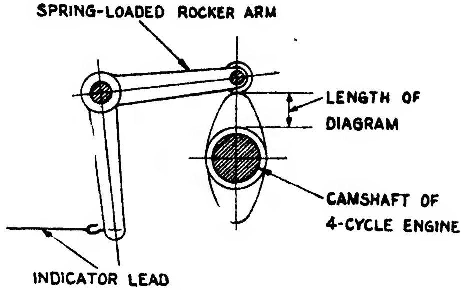


Fig. 4.—CAM TYPE GEAR

Cam profiles must be accurately designed. Rocker arms shown of equal length.

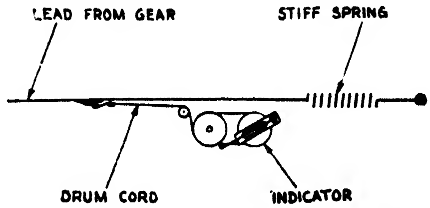


Fig. 5.—METHOD OF CONNECTING INDICATOR

Stiff spring relieves indicator drum spring from necessity of keeping lead taut.

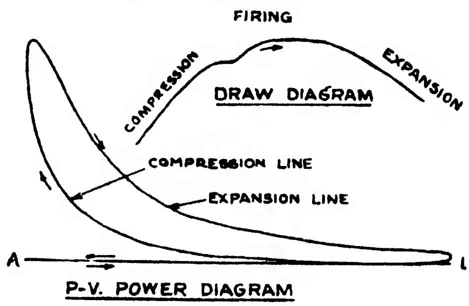


Fig. 6.—FOUR-CYCLE ENGINE INDICATOR DIAGRAM WITH HAND-OPERATED DRAW DIAGRAM ON SAME CARD

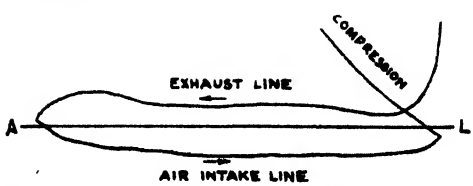


Fig. 7.—FOUR-CYCLE ENGINE LIGHT SPRING DIAGRAM MAGNIFYING THE EVENTS DURING THE TWO "IDLE" STROKES

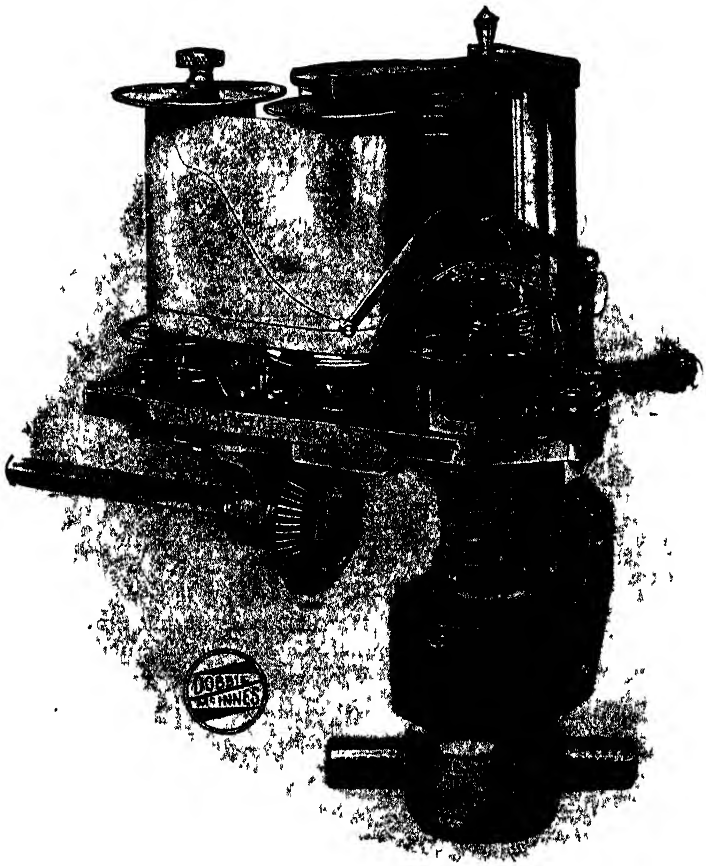


Fig. 8.—"DOBBIE-MCINNES" CONTINUOUS TIME BASE DIAGRAM DIESEL INDICATOR

(Diagram can be seen on indicator chart)

rotate forwards and backwards without reaching either stop.

Indicator Spring

After cleaning and oiling the indicator piston, a pressure spring is chosen for the instrument, from a knowledge of the maximum engine pressure, to give the requisite diagram height. On reassembly, the instrument is ready for the test, the drum cord being unhooked, the valve shut to the engine, and a diagram card placed on the drum.

The Test

When engine conditions are reached for which indicator diagrams are required, the drum cord is hooked to the loop to set the drum in motion. The valve is opened to the indicator, the pencil of which is lightly put in contact with the paper for one cycle and withdrawn. The valve is shut and the pencil is again applied to draw the atmospheric line. Since there is no condensation to clear away, as in the steam engine, the valve should always be shut, except when actually taking the card.

DIESEL ENGINE DIAGRAMS

Five important types are shown in Figs. 6 to 11, which are copies of actual diagrams obtained from large six- and eight-cylinder marine engines.

Four-cycle Engine P.V. Power Diagram

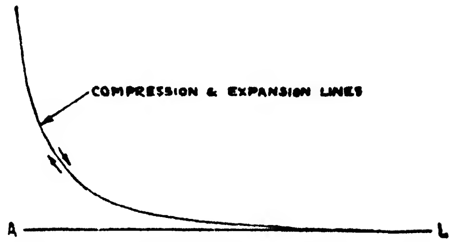


Fig. 9.—Compression diagram taken with fuel shut-off to cylinder being indicated

Fig. 6 illustrates the type of diagram obtained as described above. It will be noticed that at the peak, where firing takes place, the diagram is very narrow, because the indicator drum is at the end of its travel and is moving very slowly. To investigate what is happening during combustion a draw diagram is taken ; the most important part of this is shown on the right of the pressure-volume diagram, and is obtained by pulling the indicator drum cord by hand as the pencil rises and falls. The point at which firing begins is clearly shown, and the height of the outline at this point gives the compression pressure. AL is the atmospheric line common to both diagrams.

Four-cycle Engine Light Spring Diagram

To examine events during exhaust and intake, it is necessary to magnify the bottom of the diagram which appears in Fig. 6 as straight lines coincident with the atmospheric line. A light spring is therefore fitted to the indicator and the result is shown in Fig. 7.

Crank-angle Base Diagram

Since the shape of the peak of a diesel diagram is of such importance, means are often provided to give a mechanically operated draw card, so that the diagram has a form similar to the draw diagram shown in Fig. 6, but can be calibrated horizontally as well as vertically. Such a diagram is shown in Fig. 8—the crank-angle base diagram, where

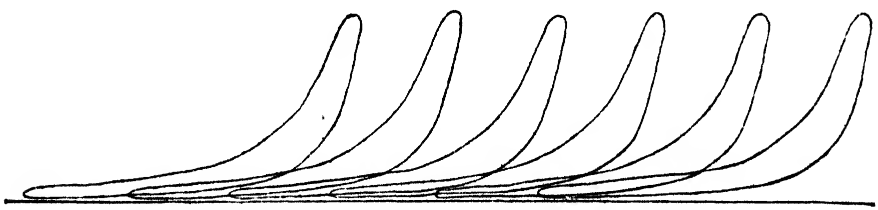


Fig. 10.—Diesel engine diagrams from continuous diagram indicator

Horizontal line at bottom is drawn by a second pencil and may be made coincident with atmospheric line as shown in Fig. 11. Engine running on full load.

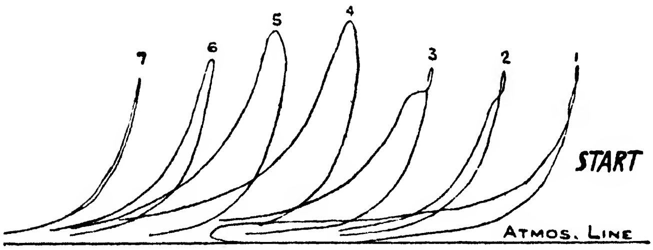


Fig. 11.—DIESEL ENGINE DIAGRAMS FROM CONTINUOUS-DIAGRAM INDICATOR, TAKEN DURING STARTING AND STOPPING

1. Air impulse (pressure carried nearly full length of stroke) 2. Firing lightly. 3. Firing (ignition late). 4. Firing heavily (handles hard over). 5. Full power (fuel being shut off). 6. Fuel being shut off. 7. Fuel off (almost a compression card—engine nearly stopped).

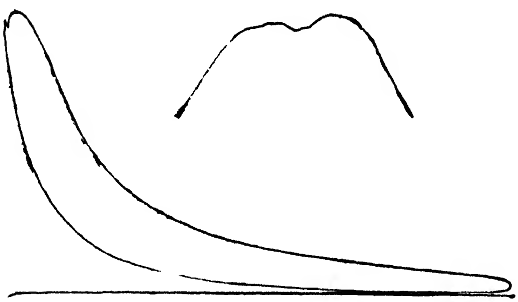


Fig. 12.—DIAGRAM SHOWING LATE FUEL INJECTION

Compare with Fig. 6.

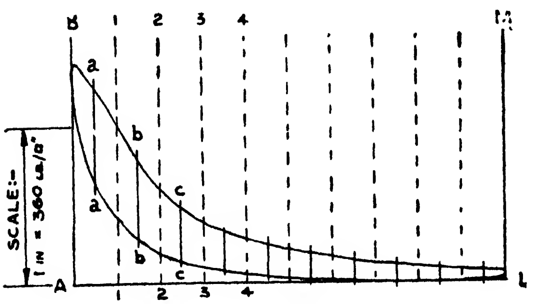


Fig. 13.—THE "MEAN ORDINATE" METHOD OF MEASURING UP THE DIAGRAM FOR CALCULATION OF M.I.P. AND I.H.P.

(M.I.P. of this diagram is 90 lb. per sq. in.)

horizontal measurements represent not piston stroke or volume but degrees turned through by the crankshaft. It is obtained on a continuous roll of paper driven by a spindle coupled to the camshaft, the special instrument used being the "Dobbie-McInnes" continuous time-base diagram diesel indicator.

Compression Diagram

This is obtained by shutting off the fuel from the cylinder being indicated and is used to test the setting and accuracy of the indicator gear. Its correct shape is as shown in Fig. 9, with compression and expansion lines apparently coincident. Should it be looped, the gear requires adjustment.

Continuous Diagrams

It is sometimes of value to study changes in the form of the diagram under varying conditions. For this purpose the continuous-diagram indicator is used and gives a complete record of consecutive diagrams on the same paper. A roll of paper is used, which is wound from a spindle inside the drum round the periphery of the drum and back to a second internal spindle. Movement of the paper with respect to the drum occurs automatically during the intake or exhaust stroke, and therefore does not interfere with the form of the diagram, which is the normal p.v diagram repeated. Fig. 10 shows continuous diagrams from a four-cycle diesel engine running at full load. Fig. 11 illustrates the pressure and power changes while the engine starts up and stops. It should be noted that Figs. 10 and 11 are tracings of the originals, and that in Fig. 11 the toes of diagrams 2 to 7 have been omitted, as in this particular test only the peaks were under consideration.

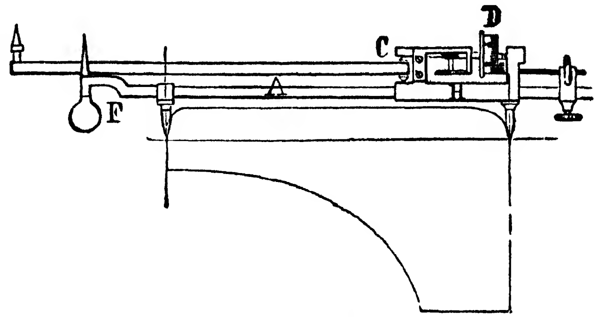


Fig. 14.—SETTING THE NO. 6 PLANIMETER TO THE DIAGRAM WIDTH

Engine Faults

To obtain maximum economy in running, and to ensure there are no undue strains on the engine, it is essential that valves should open and close at the correct points of the cycle and that combustion should be even. Valve setting is checked by examination of the indicator diagram, which also shows such faults as choked atomisers, early or late firing, over- and under-loading of the engine. Fig. 12 shows an example of late firing. Note the dip at the top of the draw card and the low maximum pressure as compared with the compression pressure ; such conditions prevent the particular cylinder from giving full power and efficiency.

MEASUREMENT OF M.I.P. AND I.H.P.

The mean indicated pressure, sometimes called indicated mean effective pressure—I.M.E.P.—can be found by the planimeter, an instrument for measuring areas, or by the following simple method :

Referring to Fig. 13, draw a straight line perpendicular to the atmospheric line AL at each end of the diagram AB and LM and divide the distance between the perpendiculars into 10 equal parts, A-1, 1-2, 2-3, etc. At the midpoint of each division draw 10 straight lines, *aa*, *bb*, *cc*, etc., also perpendicular to the atmospheric line. Find the total length of those parts of *aa*, *bb*, *cc*, etc., contained by the diagram, multiply by the pressure scale of the diagram, and, by dividing by 10, average the result to give the required mean pressure. For example, if the total length of the "mean ordinates" was found to be 2·50 in., and the

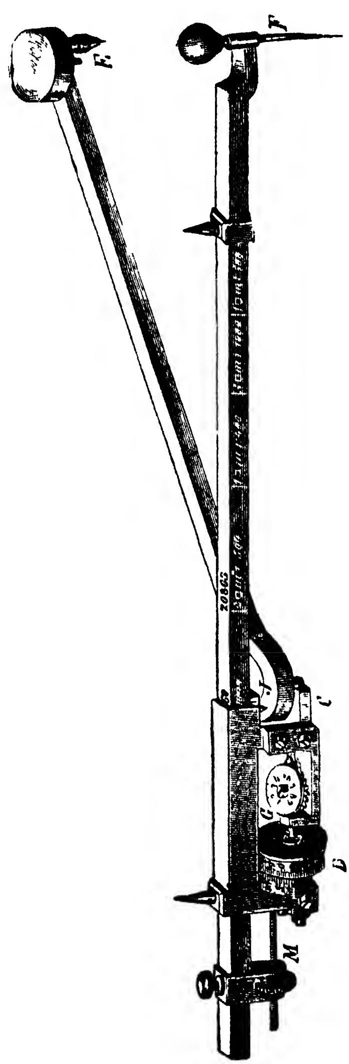


Fig. 15.—"Dobbie-McInnes" "Amsler" No. 6 Planimeter for measuring M.I.P. and I.H.P. Indicator Diagrams

indicator spring scale was 360 lb./sq. in. per inch, then :

$$\text{M.I.P.} = \frac{2{\cdot}50 \times 360}{10}$$
$$= 90 \text{ lb./sq. in.}$$

I.H.P. is obtained from the M.I.P. thus found by multiplying it by the product of the stroke in *feet* L, the cylinder area in *square inches* A and the number of *working strokes* per minute N, dividing the result by 33,000, i.e. :

$$\text{I.H.P.} = \frac{\text{M.I.P.} \times L \times A \times N}{33{,}000}$$
per cylinder.

For a two-cycle engine N is the same as the number of revolutions per minute ; for a four-cycle engine N is half the r.p.m., as there is only one working stroke every two revolutions.

Use of the Planimeter

The above method of determining M.I.P., while frequently used, is not as accurate theoretically as one which enables the diagram area to be determined, thus eliminating calculation by mid-ordinates. The "Amsler" No. 6 planimeter shown in Figs. 14 and 15 measures the actual area of the diagram, and it has, in addition, an arrangement for finding the mean height.

Thus, a small variation at the peak of the card, which would not be taken into account by the mid-ordinate method, would be shown in the result obtained by the planimeter.

The diagram card is pinned to a drawing-board, and, as shown in Fig. 14, the planimeter is reversed.

By moving the slide on the tracing arm, the planimeter is set so that the distance between the points on the upper side of the arm is equal to the width of the diagram. Without altering this distance, the planimeter, Fig. 15, is placed on the board in a convenient position with the needle point E outside the diagram and the pointer F resting on the outline of the diagram. An initial reading is taken on the dials G and D. Without disturbing E, the pointer F is carefully traced round the diagram, following every feature of the curve until one complete circuit is made. The final reading is taken, and the initial reading subtracted from it. Dividing the result by 0·4 gives the mean height in inches, which, when multiplied by the scale of the indicator spring, gives the M.I.P. from which I.H.P. is found in the usual way.

Example :

Second reading of planimeter	1·784
First reading of planimeter	1·682
Difference	0·102
Divide by 0·4	0·255 in. mean height.

If scale of spring is 360 lb./sq. in. per inch,

$$\text{M.I.P.} = 0{\cdot}255 \times 360$$
$$= 91{\cdot}8 \text{ lb./sq. in.}$$

It is now an easy matter to calculate the indicated horse-power of the engine by using the formula $\text{I.H.P.} = \frac{\text{M.I.P.} \times \text{L} \times \text{A} \times \text{N}}{33{,}000}$, bearing in mind that the formula gives the horse-power of one cylinder only. The total I.H.P. of a 4-cylinder engine, for example, would be four times the value given by the formula.

Chapter V

THE MARINE HEAVY-OIL ENGINE

ERECTION, OPERATION, AND MAINTENANCE

THESE notes refer to a typical engine of the four-cycle, cold-starting, solid-injection, vertical type, all working parts being totally enclosed. The example selected for treatment is the National Series " DM " heavy-oil engine for marine purposes. This is a multi-cylinder engine with direct reverse and with reverse-reduction gears. Much of the general information given here with regard to erection, operation, and maintenance naturally applies to other engines of similar type.

In the case of a marine engine successful running depends very largely on its proper installation in the first place. Great care should therefore be given to this work, and only a skilled man allowed to carry it out.

PREPARATION OF BOAT

Determine the position of the engine in the boat, and thus the position and inclination of the sterntube. If the makers have been consulted, this will be found on their seating drawing, otherwise it will be necessary to make a drawing—using the makers' outline drawing of the engine. Remember that the normal inclination of the engine must not exceed 7°. Also bear in mind that the propeller should be as low and as far aft away from the sternpost as practicable, so as to obtain the best possible stream of water. The propeller blades should have a clearance of not less than 1 in. (25 mm.). The propeller should not overhang so much that the exposed portion of the tailshaft is longer than about one and a half times the tailshaft diameter.

Checking Alignment of Hole for Sterntube

Bore the hole for the sterntube, having first made a pilot hole. Take great care to see that the alignment of the finished hole is correct to the drawing. This can be done by first stretching a thin steel wire tightly through the pilot hole and lining it up to the drawing, and then by lining up the boring bar to the wire. The sterntube must on no account be a slack fit, but at the same time it must not be driven in too tightly, as this will tend to distort it and interfere with its bearings.

The Sterntube

Insert the sterntube, placing under the flange at each end a grummit soaked in red lead. If the sterntube is found to be slightly too long, even when full advantage is taken of the screwed portion, then a hardwood packing piece should be placed under the inboard flange.

Installing the Bearers

Install the bearers, making them extend as far as possible fore and aft of the engine, so that the weight of the engine is spread over a large number of frames. See that the bearers are of good proportions, and that they are securely fixed and cross-braced. The bearers can be lined up by means of a thin steel wire tightly stretched through the centre of the sterntube, the top face of the bearers being left about $\frac{3}{4}$ in. to 1 in. (19 mm. to 25 mm.) lower than the underface of the engine baseplate.

Tailshaft

Smear the tailshaft with oil and insert it in the sterntube.

Forward Stuffing Box and After Gland

Pack the forward stuffing box of the sterntube with soft greasy hemp or cotton packing and screw it up. If there is an after gland, pack this in the same way, but leave it untightened.

Force in light grease or gear oil, by means of the grease cup at the inboard end, until it squeezes out at the after end.

If there is an after gland, this should now be screwed up.

Fitting the Propeller

Fit the propeller, taking care to see that the holding nut is hammered up and the locking setscrew centre punched to prevent it slacking back.

Tanks and Sea Cocks

Install any tanks, if their position is such that they could not be fitted in after the engine is in place (see " Erection ").

If the boat is to be launched before installing the engine, the sea cocks should now be installed (see " Erection ").

ERECTION

Install the engine with wooden slivers or strips (or cast-iron chocks if the boat is of steel) between the bearers and the engine baseplate.

When Boat is Waterborne

If the boat is waterborne, the engine can now be finally lined up, bolted down, and coupled up. Lining up can be done by adjusting the thickness of the slivers or chocks, taking great care to see that the weight of the engine is being taken evenly over the whole length of the baseplate, as otherwise there is a danger of distorting and possibly cracking it.

In many cases it is not possible for all the holding-down bolts to be through bolts, in which case coach bolts must be used. In all cases, however, an endeavour should be made to have at least four through bolts per engine. When coach bolts are used, preference should be given to the type which are threaded at the top and fitted with a nut for finally tightening down.

When checking the final alignment great care should be taken to see that the half-couplings not only coincide vertically and horizontally but that their axes are also accurately in alignment. This latter can be determined by inserting feelers between the half-couplings before they are bolted up, and seeing that there is the same clearance all round.

When Boat has Still to be Launched

If the boat has still to be launched, the engine should only be approximately lined up, and finally lined up when the boat is in the water. This is a most important point, as no boat is an absolutely rigid structure, and therefore its form is bound to change slightly when it is launched, and consequently the alignment is upset.

Water Piping and Fittings

Install the water piping and fittings according to the manufacturers' arrangement drawing. The sea cocks should be so placed that they are not likely to be above water-level when the boat is rolling, and yet they should not be so low that mud or sand is drawn in when the boat is working in shallow water. All sea cocks must, of course, be fitted with a removable strainer. Keep the suction pipe from the sea cock to the circulating pump as short as possible, and free from sharp bends. The bilge suction must also be kept as short as possible to avoid trouble in priming. The delivery side of both the circulating and bilge pumps must be kept free of any cocks or fittings which might cause a restriction or temporary stoppage of the flow. All piping should have a bore of not less than $\frac{3}{4}$ in. (19 mm.).

The Exhaust System

Install the exhaust system. Two forms of silencer are supplied, these being the water-jacketed type and the water-injection type. The former is the simpler, and is to be recommended where it is of no consequence when the exhaust pipe becomes hot, such as when the exhaust is led vertically up through the deck. If, however, the exhaust pipe is to be run a considerable distance near woodwork, such as when it is led under the deck to the stern of the boat, it is advisable that the water-injection type of silencer should be installed. In this type, the cooling water from the engine mixes with the exhaust gases, and the exhaust pipe becomes only warm.

The water-jacketed type of silencer can be installed vertically or horizontally, so long as the cooling water is led into the bottom and out to the overboard connection at the top.

The water-injection type silencer must be installed horizontally, so that the cooling water enters at the top and the combined exhaust and water outlet pipe leaves at the bottom.

This latter type of silencer should be installed as high up as possible, and the outlet pipe must slope down appreciably away from the silencer to the ship's side.

If the first type of silencer is installed, the exhaust pipe can be of iron or steel, but in the case of the second type we recommend that the outlet pipe be of reinforced rubber or copper, due to the corrosive effect of the mixture of exhaust gas and water.

Main Fuel Tanks

Install the main fuel tank(s), if this has not already been done before the installation of the engine. Unless the main fuel tank(s) can be situated at least 2 ft. (610 mm.) above the engine-fuel pump, it will be essential to install a service tank at, or above, this height, together with a hand pump for transferring oil to the service tank from the main tank(s).

Install the fuel pipes and fittings according to the manufacturers' installation drawing.

Deck Controls

Install the deck controls, if these are to be fitted. The governor control can consist of rods and levers, or some form of wire. In the case of an engine with a direct reverse gear, distant operation of the reversing lever can be accomplished with the rods and levers; whilst if it is fitted with a reverse reduction gear, a vertical spindle together with pulleys and "Gypsy" chain will be found to be the best solution.

ATTENTION BEFORE STARTING UP FOR THE FIRST TIME or After Long Periods of Standing

Clean the engine, removing all rust-preventing compound.

Remove the crankcase doors and splash oil over the working parts.

Filling the Sump

Fill the sump through the filler on the crankcase door. The oil level should be up to the higher of the two marks on the dipstick. (On older models dipsticks are not provided with marks, but have a flat portion, and the oil level should be up to the top of this.) Quantity required to fill the sump varies with the type and size of engine. The level should be rechecked and oil added as necessary, after a few minutes' running, when the engine is started for the first time.

In cases where a direct reverse gear-box only is fitted, fill the gear-box with engine-lubricating oil to the level on the gauge rod.

When a reverse reduction gear-box is fitted, the reverse gear compartment should be filled as above, and the reduction gear compartment should be filled to the level of the plug in the side of the case with a good-quality gear oil.

Remove the top covers from the cylinder-heads, and lubricate the valve levers and tappet rods copiously.

Pour half an eggcupful of lubricating oil into each air intake.

Examine and fill the wick oilers in the cylinder-head covers.

Check Functioning of Lubricating Oil-pressure System

Make certain that the lubricating oil-pressure system is functioning properly as follows :

Remove the auto-cleaning strainer cartridge from its casing, fill the casing with oil, and replace the strainer. Now open the small cock on this casing and turn the engine by hand (with the fuel-pump control disc in the " Stop " position) until oil, free from air bubbles, runs from the cock, after which it should be shut. Rotate the engine by hand until a pressure is indicated on the gauge. On no account must the engine be started until at least a small pressure is indicated, which shows that the lubricating system is working.

Carefully rinse out the fuel-service tank and piping before connecting up.

Testing the Fuel System

Test the fuel system as follows :

First allow any air present in the supply piping to the fuel pump to escape by means of the test cock on the side of the fuel filter. Allow fuel to escape from this cock until a steady flow is obtained free of air bubbles.

Now slacken the fuel-pipe union nuts on the atomisers, and operate each fuel-pump plunger in turn by means of the priming tool provided, until fuel free from bubbles escapes at each atomiser nut (the engine must be turned before operating each plunger, so that the particular plunger is at the bottom of its stroke, otherwise no pumping action can be obtained). The atomiser union nuts should now be retightened, and the pump plungers tried again with the priming tool. After a few strokes the system should be quite free from air, in which case the priming tool will feel solid and the atomiser can be heard to operate with a creaking noise.

If air is still present and is preventing the operation of any of the atomisers, the following procedure should now be adopted :

Remove the pipe between the pump and the atomiser in question. Then remove the appropriate delivery valve nut on top of the pump, and the spring which it contains. Turn the engine so that the fuel-pump plunger is in its lowest position and with the fingers raise the delivery valve slightly from its seating, when fuel should appear. Hold the delivery valve off its seat to allow fuel to run freely through the pump, until all traces of air bubbles have ceased. The delivery valve nut and the fuel piping should now be carefully replaced, when the system will be found to be in order. Great care must be taken to see that no dirt enters the fuel pump or the piping.

Priming the Cooling-water System

Prime the cooling-water system as follows :

Open the circulating-water sea cock, which will ensure the water filling the suction pipe up as far as the circulating pump. Then disconnect the outlet water pipe from the water manifold on top of the cylinder-heads, and fill the engine with water by means of a hosepipe, if available, or otherwise by hand. Replace the outlet pipe.

STARTING

Open the sea cock.

See that the cock on the fuel-service tank is turned on.

See that the reverse gear is in neutral.

See that the fuel-pump control disc on the side of the governor is in its "starting" position, and that the governor-control handle on the engine or in the wheelhouse is in its minimum position.

Raise all the valve lifters to release compression (the lever on No. 1 cylinder—the cylinder next to the starting handle—holds up the exhaust valves on Nos. 1 and 2).

Turn the engine with the starting handle as quickly as possible, and after, say, half a dozen turns drop the valve lifter on No. 1 cylinder, continuing turning if an immediate start is not effected.

Directly the engine fires, drop the remaining valve lifters into their "working" positions, and look at the lubricating-oil pressure gauge to see that the lubricating-oil pump is working. If it is not, the engine should be shut down immediately, and the lubricating system reprimed, as described under "Attention Before Starting Up for the First Time or After Long Periods of Standing." When the engine is warm, a pressure of about 12 lb. per square inch should be maintained on the engine-room gauge (see "Adjustments").

Look to see that the circulating water is being discharged overboard, so as to know that the circulating pump is functioning properly.

Move the fuel-pump control disc from the "starting" position into the "working" position.

Note.—In cold weather, when oil on the pistons may be sticky, the engine can be made easier to turn by operating the fuel-pump plungers several times with the priming tool to inject some fuel into the cylinders, and allowing the engine to stand a few minutes before attempting to start.

STOPPING

Always stop by turning the fuel-pump control disc into its "stop" position, and never by shutting off the fuel or by raising the valve lifters.

After shutting down, it is advisable to close the sea cock, from the point of view of safety.

If the boat is working in fresh water and there is any danger of freezing, drain off the water from the cylinder jacket and pump after shutting down.

Reversing

Although the gear-box is designed to withstand sudden reversing at full speed in cases of emergency, we strongly recommend that the engine should always be slowed down before going from " ahead " to " astern," or vice versa, so as to prolong the life of the gear-box.

REGULAR ATTENTION

Daily

(1) Keep the engine clean.

(2) Check the lubricating-oil level in the sump, and add oil if necessary.

(3) Use an oil-can for small parts, such as the governor control rods and spindles.

(4) Examine the wick oilers and fill up if necessary.

(5) Give a turn to the greasers on the circulating and bilge-pump eccentric straps.

(6) Give the auto-cleaning strainer a few turns to ensure that it is kept free.

(7) Give a turn to the greaser on the sterntube and attend to the lubrication of any intermediate shaft bearings.

(8) Sound the level of the fuel oil in the main tanks to ensure that the supply is not running out.

Every 200 Hours' Running

(1) If a reduction gear is fitted, check the oil level, and add, if necessary (see " Attention Before Starting Up for the First Time or After Long Periods of Standing ").

(2) Remove and scrub the fuel filter in a bucket of fuel oil.

(3) Remove the atomisers. In each case unscrew the nozzle from the body and withdraw the needle valve. Remove any carbon from the end of the nozzle, using only a brush, not a file or emery paper. Finally, wash both the needle and nozzle thoroughly with clean fuel oil, and flush well with clean lubricating oil before reassembling.

(4) Remove the auto-cleaning strainer cartridge and clean it in fuel oil. Also clean out the inside of the strainer casing thoroughly, taking great care that no dirt enters the pipes attached to the casing.

(5) Remove the crankcase doors and examine the connecting-rod nuts for any possible slackness.

(6) Examine the outlet end of the exhaust pipe, where the exhaust discharges into the atmosphere, as sometimes the pipe will become appreciably blocked up within the last inch or two of its length. If this is found to be the case, it should be cleaned.

Every 300 Hours' Running

Drain the gear-box and reduction gear if fitted, and refill to the correct levels (see "Attention Before Starting Up for the First Time or After Long Periods of Standing").

Every 1,000 Hours' Running

(1) Grind in the valves if necessary (see Figs. 5 and 6 for the removal of the exhaust-valve springs and levers).

(2) Clean the exhaust system.

Every 2,500 Hours' Running

(1) Remove the cylinder-heads and decarbonise the combustion spaces.

(2) Remove the pistons and examine the piston rings. Remove the rings and decarbonise them and their grooves if necessary, not forgetting the small holes which lead the oil from the scraper rings back into the insides of the pistons.

(3) Examine all bearings for wear. If necessary, the big-end and main bearings can be adjusted, whilst the small-end bearings can easily be renewed if they are appreciably worn.

Note.—In all cases where castle nuts are used for securing a bearing cap, great care should be exercised when retightening to see that the nut is tight, but not strained to bring it to the next split-pin slot. If necessary, the nut should be filed carefully underneath, and on no account must it be slackened back slightly to insert a split-pin, or wrenched unduly to obtain the next split-pin position.

(4) Examine the coconut matting in the air silencer, and if it is dirty it must be beaten well, or renewed if necessary. On no account must it be washed with petrol, paraffin, or fuel oil.

Change of Lubricating Oil in the Engine

The recommended number of hours after which the oil in the National engine sump should be drained is as follows:

Type "2DM"	550 hours
Type "3DM"	500 hours
Type "4DM"	450 hours

After draining, the circular filter should be withdrawn from the sump and cleaned and the crankcase washed out before pouring in new oil.

ADJUSTMENTS

Governor

This is set before the engine leaves the works, and requires no further adjustment. On no account whatever should the control rod between the governor and the fuel pump be interfered with, as this may lead to overloading of the engine, with serious consequences.

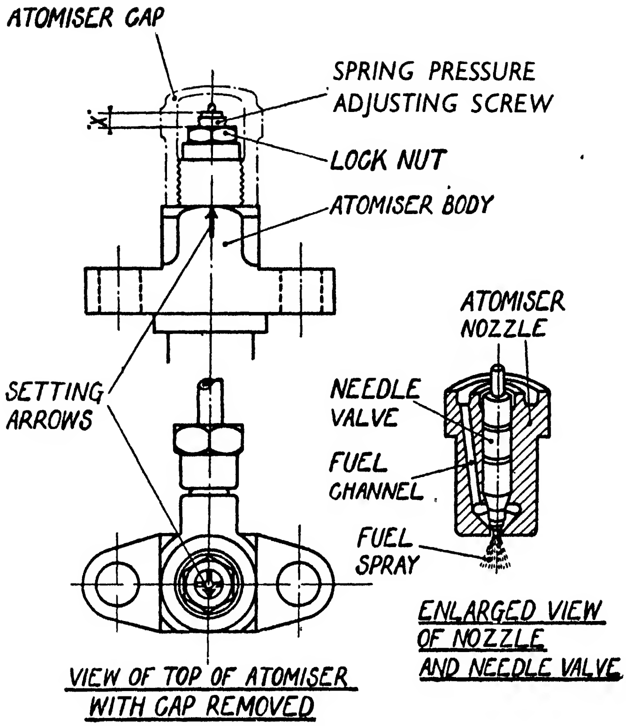


Fig. 1.—Atomiser—spring pressure setting

Under no circumstances must any attempt be made to interfere with the position of the control rod on the fuel pump to obtain a slightly increased speed from the boat. If this is done, there is a grave danger of damaging the engine.

Tappets

Adjustment is provided at the top ends of the push-rods. When the engine is cold, the clearances should be ·006 in. (·15 mm.) in the case of the inlet valve and ·008 in. (·20 mm.) in the case of the exhaust valve. If feelers are not available, an approximate guide to the correct clearance can be obtained by using thick brown paper. This method should only be used as a temporary measure until feelers have been obtained. Care should be taken to see that a valve has not commenced to open when its clearance is being set.

Atomisers

The atomisers are adjusted for correct spring tension before they leave the works, and in each case an arrow is stamped on the adjusting screw so that it is opposite one stamped on the atomiser body. The distance *X* (see Fig. 1), which is about 4 mm., is also carefully measured and stamped on the bodies of the atomisers for reference. The springs should always be set to the same tension after the atomisers have at any time been dismantled.

For the information of those who have facilities for testing the injection pressure, the atomiser is set at the manufacturers' works to " blow-off " at 1,750 lb. per square inch (123 kg. per square centimetre).

When, in the course of time, an atomiser needle and bush fail in any

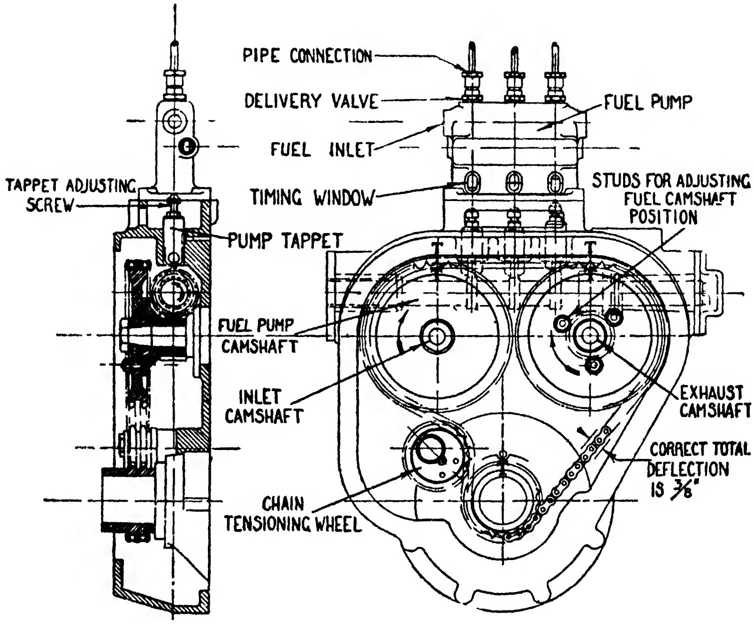


Fig. 2 FUEL PUMP—TIMING ADJUSTMENTS

way, it is advisable that new ones should be fitted. The old needle and bush can then be returned to the manufacturers for reconditioning, and can afterwards be kept as spares.

Fuel Pump

Two forms of adjustment are provided on the gear operating the fuel pump. From Fig. 2 these will be seen to be the position of the fuel camshaft itself and the tappet-adjusting screws. These adjustments enable the timing to be correctly adjusted in the first place, and should not be interfered with unless it is found that the timing is definitely incorrect, due to one or other of the adjustments having slipped back, or to appreciable wear after long service. The timing can be checked and, if necessary, adjusted as follows

Turn the flywheel into position for the commencement of injection of No. 1 cylinder, i e., at the end of the compression stroke, and when the line on the flywheel marked F.I. is opposite the pointer projecting from the column, or when the crank is about 10° before T.D.C. The lines in the timing window of No. 1 fuel pump should now coincide. If they do, it can be assumed that the position of the camshaft is correct, and it is now only necessary to check the tappet-adjusting screws of the remaining cylinders, as described below. If the lines are not coincident, it will be necessary, in addition to checking all the tappet-adjusting screws, to check and, if necessary, adjust the camshaft position. This operation is also described below.

Tappet-adjusting Screws

Taking each fuel-pump plunger in turn, rotate the engine until the plunger reaches its highest position, i.e., when the tappet roller is on the peak of the cam, and measure the distance of the mark on the plunger in the timing window from the top of the window. Now turn the engine until the plunger is in its lowest position, i e., when the tappet roller is resting on the back of the cam. Again measure the distance of the mark on the plunger, this time from the bottom of the window. The two distances measured should be approximately the same, and if they are not, the tappet-adjusting screw should be altered until they are.

Camshaft Position

Having checked and, if necessary, reset the tappet-adjusting screws, the position of the camshaft should now be checked. Turn the flywheel into position for the commencement of injection of No. 1 cylinder, as described above. The lines in the timing window of No. 1 fuel-pump plunger should now exactly coincide If they do not, the position of the camshaft must be reset as follows

Remove the union nuts of the two copper pipes leading to the auto-cleaning strainer, then undo the three nuts holding the inspection door, and remove this door complete with the auto-cleaner strainer which is attached to it. This gives access to the exhaust-camshaft chain-wheel, behind which is secured the gear-wheel driving the fuel-pump camshaft gear-wheel by means of studs passing through large clearance holes in the chain-wheel. The nuts on these three studs must be slackened, and the fuel camshaft driving the gear-wheel rotated—relative to the chain-wheel—to bring the lines in the timing window coincident. The three nuts must now be retightened

Rotating the three studs in a clockwise direction relative to the chain-wheel when looking through the inspection cover advances the timing, and vice versa.

As stated above, the standard time of injection is 10° before T.D.C. With some fuel oils, however, this may be found to be slightly early, and in such cases the angle can be reduced, but not below 7°.

Caution

On the side of the fuel pump itself is a cover, behind which are the fuel-pump control rack and pinions. On no account must the adjustment of these be touched.

Timing-wheels and Chain

Should the engine be dismantled at any time, great care must be taken to see that the various chain-wheels and timing-wheels are reset correctly.

If the chain driving the camshaft is to be replaced, proceed as follows :

Turn the flywheel until the "T" stamped on the crankshaft is opposite the pin in the end of the bearing cap at the top. Turn each camshaft so that the "T" stamped on its chain-wheel is at the top, and opposite the corresponding "T" stamped on the chain casing. The chain, which will have been disconnected, can now be fitted, care being taken to see that none of the wheels is moved during the process.

To adjust the tension of the chain, the bolt holding the eccentrically mounted tensioning wheel must be slackened, and the eccentric boss turned until the tension of the chain is such that the total deflection is $\frac{3}{8}$ in. (10 mm.), as shown in Fig. 2.

Reassembling Skew-wheels

If the skew-wheels driving the fuel-pump camshaft have been disturbed, the following procedure must be adopted when reassembling :

On the driving-wheel which is bolted to the exhaust-camshaft chain-wheel an "o" will be found opposite a tooth, whilst on the driven wheel on the fuel-pump camshaft an "o" will be found opposite a space between two teeth. The wheels must be meshed so that the tooth marked with an "o" falls in the space similarly marked.

If the fuel-pump camshaft driving the wheel has been separated from the exhaust-camshaft chain-wheel, care must be taken that they are replaced correctly. A mark will be found to be stamped on one of the three studs, whilst a similar mark will be found on the chain-wheel adjacent to the correct hole for that stud.

The skew gears driving the circulating and bilge-pump cross-shaft can be meshed in any position relative to each other.

Lubrication System

When the engine is warm, a pressure of about 12 lb. per square inch should be shown on the engine-room gauge. This pressure can be regulated by means of the oil-pressure adjusting screw, which will be found on the lubricating-oil pump. This controls the amount of oil by-passed, by means of a spring-loaded valve. Its locknut must be slackened back before adjustment, and afterwards retightened.

In addition to the above adjustment, which controls the pressure in the lubrication system of the engine, there is an additional adjustment for controlling the amount of oil supplied to the exhaust-valve spindles. To check the amount of oil which is being delivered to the spindles it is necessary to remove the pipe union at the bottom end of the pipe leading from the special control valve up to the cylinder-heads. When the engine

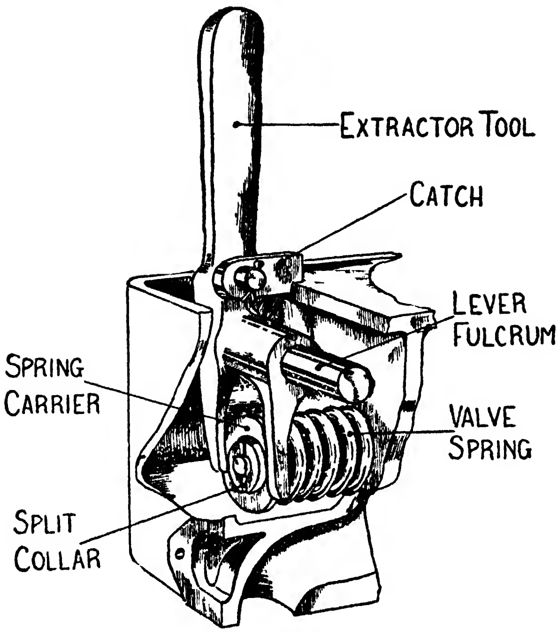


Fig. 3.—EXTRACTION OF EXHAUST-VALVE SPRING

is running and the oil is warm the special adjusting screw must be so set that oil can just be seen to be flowing, i.e., two to four drops per minute. As in the case of the pressure-adjusting screw, the special adjusting screw also has a locknut, which must be slackened off before adjustment and afterwards re-tightened. It should be mentioned that all the oil which passes up the pipe to the cylinder-heads does not find its way to the exhaust-valve spindles.

Extraction of Exhaust-valve Spring (Fig. 3)

To remove spring:

(1) Remove top cover and extractor door from cylinder-head.

(2) Remove the valve-lever fulcrum and valve lever.

(3) Replace the valve-lever fulcrum, substituting extractor tool for valve lever.

(4) Holding exhaust valve on its seat with grinding handle, depress spring with extractor tool and remove split collar.

To replace spring:

(1) Insert valve and hold in position with grinding handle.

(2) Put spring and spring carrier in place, and depress with extractor tool—using catch to keep spring depressed.

(3) Insert split collar and release spring.

Removal of Valve Levers (Fig. 4)

(1) Remove nut (*A*) from next cylinder-head, and push its spindle (*C*) back, as shown by (*D*).

(2) Remove nut (*B*) from the spindle to be taken out, and slide the spindle back as far as possible.

(3) Pull out bush by compressing spring as shown by (*E*).

(4) Tilt the spindle as shown by (*G*).

(5) Withdraw the spindle and lever together, during which process it will be found necessary to turn the lever so that the arm (*J*) operated by the pushrod points upwards.

Note.—Care must be taken when replacing the valve lever to see that the ball end of the lever (*J*) drops properly into the socket on the end of the pushrod.

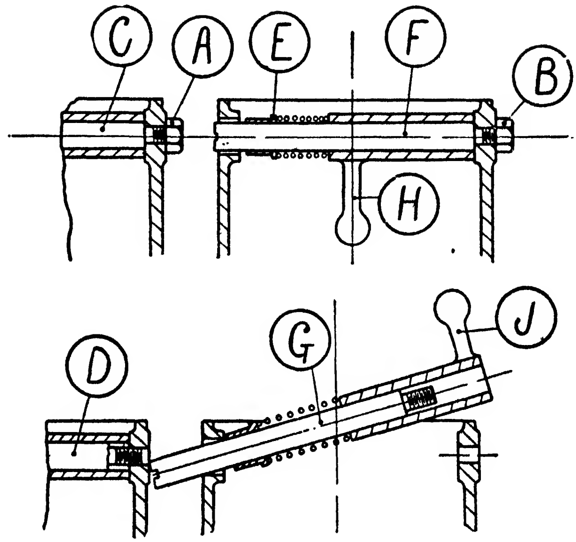


Fig. 4.—REMOVAL OF VALVE LEVERS

Fuel Oil

The engine is designed to run on solar, shale, gas, or light diesel oils. The oil to be used should be within the limits of the following specification :

Viscosity—Redwood No. 1 in Seconds—
at 100° F. (38° C.) not exceeding 60

Engler Viscosity—
at 100° F. (38° C.) . . . . . . not exceeding 20

Gross calorific value in—

B.Th.U.s per pound, not less than	19,000
Calories per kilogramme, not less than	10,560

The following fuel oils, which are procurable in most parts of the world, are amongst those which conform to the above specification :

Gas Oils.
Shale Oil.
Solar Distillates.
Balik Papan Solar Oil.
Pratts' Diesel Oil, Grade " A."
Shell Diesel Oil.
Shell Diesoline.
B.P. Light Diesoleum.
Venezuela Gas Oil.
Anglo-Persian Diesoleum.

If unable to obtain a suitable fuel, it is advisable to consult the manufacturers before using any fuel which does not conform to the specification.

Lubricating Oils

Only the best lubricating oil should be used, and should be within the limits of the following specification :

Specific Gravity at 60° F.	0·882–0·930
Flash Point (Open)	400–430° F.
,, ,, ,, ...	204–221° C.
Flash Point (Closed)	385–400° F.
,, ,, ,, ...	196–204° C.

Viscosity—Redwood No. 1 in Seconds—

at 70° F. (21° C.)	700–1,300
at 140° F. (60° C.)	112–133
at 200° F. (93° C.)	50–56

Engler Viscosity—

at 70° F. (21° C.)	22·68–42·12
at 140° F. (60° C.)	3·63– 4·31
at 200° F. (93° C.)	1·72– 1·90
Cold Test or Pour Point	35° F.–0° F.
Total Sulphur	Not exceeding 0 8 per cent

Points to Remember

(1) If the engine is neglected in any way, trouble of some sort will surely be experienced.

(2) The sump should not be overfilled. This causes waste, and also causes the engine and exhaust system to be sooted up.

(3) Always allow the engine to run a few minutes after starting up, before getting under way.

(4) The lubricating-oil level in the engine sump and reverse gear should be examined whilst the engine is stopped and the boat on an even keel, as otherwise a false indication may be given.

(5) When replacing an atomiser in a cylinder-head, be careful that the copper washer has not been forgotten.

(6) If fuel oil is used from barrels, always allow these to stand so that any sediment or water can settle.

(7) On no account must petrol be used for pouring in to the cylinders or for washing out the crankcase.

(8) If the boat is being laid up for an appreciable time, it is advisable to cover up the end of the exhaust pipe—especially if this points in an upward direction, to prevent the entrance of rain or spray.

(9) Sterntube glands should not be tightened unnecessarily, as this only causes excessive wear.

(10) If the boat is working in fresh water and there is any chance of the water in the cylinder jacket freezing, be on the safe side and run it off. Failure to do this may result in a cracked column.

LOCATION OF TROUBLES

Below are set out the various troubles most likely to be encountered, together with their causes and remedies.

Engine will Not Start

(1) Not turned Fast Enough by Hand.

Try to continue turning after the valve lifter has been dropped

There is no danger of backfiring as with petrol engines. See that the reverse gear is in neutral.

(2) Loss of Compression.

(*a*) Sticky Valves. Remove and clean the valve spindles, and if necessary polish with fine emery cloth (see Figs. 3 and 4 for the removal of the exhaust-valve springs and levers).

(*b*) Insufficient Valve Clearance. Check the valve clearances. See "Adjustments" (page 107).

(*c*) Valve Seatings not Tight. Examine these, and if they show signs of being pitted and are not seating properly, they should be lightly ground in.

(*d*) Dry Pistons after Standing. Pour a small quantity of lubricating oil into each air intake.

(3) Air in the Fuel System.

Proceed as described under heading "Attention Before Starting Up for the First Time or After Long Periods of Standing."

Engine Runs Irregularly

(1) Sticky Valves. . . . See above.

(2) Dirty Atomisers. . . . See "Regular Attention" (page 106).

(3) Air in the Fuel System.

See "Attention Before Starting Up for the First Time or After Long Periods of Standing" (page 103).

(4) A Fuel-pump Delivery Valve has Stuck Up.

Remove the delivery valve, as described under "Starting Up for the First Time or After Long Periods of Standing." If the delivery valve is found to be stuck, it will be due to dirt, and after carefully cleaning the valve and its guide it should move freely. On no account must emery paper or powder be used.

(5) Water in the Fuel.

Drain all parts of the fuel system, including the fuel pump, and fill up with clean fuel.

(6) Fuel Filter Choked.

Remove and wash. See "Regular Attention."

Dirty Exhaust

(1) Black Smoke.

(*a*) Engine is overloaded. . . . Reduce speed.

(*b*) A fuel-pump delivery valve has stuck up. . . . See above.

(2) Grey Smoke.

(*a*) Atomisers need Cleaning. . . . See "Regular Attention."

(*b*) Time of Injection is Incorrect. . . . Check timing. See "Adjustments."

(3) Blue Smoke.

Too much lubricating oil. Check the level in the sump; if blue smoke persists, inspect the piston rings and clean if stuck. Also inspect the scraper rings and see that the holes in the pistons (which lead oil from the scraper rings back to the insides of the pistons) are not choked. If any of the piston rings are badly worn, they must be renewed.

Engine Knocks

(1) Time of Injection is Incorrect.

Check and reset if necessary. See "Adjustments."

(2) A Bearing is Loose.

Examine all bearings and adjust if necessary. See "Regular Attention."

(3) A Piston is Seizing.

See that the engine is not being overloaded. Examine the pistons and smooth up any rough parts on the pistons and in the liners.

(4) Carbon on the Pistons hitting the Cylinder-heads.

Decarbonise.

Note.—If the engine is heard to be knocking at any time, it must be slowed down at once and, if possible, stopped, and the cause investigated. On no account must it be allowed to continue running, except at a greatly reduced speed.

Engine Overheats

(1) Water Circulation Defective.

See that no foreign matter has collected over the sea intake, in the sea-cock strainer, or in the suction piping. Inspect the valves in the pump and see that there is no grit on the seats and that they are seating properly.

(2) Time of Injection is Incorrect.

Check and reset if necessary. See "Adjustments."

Engine Stops of its Own Accord

(1) Dirt in Fuel Filter or other parts of Fuel System.

Investigate and clean.

(2) Water in the Fuel. . . . See page 115.

(3) Fuel Tank is Empty.

Fill up the tank and reprime the fuel system as described under "Starting Up for the First Time or After Long Periods of Standing."

(4) A Fuel-pump Delivery Valve has Stuck Up. . . . See page 115.

(5) A Piston has Seized.

Dismantle, examine, and smooth up any rough parts on the piston and in the liner.

(6) The Propeller is Fouled.

Inspect and remove any ropes or other objects which have become entangled.

Heating of Sterntube or Intermediate Shaft Bearing

(1) Misalignment.

Check and, if necessary, re-align the engine and intermediate shaft bearings, if any, from the tailshaft half-coupling.

(2) Tight Sterntube Packing.

Try slackening the nuts holding the gland slightly. If the gland cannot be eased without causing leakage, the packing has become hard and should be renewed.

(3) Damaged Propeller.

Examine the propeller to see that it has not become damaged to such an extent as to throw it appreciably out of balance. If necessary, the propeller must be repaired or renewed.

ELECTRIC STARTING

In cases where an engine is fitted with electric starting equipment, the following points must be observed:

Installation

The various components must be wired up exactly according to the diagram (Fig. 5). The battery and the solenoid switch should be kept as close to the starter motor as possible, to avoid long lengths of the heavy cable, with consequent loss of efficiency.

Care should be taken to see that all wires are protected from any likelihood of being damaged by abrasion, or by coming into contact with oil, grease, water, etc.

The size of cable recommended for the starter circuit is 61 wires each of ·036 in. (·91 mm.) diameter, whilst that recommended for the remaining parts of the system is 35 wires each of ·012 in. (·31 mm.) diameter. The above are standard sizes of cable, but if they are not obtainable, other sizes can, of course, be used, assuming that they have the same current-carrying capacities.

Regular Attention

Weekly.—Inspect the levels of the acid in the battery and, if necessary, fill up so that the plates are just covered. If the level has dropped due to evaporation, distilled water must be used, whilst if it has dropped due to spilling or leakage, battery acid of the correct strength must be added.

Monthly.—Attend to any greasers or oilers on the starter motor and the dynamo. On no account must too much oil or grease be supplied to the bearings, as it will find its way to the commutator and the armature and cause damage. A greaser should be given only half a turn monthly, whilst an oiler should receive only one or two drops in the same period.

Three-monthly.—Inspect the brushes of the dynamo and the starter motor, and blow or wipe away any carbon dust which has accumulated.

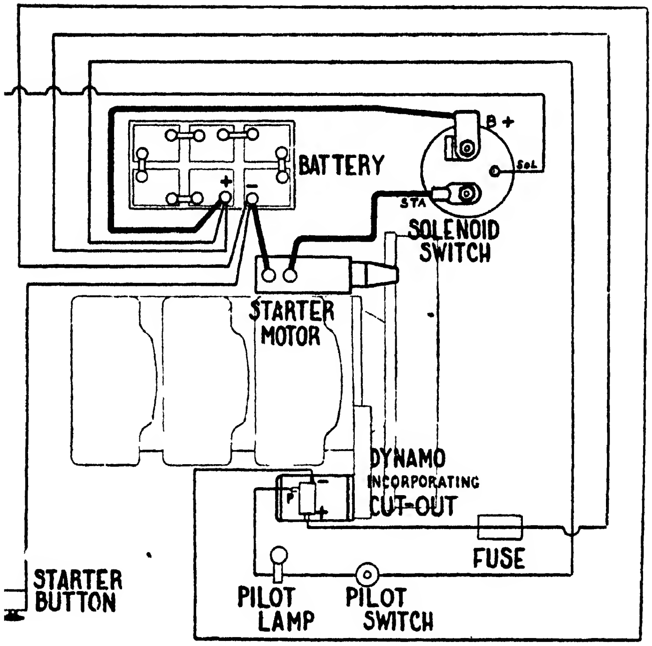


Fig 5.—Wiring diagram of electric starting equipment

If the commutator shows any signs of roughness, it can be cleaned with very fine emery paper.

Inspect all connections and keep them clean. Those on the battery should be kept smeared with vaseline to avoid corrosion.

Adjustments

Dynamo Chain.—This can be adjusted for tension, if necessary, by slackening the three bolts holding the dynamo flange and by swivelling the dynamo about the bottom bolt, the two top bolts working in slots. When correctly tensioned, slackness in the chain should be just perceptible.

Brushes.—If, at any time, it is found necessary to fit new brushes to the dynamo or starter motor, it is very important that these should be bedded on to the commutator if sparking, and consequent damage, is to be avoided. The new brush can be bedded by placing it in its holder and pressing it lightly on to the commutator, over which a piece of fine emery paper has been stretched, and which should then be turned in the direction in which it normally rotates.

Fuse.—If this is at any time replaced, care should be taken not to use a heavier grade than the original one.

Important Note

The battery is not intended to provide current for any purpose other than starting. It should not, therefore, be used for a large number of electric lights, or any other form of electric auxiliary which requires a large amount of current. It can, however, be used for a few electric lights, assuming that the maximum load imposed upon it does not exceed 7 amperes, and that the engine does not remain idle for long periods, leaving the battery uncharged.

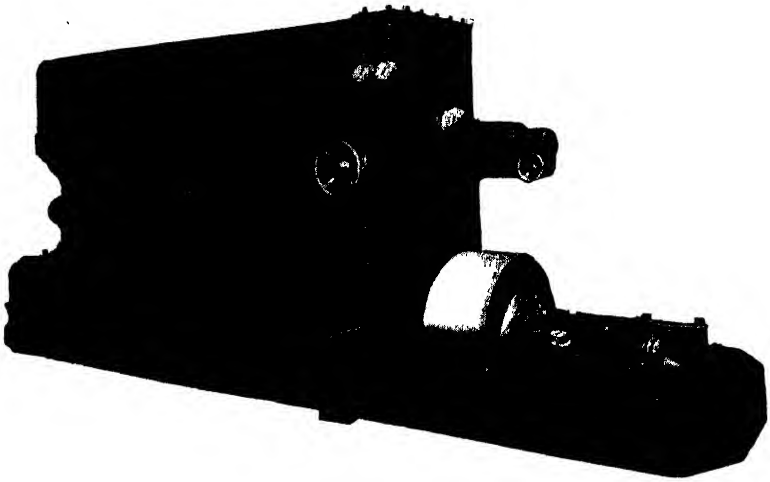


Fig. 6.—A TYPICAL MARINE ENGINE

In Fig. 6 we show an example of a National Marine Engine capable of developing 330 brake horsepower at a speed of 550 revolutions per minute. The bedplate and column are single well-dibbed castings bolted together along their whole length to form a rigid structure. Columns are bored to accommodate the cylinder liner held down at its top end by the cylinder-head with horizontally disposed valves and a vertical centrally situated atomiser. The inlet valve being carried in a renewable cage and exhaust valve operating in a renewable guide, dismantling of both valves is possible without disturbing the cylinder-head or breaking any pipe connections. For the operation of the two valves two camshafts driven from the crankshaft by roller chain actuate vertical pushrods and bell-crank type rockers.

The upper end of the piston is machined to a conical shape with a steel plug fitted to its apex, the proportion of the plug and corresponding throat in the cylinder providing a degree of turbulence conducive to effective starting and economical combustion.

Lubricating-oil pumps of the gear-wheel type with hand-priming pump device are fitted. On the suction side of each pump there is a gauze type filter of large area, whilst on the pressure side the oil passes through an auto-cleaning type on its way to the main and big-end bearings, through hollow connecting rod to the small-end bearing, and other parts.

For further information regarding the latest types of heavy-oil engines, both marine and stationary, the reader is referred to "Modern Oil Engine Practice" (Edited by E. Molloy) published by George Newnes Limited.

Acknowledgment

We are indebted to the National Gas & Oil Engine Co., Ltd., for supplying the above information. It should, however, be borne in mind that alterations and improvements are made to engines from time to time which may affect the above instructions.

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