Maintenance of High Speed Diesel Engines

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A Practical Handbook
for Diesel Engine Fleet Owners, Maintenance Engineers, Operators, Drivers and Mechanics

By

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PREFACE

With the rapidly increasing use of high speed compression-ignition or Diesel engines in various fields there has arisen a demand for a book dealing with the maintenance and overhaul of this type. The present small volume has been written with the object of supplying a comparatively inexpensive, but sufficiently complete, book to meet this demand.

Whilst written primarily for the user of small high speed oil engines used for automobiles, stationary and marine craft, the general information given will be found more widely applicable to other types of Diesel engine.

It has been assumed that the reader is familiar with petrol engine practice, in order to avoid duplication of the sections dealing with petrol engine maintenance, that are available in existing literature on this subject; this has enabled the author to devote all of the present volume to the special requirements of the Diesel engine.

A good deal of essentially practical information has been included, dealing with engine adjustments, troubles and their remedies, fuel pumps and injectors, starting and slow running, fault location and cure, etc.

Throughout, the actual experience of the leading manufacturers of high speed Diesel engines has been largely drawn upon, so that the reader is presented with data of direct utility.

The *Fault Finding Chart* on page 187 will be found particularly useful in the rapid diagnosing of Diesel engine troubles and in suggesting the appropriate remedies.

The author would like to express his appreciation of the kind assistance afforded in the preparation of this volume by various firms, in particular to Messrs. A.E.C., Leyland, Crossley, Armstrong-Saurer, Cummins, and Tangye, Messrs. Norris, Henty and Gardner and Messrs. C.A.V.-Bosch.

In conclusion the author would welcome any criticisms or suggestions that might be useful in improving future editions of this volume.

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PREFACE TO SECOND EDITION

THE favourable reception accorded to the first edition of this book, which was published less than two years ago, has necessitated not only a subsequent reprinting of the first edition, but also the present new edition, which brings the book up to date.

A number of new features and illustrations have been included, together with appendices dealing with the maintenance of typical high speed oil engines.

The new matter relates to more recent servicing methods and equipment ; the lubrication system, care and maintenance of the cooling system, new patterns of fuel feed and injection pumps and nozzles ; the pneumatic type of fuel pump governor ; reconditioning of worn parts by the nickel and chromium electrodeposition method ; valve insert methods and tools ; timing chain maintenance ; fuel filters and air cleaners. In addition, a number of practical hints on the tuning, speed regulation starting and stopping of oil engines and their fuel injection equipment are given.

It is believed that the additional information and new illustrations will extend the field of usefulness of this book.

A. W. JUDGE.

FARNHAM, SURREY,
1938.

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CHAPTER XII

MAINTENANCE OF HIGH SPEED DIESEL ENGINES

CHAPTER I

WORKING PRINCIPLES OF C.I. ENGINES

A KNOWLEDGE of the working principles underlying the operation of the high speed compression-ignition engine [1] is essential to all concerned with the manipulation, maintenance and repair of this type of engine.

For this reason it is proposed to devote the present chapter to considerations of the working cycles employed and to point out the differences between the C.I. engine and the petrol one.

As is generally well known, the petrol engine employs a mixture of petrol vapour and air in the proportions of one part of the former to 12 to 16 parts of the latter by weight. This mixture is supplied by the carburettor to the cylinder, where it is compressed by the ascending piston to about $\frac{1}{5}$ to $\frac{1}{6}$ of its initial volume; the corresponding pressure at the end of the compression process is usually from 90 to 110 lbs. per sq. in. This compressed charge is then fired by means of an electric spark, so that it experiences a relatively high increase in temperature and pressure. The expansion of the highly heated combustion products supplies the energy for the power or firing stroke of the petrol engine.

The C.I. engine operates upon a different principle, for it requires neither a carburettor nor an electric spark for ignition. It utilizes a heavier and more viscous fuel—known, popularly, as Diesel oil—and forces this oil directly into the combustion space through a suitable nozzle or injector, in the form of a fine spray or mist.

Instead of introducing a mixture of fuel and air into the cylinder, the C.I. engine draws in pure air only. This air is then compressed by the ascending piston to a considerably higher pressure than that used in the petrol engine; thus the

[1] Throughout this book the abbreviation "C.I. engine" will be used to denote the compression-ignition, Diesel or high speed oil engine.

air is compressed to $\frac{1}{12}$ to $\frac{1}{16}$ of its original volume, giving a compression pressure of about 450 to 550 lbs. per sq. in.

As a result of its high compression the temperature of the air is raised considerably—usually to about 500° to 550° C. Now, the temperature required to "self-ignite" the Diesel oil is about 350° to 400° C. It will be evident, therefore, that the effect of injecting the Diesel oil into the combustion space containing this highly compressed and heated air charge will be to cause it to burn very rapidly. There is thus no necessity for any electric spark to ignite the oil spray and compressed air. Immediately after the given amount of oil has been injected the temperature of the combustion products is raised considerably, namely, to about 2,000° C. to 2,700° C., but the pressure does not rise appreciably above the compression pressure as in the case of the petrol engine; usually, it reaches a maximum value of 700 to 850 lbs per sq. in. Thereafter the gaseous products expand, forcing the piston downwards (or inwards), thus providing the energy for the power stroke.

Having pointed out the fundamental differences between the petrol and oil engine, the two principal cycles of operation employed in commercial engines will be considered.

The Four-Cycle Oil Engine

The name "four-cycle" is applied to the C.I. engine for a similar reason to its association with the petrol engine, namely, because the complete working period or cycle occupies four consecutive piston strokes, equivalent to two complete revolutions. Of these four strokes only one is a power stroke, the other three essential strokes being idle ones.

Referring to Fig. 1, this denotes diagrammatically a section through one cylinder of a C.I. engine, the piston and crank positions being shown for the different stages of the cycle.

The engine has the usual arrangement of cylinder, piston, crank, inlet and exhaust valves to those employed in four-cycle petrol engines. In place of the usual sparking plug, however, it has a fuel injection valve for giving a fine fuel spray.

Diagram A shows the piston near the top of its exhaust stroke, the combustion chamber being filled with the remaining or non-ejected exhaust gases from the previous combustion process. The piston is shown descending, the inlet valve being open. As the inlet port is open (usually through a dust-extractor, or air filter, to the outside air) the piston during its descent sucks pure air into the cylinder.

When the piston reaches the bottom of its stroke the inlet valve is closed and since the exhaust valve is also kept closed, on its succeeding upward stroke (Diagram B) it compresses the air charge, finally giving the latter—as previously mentioned—a pressure of about 450 to 550 lbs. per sq. in. and a temperature of 500° to 550° C. Just before the piston reaches the top of its compression stroke (Diagram C), a mechanically - operated plunger pump is timed to force the fuel oil for combustion, under a high pressure of 1,500 to 3,500 lbs. per sq. in., through the fuel injector, where it emerges into the heated air charge as a conical highly "atomized" spray. It almost at once ignites and continues to burn all the time the fuel is forced through the injector; this usually continues for a period equivalent to the rotation of the crankshaft through an angle of 15° to 30°.

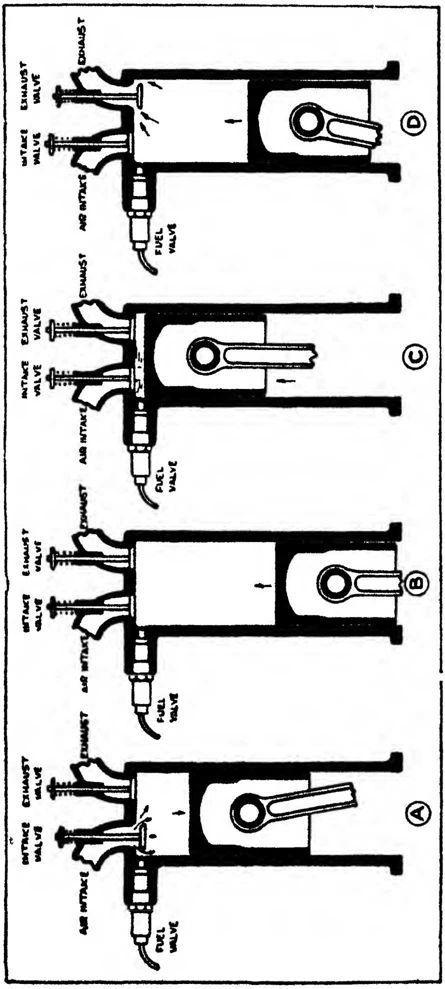

Fig. 1.—The Four-Cycle Compression Ignition Engine Operation.

On the next descending stroke the highly heated exhaust gases expand from their initial combustion pressure of about 700 to 850 lbs. per sq. in. down to atmospheric pressure (14.7 lbs. per sq. in.) which occurs when the exhaust opens, towards the end of expansion stroke valve. The inlet valve is kept closed during the expansion stroke and also the succeeding exhaust stroke (Diagram D). During the latter the piston ascends, sweeping the exhaust gases out of the cylinder through the exhaust valve. At about the end of this exhaust stroke the exhaust valve closes and the inlet valve opens; the cycle of operations is thus completed in two revolutions.

Pressure Conditions

An important difference exists between the pressure conditions of the C.I. and petrol engines. In the former case, most commercial engines aim at keeping the combustion pressure, i.e., the maximum cylinder pressure, down so that it is not very appreciably higher than the compression pressure. In the slower speed Diesel engines the two pressures were practically the same so that as the fuel burnt in the cylinder head the pressure did not rise appreciably, for the piston was commencing to move down its power or "expansion" stroke. For this reason this type was known as the *Constant Pressure* engine.

In modern high speed engines, however, it has been found advantageous to commence the fuel injection some 10° to 15° before the piston reaches the top of the compression stroke. The pressure, on this account rises above the maximum compression value. In most commercial engines the maximum cylinder pressures do not exceed about 700 to 800 lbs. per sq. in., i.e., from about 1·4 to 1·7 times the compression pressure. The principal reason for this is to keep down the weight of the engine, for the weight per H.P. increases as the maximum pressure is raised. In the petrol engine the maximum pressure is usually from 4 to 5 times the compression pressure, although in normal designs of petrol motor vehicle engines the former seldom exceeds about 650 lbs. per sq. in.

On the other hand, the petrol engine will yield mean, or average pressures of 100 to 145 lbs. per sq. in. for non-supercharged four-cycle types, and will attain speeds up to about 7,000 r.p.m., whereas present-day C.I. engines give appreciably lower mean pressures of about 80 to 110 lbs. per sq. in. and operate at speeds of about 2,000 r.p.m. Actually, however, engines have been run satisfactorily at speeds of 4,000 r.p.m. and there does not appear to be any theoretical reason why much higher speeds cannot be attained.

The Two-Cycle Engine

It is possible, as with the petrol engine, to operate the C.I. engine so that it completes a working cycle in two successive piston strokes or one revolution of its crankshaft, thus giving twice as many power strokes as the four-cycle engine.

Referring to Fig. 2, illustrating the principle of the two-cycle C.I. engine, the cylinder (Diagram A) has an exhaust port *B*; inlet port leading from the open air to the crankcase, *C*, and air charge transfer port *D* between the crankcase and the cylinder. This arrangement is identical with that of the three-port two-cycle petrol engine.

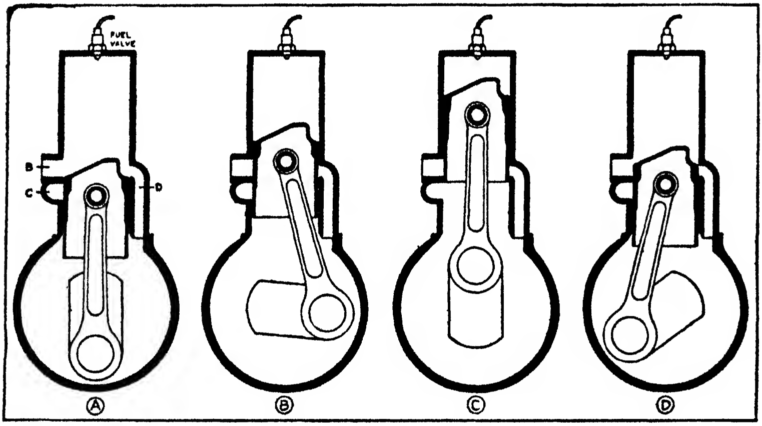

FIG. 2.—The Two-Cycle Compression Ignition Engine.

In (Diagram A) the expansion stroke has just been completed. When the piston neared the end of this stroke its upper edge uncovered the exhaust port *B*, thus allowing the exhaust gases to escape. The piston then descended a little lower so as to uncover the transfer port *D*. This allowed the air charge which had previously been drawn into, and compressed by the descending piston in the crankcase, to enter the cylinder. The piston now ascends, as shown in Diagrams B and D, shutting off both the transfer and exhaust ports *D* and *B*, respectively, and compressing the air charge.

When the piston is practically at the top of its compression stroke, as in Diagram C, with similar high compression pressure and temperature conditions to those of the four-cycle engine, previously described, fuel oil is injected under a high pressure, by means of the fuel pump and injector, into the cylinder head space, where it spontaneously ignites in the heated air charge. The fuel is then cut off, at a predetermined moment, and the piston is forced down on its power stroke, as shown in Diagram A, until its top left edge uncovers the exhaust port *B* and the cycle is completed.

The two-cycle oil engine has a marked advantage over the petrol type in that only air is compressed, so that, although a small quantity of air escapes from the transfer to the exhaust port when the two ports are open together, no actual fuel escapes and is lost as with the petrol engine—which uses a petrol-air charge compressed in the crankcase.

Whilst, theoretically, the two-cycle engine should give double the power of a four-cycle engine, in practice it seldom gives more than 50% to 60% on account of its lower volumetric efficiency and certain unavoidable power losses.

It is, however, possible to reduce the weight of a high speed C.I. engine considerably by employing the two-cycle principle. In this connection it may be mentioned that the well-known German Junker's two-cycle aircraft engine known as " Jumo," weighs only 2¼ lbs. per h.p., which is comparable with the weights of four-cycle petrol engines of similar output.

The two-cycle engine shown in Fig. 2 is an elementary type chosen for explanatory purposes. Modern two-cycle C.I. engines[1] do not employ crankcase compression, but embody rotary or reciprocating air compressors for charging the cylinders. In some cases, also, ordinary poppet valves are used for the exhaust and scavenging air.

Petrol and C.I. Types Compared

Since the majority of our readers will be more familiar with the operation and maintenance of the petrol engine, it may be as well to point out some of the essential differences between this type and the high speed C.I. engine now used for transport, marine, aircraft and stationary purposes. The petrol engine uses a fuel-air charge produced in an external apparatus, viz., the carburettor, and depends upon the induction pipe and cylinder suctions to obtain equal distribution to all cylinders; thus, ideal charging is seldom realised, nor is a full charge obtained at normal and higher engine speeds. Moreover, the carburettor is called upon to deliver the correct mixture proportions under a fairly wide range of temperature, air density,

[1] A full account of both two- and four-cycle C.I. engines is given in " High Speed Diesel Engines," A. W. Judge (Chapman & Hall, Ltd.).

humidity and pressure conditions, at various engine speeds and throttle-openings; no commercial carburettor can claim to fulfil all these conditions satisfactorily.

On the other hand the C.I. engine draws only pure air into its cylinders; it experiences much less obstruction to its flow than in the case of the petrol engine air supply, for the latter must pass through the carburettor and along the winding passages of the induction manifold.

The fuel is injected into each cylinder of the C.I. engine in accurately measured amounts, so that the correct fuel-to-air proportions are ensured for all the cylinders. Better volumetric or charging efficiency and fuel distribution are therefore obtained in the C.I. engine.

The petrol engine controls its power output by means of a throttle device situated on the induction side of the carburettor, so as to admit more or less mixture to the cylinders as required.

The power output control of the C.I. engine, on the other hand, is entirely on the fuel supply. In all cases a full charge of air is drawn into the cylinders, over the working range of engine speeds, but the quantity of fuel injected is varied from a minimum at idling speeds to a maximum at full loads and speeds. The fuel pump is, therefore, arranged to vary the period of time during which the fuel is injected; it is usual to refer to this injection period in terms of crank-angle degrees. Thus the injection might commence at 15° of crank-angle before top centre (compression stroke) and end at 10″ or 5″ before, for low loads; for full loads it would continue until the crank was 5″ to 15″ past top centre. The injection periods, in the two instances, would be 5″ to 10″ and 20″ to 30″ of crank-angle. *The moment of injection, i.e.*, the point at which it begins, has an important influence upon the running and fuel consumption just as the spark advance has in the case of the petrol engine. Up to a certain point it is found advantageous to advance the injection, but beyond this point excessive cylinder pressures are usually developed. *The setting of the injection advance* is therefore of primary importance in C.I. engines.

The C.I. engine, on account of its high compression, gives a much lower fuel consumption per h.p. than the best petrol engine. Thus, it is not unusual for commercial C.I. engines to use only 0·4 lb. of fuel oil per hour for each h.p. developed, whereas the petrol type uses from 0·5 to 0·6 lb. It will be evident, therefore, that if petrol and Diesel oil are sold at the same price, the C.I. engine will always show an appreciably lower fuel bill. Actually, as both of these fuels are sold by the "gallon," the user of the Diesel oil will score, since a greater weight is obtained per gallon on account of its higher density.

Another point in favour of the C.I. engine is its much better pulling effort, or torque, at all working speeds. Users of C.I. engine automobiles are well aware of the better performances of their vehicles on top gear than those of petrol engine ones. This wider range of top gear performance tends to reduce the fatigue of long distance driving.

Other advantages of the high speed C.I. engine are *the absence of magneto, or coil-ignition* and *sparking plugs*; *absence of carburettor with its various adjustments*; the *use of a fuel of much higher flash-point* than petrol—thus practically *eliminating the fire risk*; the use of *a smaller radiator*—since less heat is lost to the cylinder walls and cooling water; *better starting and "pulling" from the cold* and *less maintenance* attention.

One other important advantage lies in the fact that almost as soon as the C.I. engine is started *from the cold it can be run at nearly full load, i.e.*, it will take up its load much more readily than the petrol engine; the latter requires several minutes to "warm up" before it will begin to pull satisfactorily.

The petrol engine, however, still remains dominant in the matter of its greater power output for a given cylinder size; in other words it can be made appreciably smaller and lighter for a given h.p. output. The C.I. engine designer has, however, made a good deal of progress in reducing engine weights, by using special metals and alloys. In this connection it may be mentioned that the C.I. engine used on a well-known bus chassis is actually lighter than the petrol engine that it replaced.

In some of the earlier C.I. engines, usually having non-turbulent cylinder heads, a common trouble was that of a somewhat heavy thump at certain engine speeds. This noise is known as "*Diesel Knock*" and is due primarily to too rapid burning of the fuel so that the pressure rises too quickly. It is similar in its cause to detonation in petrol engines, but is more pronounced in effect.

The modern C.I. engines employ specially designed combustion heads of the turbulent or semi-turbulent type. These give a better control of the pressure rise and, incidentally, owing to the fuel being more efficiently burnt, obviate the smoky and pungent exhausts that were associated with the earlier commercial high speed C.I. engines.

CHAPTER II

THE C.I. ENGINE IN PRACTICE

HAVING given an outline of the working cycles and pointed out the advantages of the C.I. engine, the more practical aspects of this type will now be considered.

Fig. 3 illustrates, diagrammatically, the main features of the commercial C.I. engine, the simple example chosen for this purpose being a plain cylinder head one, in which the upper end of the cylinder forms the combustion chamber ; as will be shown later, there are other modern types having auxiliary combustion chambers communicating with the cylinder head by means of suitably arranged passages.

The class represented in Fig. 3 is known as the Direct Injection one, since the fuel is sprayed directly into the cylinder itself. The piston *R* is shown nearly at the top of its compression stroke, both the inlet valve *I* and exhaust valve *E* being closed. Commencing at the fuel source, Diesel oil is drawn through a fuel filter *F* on the suction stroke of the fuel pump *P*, in order to rid it of all solid particles ; the presence of the latter would not only cause excessive wear of the moving parts of the fuel pump but tend to choke the fine passages in the fuel injection nozzle *J*. The cam *C* runs at half engine speed.

The fuel pump accurately measures out the predetermined quantity of oil and at the correct moment delivers it, past a non-return delivery valve into the fine bore fuel pipe *L*. The pump, which is mechanically driven from the engine, at one-half engine speed, in the four-cycle engine, is designed to give a high pressure to the oil in order to force it through the injection valve in spray form against the compression pressure (450 to 550 lbs. per sq. in.) existing in the cylinder *V* at the time of injection. The usual fuel pressures given by the fuel pump are about 1,000 to 2,000 lbs. per sq. in., although pressures up to 3,500 lbs. per sq. in. have been used on some engines.

The bore of the steel injection pipe is kept as small as possible, viz., from 1½ to 3 mm. according to the size of engine.

The usual form of injection nozzle *J* is that of a spring-loaded plunger having a conical or specially shaped end, normally held on a seating, located near the wall of the combustion chamber, by the spring-pressure. During the period of injection, however, the high fuel pressure given by the pump overcomes the spring pressure and lifts the valve off its seating, thus allowing the oil to enter the combustion chamber. The

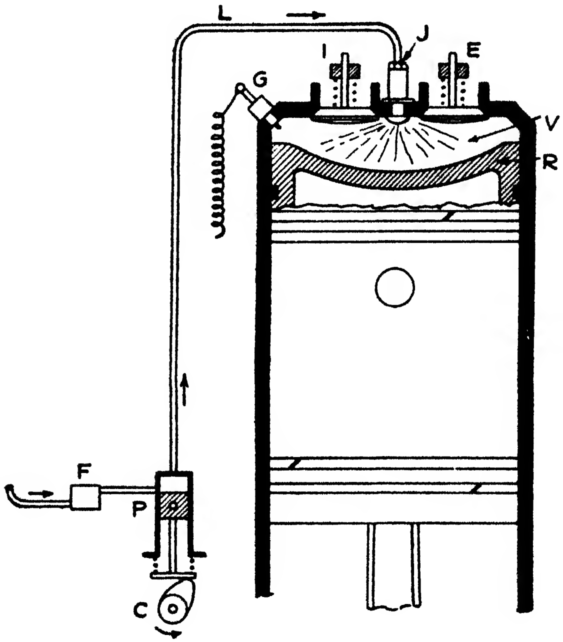

FIG. 3.—The Direct Injection C.I. Engine.

size and shape of the injection nozzle end are designed to give the desired shape of spray, whilst the injection pressure is sufficient to force the extremely fine oil particles to the farthest parts of the combustion chamber. This is an important feature of the direct injection engine for the fuel must rapidly take up its oxygen for combustion from the air in the cylinder head. In the example illustrated the crown of the piston is dished inwards, so as to tend to make the paths of travel of the fuel particles of about the same length ; the combustion process is thus made as uniform as possible all over the combustion space.

FIG. 5.
A Typical
Glow Plug.

FIG. 6.—The A.E.C. Engine Injection Nozzle.
A Fuel entry from pump; *B* Fuel passage; *C* Injection valve; *D* Valve seating: *E* Leak-

There are several alternative designs of piston and cylinder head for use with the direct injection system described. The design shown in Fig. 4 employs a kind of domed piston crown and an injector giving a wide spray angle corresponding to the general shape of the piston contour ; this results in a thorough penetration of the charge air by the finely divided fuel spray.

It is not possible to describe the other designs of direct injection head in this volume, but all of these are based upon the same general principle.

The direct injection engine requires a special design of injection nozzle to give the desired shape of spray ; usually a multiple-hole nozzle is used for this purpose. It also requires higher fuel injection pressures in order to force the fuel particles right across the combustion space in order to utilize a high proportion of the oxygen in the air charge.

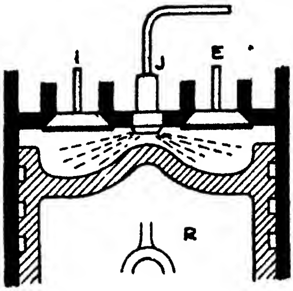

FIG. 4.
Another Type of Direct Injection Engine, with Domed Piston.

Glow or Heater Plugs

The direct injection system has the advantage of high heat efficiency, for all of the combustion occurs within the cylinder head. It is also easier for starting the engine from the cold without heated plugs.

Although not always fitted, some types of engine have an electric heater or glow plug for starting purposes. This takes the form of a small plug resembling, somewhat, a sparking plug, but having a coil of resistance wire at the cylinder end. This wire is heated to redness by means of a 6 or 12 volt current supply when it is desired to start the engine. After starting the glow plug is switched out of action.

Fig. 5 illustrates a typical glow plug with central insulated terminal, the outer shell forming the other connection for the resistance wire being earthed to the metal of the cylinder, as in the case of the ordinary sparking plug.

The glow plug is usually placed on one side of the combustion chamber or in the side wall of the ante-chamber in the latter type of engine. In Fig. 3 the glow plug is indicated at *G*, but in practice *direct injection engines* do not need such glow plugs as they start readily from cold.

The Injection Nozzle.

There are several types of injection nozzle in current use. These, however, may be grouped, broadly, into two classes, viz., *The Open Nozzle* and *The Closed Nozzle*. In the former case there is no controlling valve to prevent the flow of fuel from the nozzle after the actual injection ceases. In the latter case there is always some device — usually a spring-loaded valve to close the exit hole or holes of the nozzle when injection ceases.

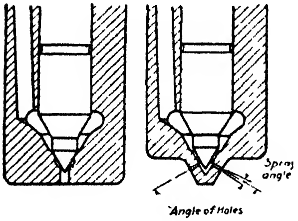

FIG. 7.—Showing (left) Single Hole Nozzle and (right) Multiple Hole Nozzle.

The open type of injector has its fuel supply controlled entirely by the fuel pump; in the closed type, hydraulic or mechanical control of the valve in the nozzle is employed. The closed type is far more widely used in high speed C.I. engines as it is free from leakage and certain other defects.

Fig. 7 shows two typical injection nozzles, in section. That on the left is a single hole closed type; and on the right a multiple hole one. In each case the fuel delivered from the fuel pump is directed down the passage shown on the left-hand side, into the space surrounding the larger cone. When the fuel is under the injection pressure it lifts the central conical-ended plunger against the action of a strong control spring; this causes the lowermost cone to lift, thus admitting fuel under high pressure through the nozzle end hole or holes into the combustion space.

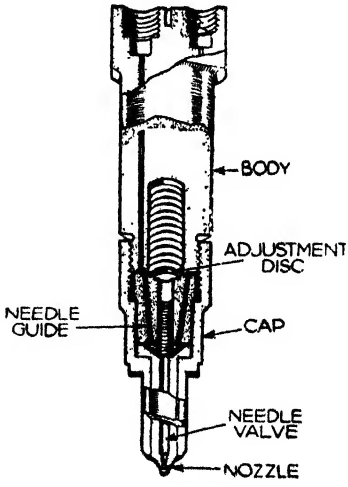

FIG. 8.—The Armstrong Saurer Injection Nozzle.

Fig. 8 illustrates the Armstrong Saurer nozzle, the various important parts being indicated.

There is another form of injection nozzle that is employed on some C.I. engines, known as the mechanically-operated type. In this case the underlying principle is that of a nozzle having a conical seating near the outlet hole or holes. The central plunger, or barrel portion, has a conical end engaging with this seating. The injection valve in this case is opened mechanically by means of a cam on the overhead shaft.

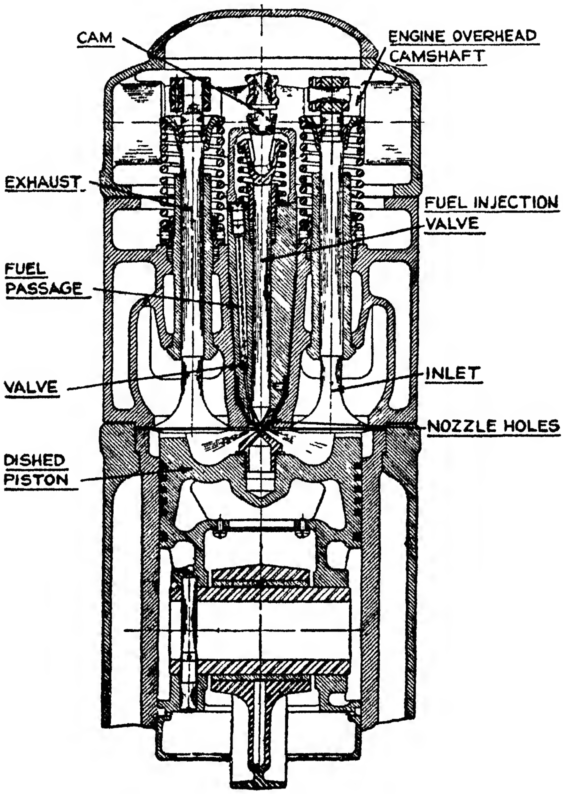

FIG 9.—The Cummins Engine Injection Arrangement.

An advantage of this method is that the fuel, which is delivered from a single pump to a common oil reservoir or storage chamber, is at an appreciably lower pressure in the fuel pipes than for the hydraulically-operated nozzles previously described. The fuel is only given its full injection pressure at the nozzle itself, by means of the mechanically operated plunger previously mentioned.

A good example of this type of injection device is shown in Fig. 9 depicting the widely used American Cummins C.I.

engine cylinder head. The central fuel valve, the fuel delivery passage with its non-return valve and the multiple-hole nozzle are clearly shown. Incidentally, the overhead camshaft, operating the inlet, exhaust and injection valves is also shown.

The engine in question is of the direct injection type with specially shaped dished piston head. The latter has an air cell or chamber which during the latter stages of the fuel combustion process releases its highly compressed air into the cylinder space. This takes place as the piston starts its downward stroke and gives a better regulation of the pressures whilst entirely preventing Diesel knock.

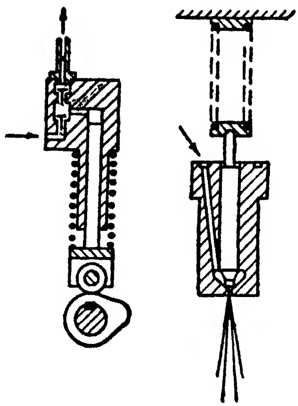

Fig. 10.—(Left) The Fuel Pump and (right) the Injection Nozzle Principle.

The Fuel Pump

The fuel pump, in the case of the more commonly used hydraulic injection valve system—of which the Bosch, Simms, Benes and Bryce are typical examples—consists of a number of separate pumps, there being one complete unit, comprising the plunger, barrel, inlet and delivery valves, for each of the engine cylinders; thus a four-cylinder C.I. engine will have a four unit pump; a six-cylinder engine a six unit pump; and so on.

For general convenience and compactness the units are arranged in a single casing and their plungers are operated from a single camshaft. From the delivery side of each unit the small-bore delivery pipe is taken to the injection nozzle of its cylinder.

Fig. 10 shows, diagrammatically, the general principle of the fuel pump. On the left is shown the plunger which is lifted by the engine-driven cam and closed by the external spring, indicated. Fuel is sucked into the pump chamber through a non-return valve on the downward stroke of the plunger and is forced out through another non-return valve to the injection valve, through the delivery pipe, on the upward stroke of the plunger.

The direction of the fuel flow is indicated by the arrows. The fuel injection nozzle is shown on the right, fuel being forced down the small inclined passage on the left to the space near the bottom of the nozzle plunger. The latter is kept on its seating by means of a spring; the latter is indicated by the dotted lines above.

Apart from its purpose of pumping the fuel to its appropriate injector, the fuel pump must be designed to deliver varying small quantities of fuel at exactly the right moment of injection.

To do this, each pump unit is provided with an adjustment for varying the quantity of fuel pumped per stroke of the plunger. All of these adjustments are connected to a single control, so that by moving the latter all of the deliveries from the separate units are regulated together. Most fuel pumps have a control rod, in the form of a toothed rack, the teeth engaging with corresponding teeth cut on the cylindrical part of the lower end of each plunger.

When the rack is pulled endwise it rotates each plunger, so that spirally-cut portions at the upper end of each are moved up or down in order to control the quantity of fuel.

The cams operating the pump plungers are cut from the solid on a single camshaft—just as in the case of petrol engine camshafts; the cams are, therefore, arranged at their correct relative angles, these being the same as those of the cranks on the engine crankshaft.

The control rod actually governs the duration, or time, of the injection, for, as previously explained, the C.I. engine power control consists in altering the period of the injection; thus the fuel pump, by means of its plunger rotation control, can be arranged to deliver fuel for a small or long period as required. The control rod is sometimes arranged for operation by means of the usual hand or foot control lever, or by means of a governor. In the latter case the governor is designed to limit the idling speed and also the maximum permissible engine speed. The driver, or operator, has a separate hand or foot control to regulate the engine output between these two limits of speed, but he cannot run the engine at a lower speed than the pre-set idling speed or above the given maximum speed.

A typical governor arrangement for an automobile C.I. engine is illustated in Fig. 11; this provides idling or "no load" and full load limitation of engine speed. There is also a provision for the full range of intermediate speed control by the driver; the mechanism for achieving this end is clearly shown in the diagram.

There is one other adjustment that is necessary in the case of the fuel pump, viz., for altering *the timing of the injection*. As previously shown, the moment at which the injection commences, near the top of the compression stroke, has a very important bearing upon the general running and performance of the engine. It is necessary, therefore, to provide some means of adjustment so that the injection can be made to occur earlier or later as required. This is effected by altering the position of the fuel pump camshaft relatively to the engine

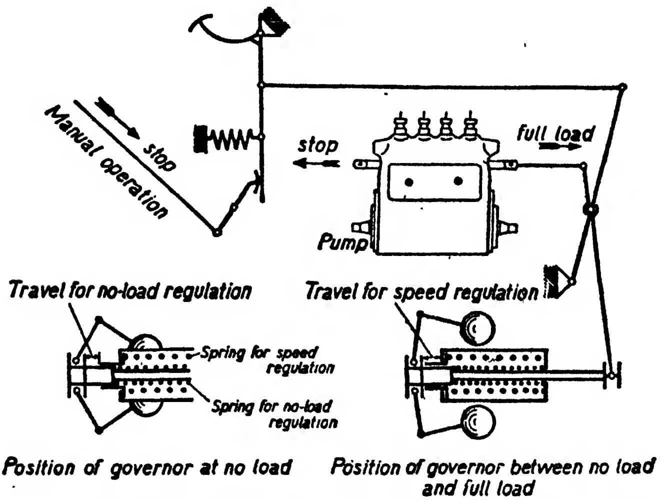

FIG. 11.—Diagram showing Method of Governing C.I. Engine to provide Regulation for both the " Idling " and maximum speeds.

drive shaft. The amount of angular change required is very small, being a matter of some 10° to 20° on the crankshaft, or 5° to 10° on the pump's camshaft. An adjustable coupling is usually fitted for this purpose between the engine drive and the pump's camshaft. Reference to this and other controls and adjustments for the fuel pump is given more fully in Chapter IX.

General Notes on Fuel Pumps

From the preceding section it will be evident that the fuel pump must deliver very small quantities of fuel, each of identical amount to the various cylinders, in rapid succession and at the correct phases.

Thus, in the case of an engine running at 2,000 r.p.m. the injection period of, say, 20°, takes place in $\frac{1}{600}$ second; this is an extremely small interval of time for the fuel pump to operate in.

Again, in the ordinary commercial vehicle C.I. engine, the quantity of fuel injected is of the order of $\frac{1}{250}$ to $\frac{1}{200}$ cu. in. at normal loads and $\frac{1}{1000}$ to $\frac{1}{500}$ cub. in. at light loads. Where spray nozzles are used for atomizing the fuel, the diameters of

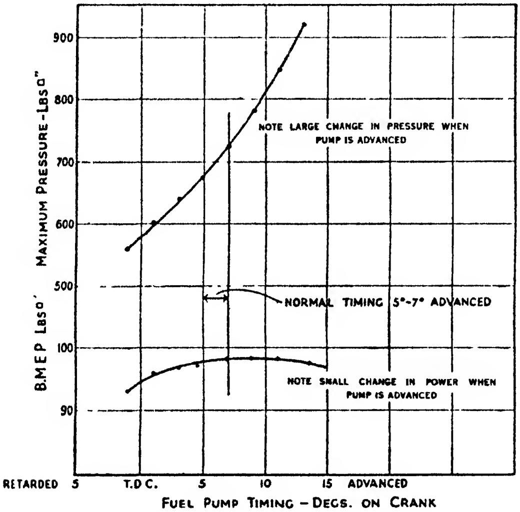

Fig. 12.—Effect of Injection Timing upon Mean and Maximum Pressures.

these vary from $\frac{8}{1000}$ to $\frac{14}{1000}$ in. The lengths of these holes usually range from $\frac{1}{50}$ to $\frac{1}{25}$ in.

The timing of the injection must be accurately set, for if it be too far advanced, higher, maximum, or "peak" pressures will be developed. The loads on the small, big-end and main bearings will, therefore, be increased—often above the designed limits of bearing pressure. In this respect it is usually found that *one degree of injection advance causes an increase of maximum pressure of* 50 *to* 60 *lbs. per sq. in.* The value given will, of course, vary according to the design of combustion chamber, the degree of turbulence and other factors.

It is here of interest to refer to Fig. 12 showing how important is the effect of the injection timing on the pressures in the case of the A.E.C. oil engine. It should be noted that the fuel pump is definitely set to give a normal injection timing of 5° to 7° before top dead centre. This setting corresponds to a maximum pressure of about 730 lbs. per sq. in. and a B.M.E.P.[1] of about 98 lbs. per sq. in.

The effect of advancing the injection beyond the standard setting is to cause a marked increase in the value of the maximum pressure without materially affecting the B.M.E.P. —and therefore the power output ; beyond about 10° advance the latter actually commences to fall off, whilst the maximum pressure increases.

The importance of keeping the injection advance within the definite limits mentioned will be evident from the fact that the maximum pressure—and, therefore, the bearing loading—in this instance, increases at the rate of approximately 60 lbs. per sq. in. for each degree of advance. The manufacturers of the A.E.C. engine are, therefore, strongly opposed to interference with the injection timing of their engines.

On the other hand, *the injection timing must not be retarded too much,* otherwise the engine will work with *a smoky exhaust.* Moreover, it will have a higher fuel consumption under these circumstances ; and the power will tend to fall off.

The *mechanical parts of the injection* pump must be made of the best materials and with high precision, for the working pressures on the delivery side are of the order, 1,000 lbs. per sq. in. and over, so that there must be no question of mechanical failure or fuel leakage. In this respect the pump plunger must be an accurate working fit in its barrel ; it is usual to lap the plunger into its barrel, for this reason. The valves, valve seatings and valve guides should also be of the highest grade materials and accurately made.

In regard to the valves and their seatings these must be very hard and precision-ground to corresponding shapes. The seating should be made small enough to prevent leakage. As the velocity of the oil through the valve seating port is very high the valve lift is limited, in practice. The *usual method of preventing leakage* is by the use of hardened and ground surfaces for the joints ; in certain cases, however, copper gaskets are used.

Another essential feature is rigidity of the parts ; in particular the cams and camshaft must be of robust construction and made of high grade alloy steel, suitably heat-treated.

[1] Brake Mean Effective Pressure, which is a measure of the horse-power output.

Combustion Chamber Arrangements

As the maintenance engineer may be called upon to deal with more than one type of high speed C.I. engine, it is advisable for him to be acquainted with the more commonly used combustion chamber arrangements. These can conveniently be grouped into four main classes, as follows: (1) *The Direct Injection System*; (2) *The Pre-Combustion Chamber System*; (3) *The Turbulent Head Type*; and (4) *Miscellaneous Types*; the latter include a number of original designs involving special shapes of piston, cylinder-head, ante-chamber, and

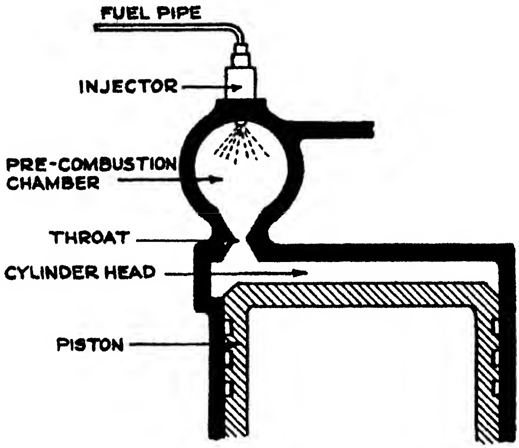

FIG. 13.
Showing Principle of Pre-combustion Chamber Engine.

other patterns representing combinations of the first three main types mentioned.

As the first system has already been dealt with, no further reference is here necessary.

(2) THE PRE-COMBUSTION CHAMBER SYSTEM.—In this type there is a small auxiliary chamber which communicates with the cylinder itself by means of a relatively narrow neck. The principle aimed at is to promote the projection of burning fuel particles from the auxiliary chamber, through the neck or throat into the cylinder head, in order to obtain a more progressive and less rapid combustion effect. At the end of the compression stroke the piston almost reaches the end of the cylinder and thus forces the air charge into the auxiliary chamber. At the correct moment the fuel is injected into the

latter space in a partially pulverized condition. It immediately begins to ignite and in so doing projects a mixture of burning and unburnt fuel from the auxiliary chamber through the throat into the cylinder. In some cases the throat is replaced by a perforated plate of refractory material. A relatively large fuel orifice can be used with this system. The direction of the spraying is not very important, nor is a high injection pressure essential.

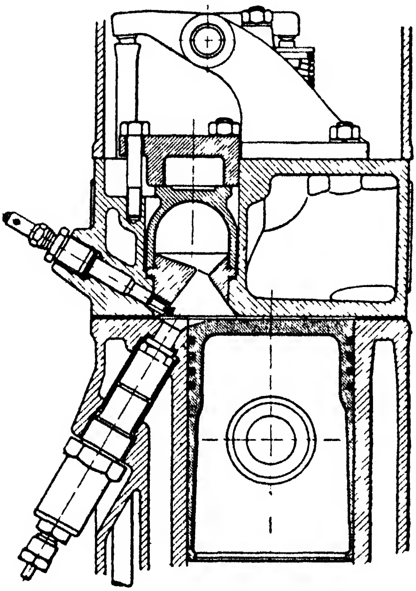

Fig. 14.—The Bosch Acro External-type Pre-combustion Head.

The disadvantages of the pre-combustion chamber are briefly as follows:

(1) A high compression ratio is required in order to give a sufficiently high temperature in the auxiliary chamber, for a certain proportion of the compression heat is absorbed by the metal of the throat and auxiliary chamber walls.

(2) From 10 to 15 per cent. of the heat of the burning fuel is lost through the throat during combustion.

(3) This type is more difficult to start from the cold, owing to the previously mentioned heat loss during compression. Electric glow plugs or starting cartridges are invariably employed, unless the engine has a hand-operated device for raising the compression for starting.

The Bosch Acro head is perhaps the best known and most widely used pre-combustion type. It is made in two patterns, viz., one with the auxiliary chamber outside the cylinder, and the other with this chamber formed inside the piston head. The two types are known as the *External* and *Internal* ones, respectively.

Figs. 14 and 15 illustrate these two combustion heads, and show also the positions of the injectors, which are arranged to discharge the fuel directly into the throats of the chambers.

The smaller devices shown, with their inner ends in the cylinder head spaces, are the electric glow plugs for starting.

(3) THE TURBULENT HEAD TYPE.—Whilst it is true that there is a certain amount of movement or agitation of the compressed air in the combustion chamber just prior to the injection of the fuel, in practically all types of engine, in many cases this turbulence is more or less accidental and of relatively low degree. The type of combustion chamber under consideration is that in which the designer has specifically arranged to impart a moderate to high degree of turbulence to the compressed charge for the purpose of securing a satisfactory admixture of the air and fuel particles. The injector, in this case, is usually of the single hole type, having a relatively larger hole than the direct injection type of nozzle. It is placed in the combustion chamber so that the turbulent air stream sweeps rapidly past the outlet hole and each particle of fuel is given its proper air supply for combustion soon after it emerges from the nozzle.

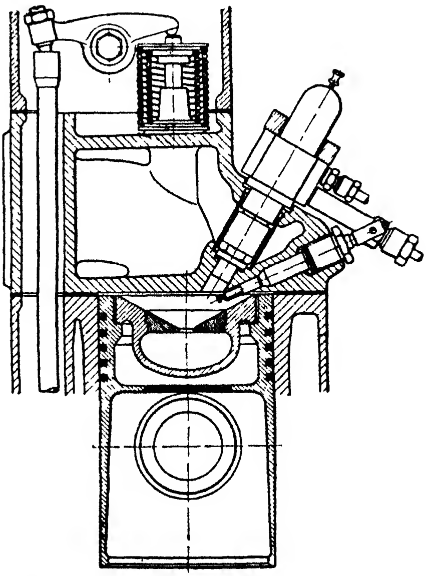

FIG. 15.—The Bosch Acro Internal-Type Pre-combustion Chamber.

There are various methods of producing this turbulence, one common process being that of making the piston force the compressed charge into an auxiliary chamber. The piston, which may be plain or with a central projection, is arranged almost to touch the cylinder top at the end of its stroke, thus forcing the remaining air charge through comparatively narrow spaces into the auxiliary chamber; the air is given a high degree of turbulence in this case. Some typical examples of turbulence heads of the kind just mentioned are shown in Fig. 16. Those indicated in Diagrams A and B are sometimes known as the *Clerestory Head* type.

Another popular method is to arrange for the piston, towards the end of its compression stroke, to give the air a rotational motion of high velocity. This is usually attained by having a spherical or cylindrical auxiliary chamber which communicates with the cylinder proper by means of a passage which is arranged so as to be tangential to the sphere or cylinder previously mentioned The fuel injector is then placed so as to spray its fuel at right angles to, i.e., directly across, the swirling air charge path.

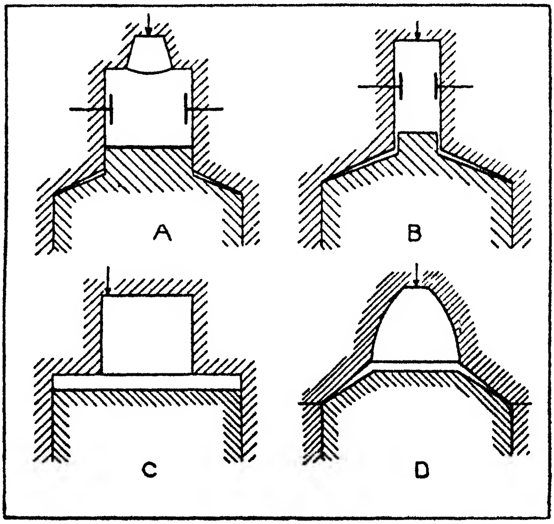

FIG 16—Air Turbulence Type Cylinder Heads.
A Blackstone; *B* Wiseman; *C* Ricardo Rotational Swirl; *D* Petters.

The Ricardo "Comet" head, fitted to the A.E.C. and other commercial makes, is illustrated in Fig. 19. This operates upon the rotational turbulence principle. It should here be mentioned that the lower part of the spherical auxiliary chamber is made of a special heat resisting steel.

The modern turbulence type C.I. engines undoubtedly give satisfactory combustion of the fuel with absence of exhaust smoke and also of "Diesel knock," but they have the disadvantage of being rather more difficult to start from the cold than the direct injection type. On account of the turbulence effect the air charge loses some of its heat to the metal walls, and requires more power to set the air in motion and to overcome the air frictional effects. A higher compression

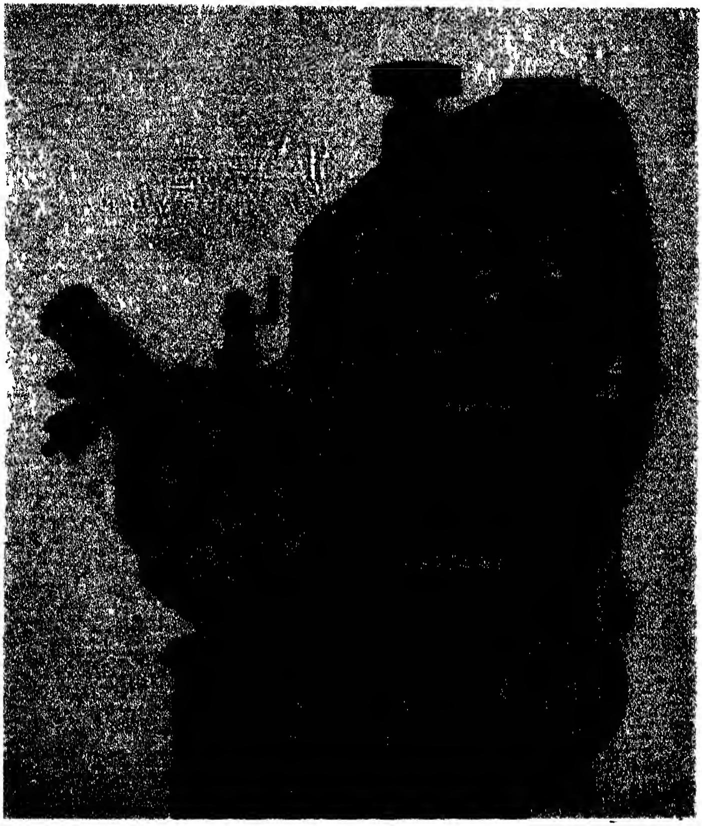

FIG 17
Sectional View of A E C Engine, showing Comet Combustion Chamber

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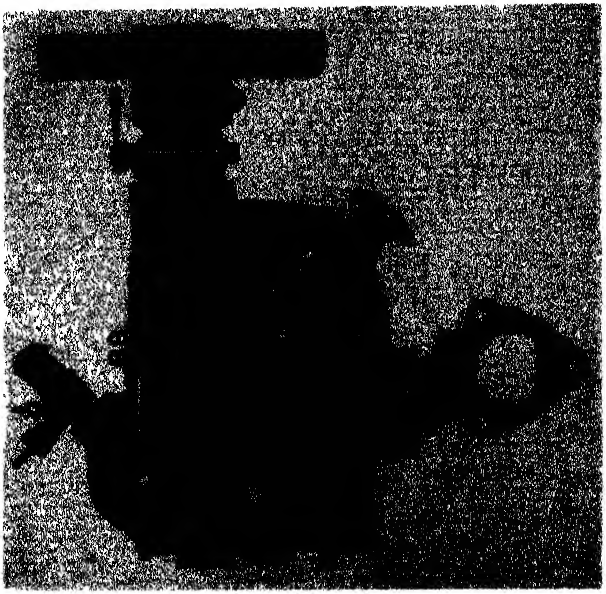

Fig. 18.
The Leyland Spherical Combustion Chamber type Engine.

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is, therefore, necessary, whilst the heat efficiency is not so high as in certain other types. On the other hand, only a plain single hole injector is required ; and the injection pressure is lower than for the direct injection combustion heads.

(4) MISCELLANEOUS TYPES.—There is a fairly wide variety of combustion heads which do not fall into any one of the particular classes mentioned, but are designed as combinations of piston, cylinder head, combustion chamber and injector to give the required conditions for burning the fuel in the air

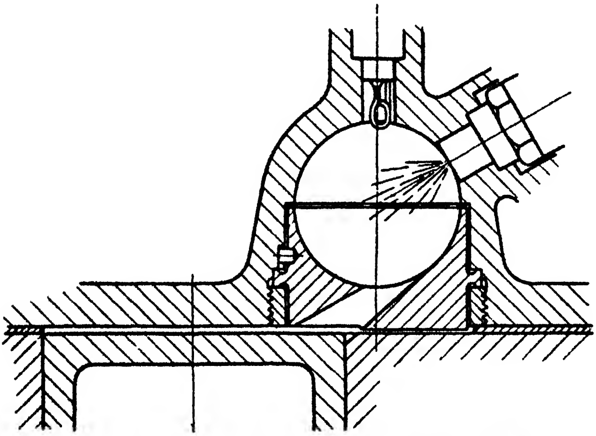

FIG. 19.—The " Comet " Combustion Chamber, giving rotary swirl effect.

charge as efficiently as possible. It is not possible to describe these types in the present work, but only to refer to a few typical examples that are employed in well-known commercial engines. A full account of the more important combustion heads will be found in the book referred to in the footnote on page 6.

In certain designs the combustion chamber or ante-chamber is formed as a cavity in the piston itself ; this arrangement gives a compact cylinder head of simple design, but involves the use of a heavier piston that requires special cooling means.

A good example of a modern cavity piston type of combustion chamber is that of the Leyland engine, shown in Fig. 21. Here, the piston is shown at the top of its compression stroke, very close to the cylinder head. The offset combustion chamber is of the direct injection type, the fuel injector spraying its fuel vertically downwards on the side of the cavity. The fuel

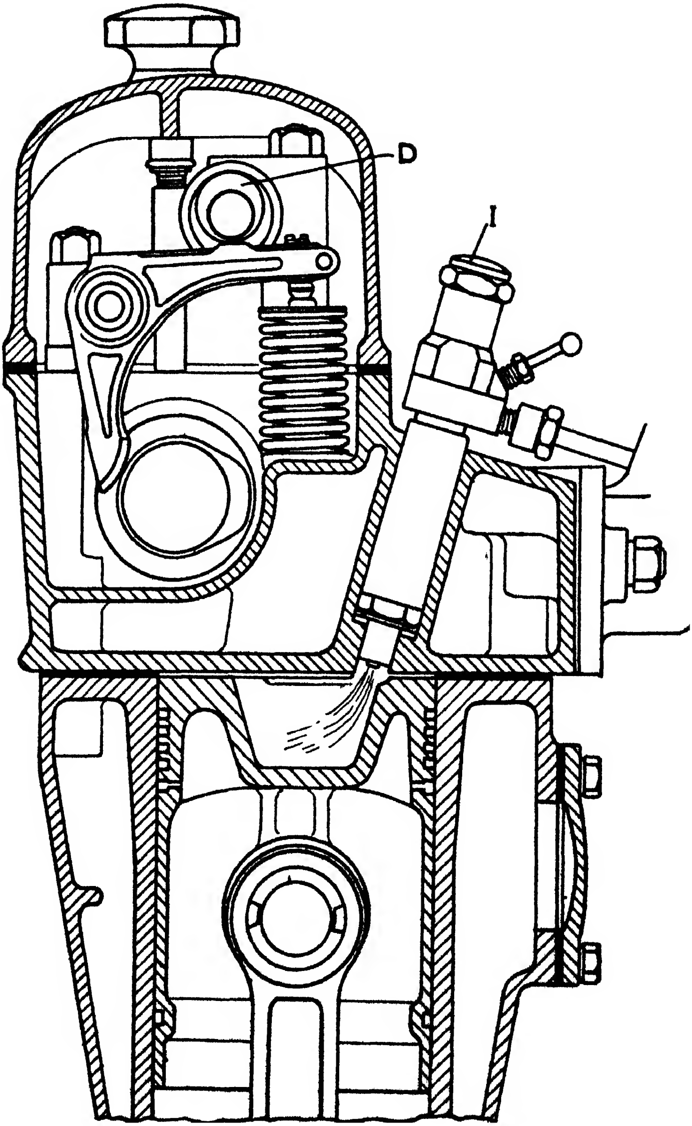

FIG. 21.
The Leyland Engine with Cavity Piston Combustion Chamber.

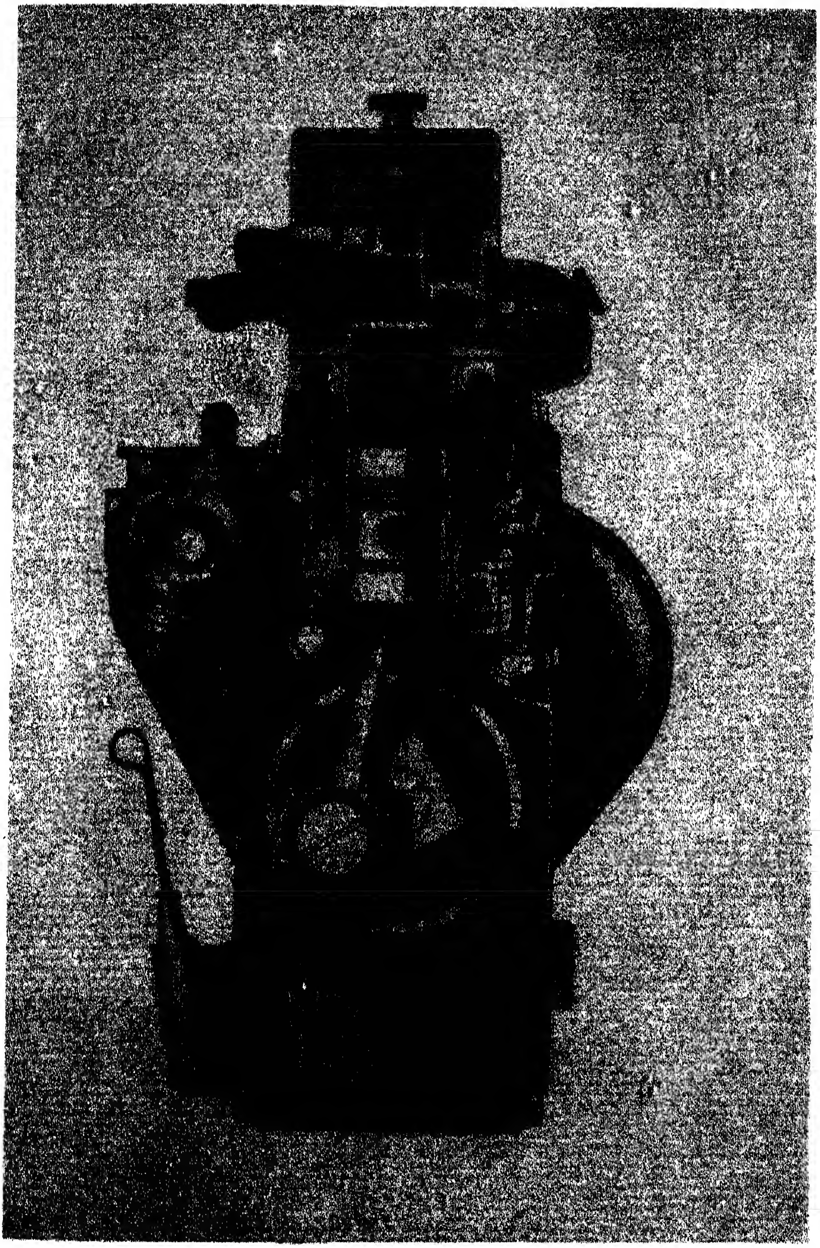

FIG. 20.—The Fowler Sanders Engine. This has a wide mouth air turbulence chamber, which is claimed to reduce heat losses in the throat and to give a higher heat efficiency.

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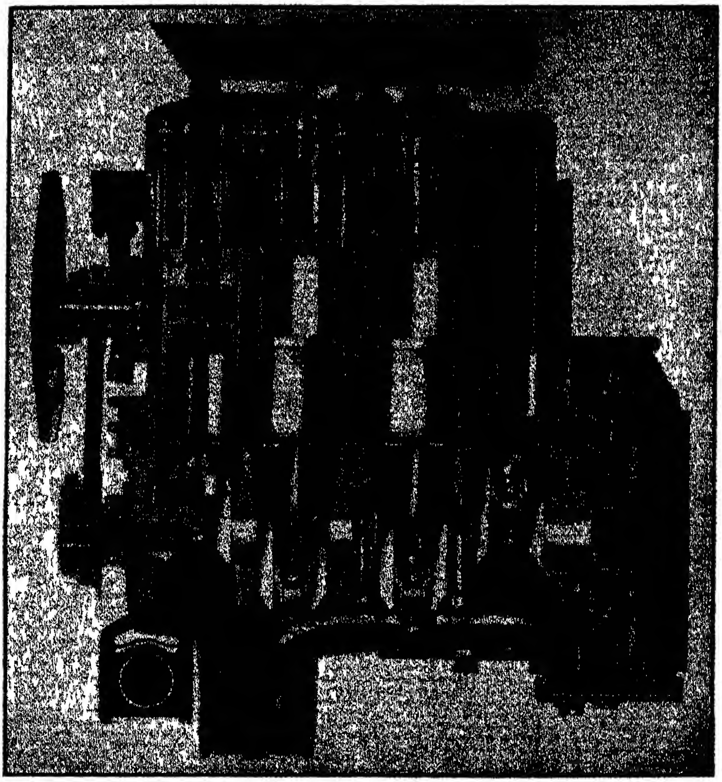

Fig. 23.—The Dennis Four Cylinder Engine with Cavity Piston Combustion Chambers

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is thus kept away from the cylinder walls where, otherwise, it might have a detrimental effect on the lubrication.

No glow plugs or other auxiliary apparatus are fitted or necessary for starting purposes. It is claimed that the air flow in the cylinder head is practically non-turbulent and non-reversing, the combustion chamber being free from the heat-losses of the turbulent type of head.

The Armstrong Saurer combustion chamber, illustrated in Fig. 22, is of the dual flow cavity piston variety. The specially shaped cavity is shown at *A*. The injector is arranged vertically

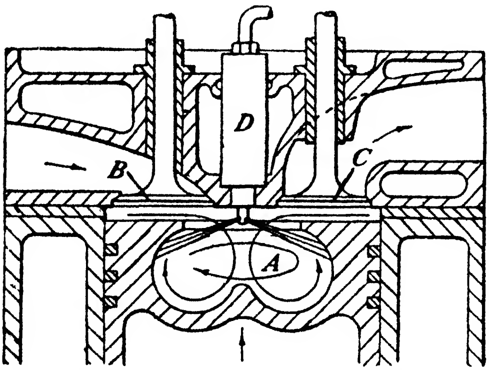

FIG. 22.—The Armstrong Saurer Dual Flow Cavity Piston Type.

at *D* and gives a wide spray effect downwards into the double-turbulent air charge. The air is led tangentially through the shrouded inlet valve *B* into the piston cavity. The air has both horizontal and vertical swirling motions due to the valve port shapes and to the rising piston effect. When the fuel is sprayed into this turbulent air charge, an intimate mixing of the fuel particles with the air is obtained. There are two inlet and two exhaust valves per cylinder in the engine in question, and tests have shown that the performance is superior to that of the Acro type of head previously employed by the same firm.

Fig. 23 shows the four-cylinder Dennis engine which has a cavity piston type combustion chamber of somewhat similar form to that shown in Fig. 22. The engine has a bore of 117·47 mm. and stroke of 150 mm. (6502 c.c.). It is rated at 34·24 H.P., and develops a maximum of 82 B.H.P.

The E.M.B. combustion chamber shown in Fig. 24 is an interesting example of a clerestory head as used on the E.M.B. engine.

It consists of an auxiliary chamber above the cylinder barrel in which the air charge is compressed with a turbulent motion. The piston has a square projection which does not completely close the communicating neck but leaves a passage which is tangential to the cylindrical ante-chamber ; the last portions of the air compressed into the latter are therefore given a rotary motion. The inlet and exhaust valves form the sides

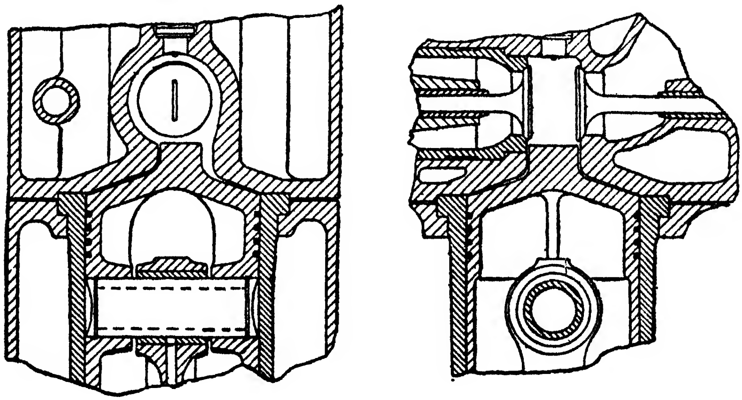

FIG. 24.
The E.M.B. Clerestory Head, giving Rotational Turbulence Effect.

(or ends) of this cylindrical space, whilst the injector is arranged directly above, so as to project the fuel in a radial direction towards the centre of the cylinder.

Another original design of combustion head is the M.A.N., shown in Fig. 25. This has two auxiliary chambers, one forming the combustion space and the other an air cell for regulating the rate of combustion. This auxiliary air chamber, or cell, communicates with the top of the cylinder through a diffuser neck. The atomizer, which is of the Bosch standard type, is arranged at an angle of about 40° to the top of the piston.

The air cell is quite separate from the combustion chamber and its object is to store up air under the compression pressure, delivering it in the form of a stream as the piston descends on the combustion-expansion stroke. There is, of course, a definite amount of turbulence in the combustion chamber when the fuel is injected, so that the effect of the air stream is to give a kind of secondary turbulence which is superposed upon the former. The partially burnt fuel in the combustion and cylinder head is, therefore, mixed thoroughly with this turbulent air stream, so as to obtain a more complete combustion than in the ordinary case.

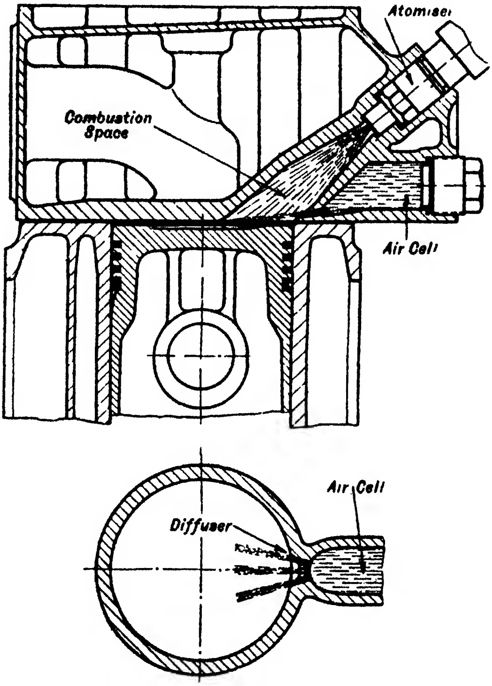

FIG. 25.—The M.A.N. Combustion Head.

It is stated that this regulated turbulence and more thorough mixing of the air and fuel gives quieter running with an exhaust practically free from odour.

Another important design is the Lanova combustion head, which may be regarded as a development of the Acro head.

In this engine (Fig. 26) a coned-top type of piston is employed, the combustion chamber being in the shape of a double annular space, each half being symmetrical (lower illustration, Fig. 26).

The fuel injection nozzle is on the left, whilst on the right a double air cell is arranged; this consists of a smaller chamber on the left communicating with a larger one on the right.

The latter can, however, be shut off from the former by means of a screw-in type of cone-valve. This enables a higher compression to be used for starting purposes, thus obviating the need for glow plugs.

When the piston is practically at the top of its compression stroke, the fuel stream is injected across the space between the two cylinder head recesses, towards the entrance to the smaller air cell. By the time the top of the spray reaches this entrance it has become heated so that ignition commences before the fuel enters the air cell.

As the piston commences to descend, the pressure in the combustion chamber will be lower than in the air cell, with the result that the air rushes out in the opposite direction to that of the fuel spray, pulverizing the latter and carrying it around in the two annular combustion spaces, thus forming two turbulent mixture streams. This gives an intimate mixing of the fuel particles with the air.

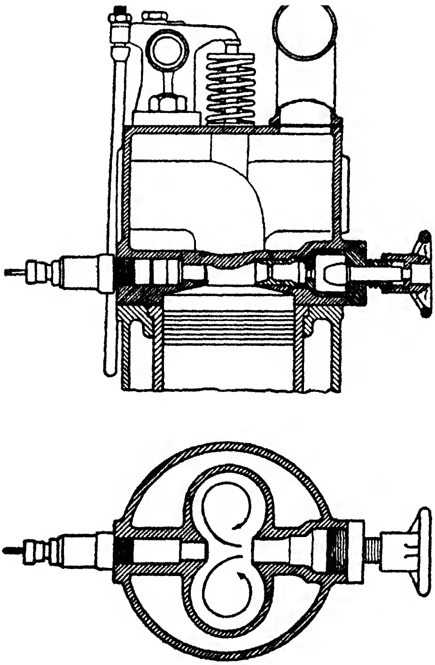

Fig 26.
The Lanova Combustion Head.

The rate of pressure rise at the commencement of ignition is relatively low, since only a portion of the air is available for combustion; indicator diagrams show that the maximum cylinder pressures are quite moderate, viz., from 550 to 650 lbs. per sq. in., due to the nature of the combustion process. The maximum compression pressures employed are 380 to 440 lbs. per sq. in. The highest values obtained for the mean effective pressures are 115 to 125 lbs. per sq. in.

The injection pressure employed is 1,200 lbs. per sq. in.

As a final example of modern combustion chamber design, the system employed on one of the smallest four cylinder engines, viz., the Perkins 14·4 h.p. type, will be described. Incidentally, it may be mentioned that one of these engines has run satisfactorily at a speed exceeding 4,000 r.p.m.

In this case there is a turbulent type of air cell (Fig. 27) of spherical form communicating with the cylinder through an inclined passage. The fuel is injected into this neck, the injector having two orifices, so arranged that part of the fuel charge is directed upwards into the air cell, thus becoming

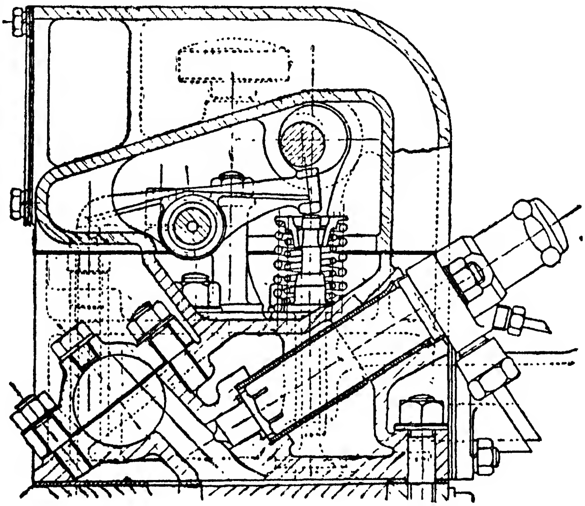

FIG. 27.—The " Aeroflow " Combustion Head used in the Perkins Engine.

entrained in the air stream, while the remainder is forced down the passage against the air stream towards the cylinder. The combined advantages of the turbulent air cell and direct injection systems are claimed for this arrangement, with easy starting and smooth running and an entire absence of " Diesel knock." No pre-heating is necessary when starting from the cold, but two small priming holes are provided in the air passages, through which a small quantity of paraffin may be injected for assisting easy starting in cold weather. The compression ratio used is 16·5 : 1, fuel being injected at 850 lbs. per sq. in. The B.M.E.P.'s obtained at speeds of 1,000 to 2,500 r.p.m. in the different Perkins engines vary from 100 to 90 lbs. per sq. in.; the fuel consumptions average about 0·42 pints per B.H.P. hour.

In concluding this section it should be mentioned that only a few of the many alternative arrangements of combustion chambers and fuel injector positions have been described, but sufficient it is believed to give the maintenance engineer a general idea of the types likely to be met with commercially.

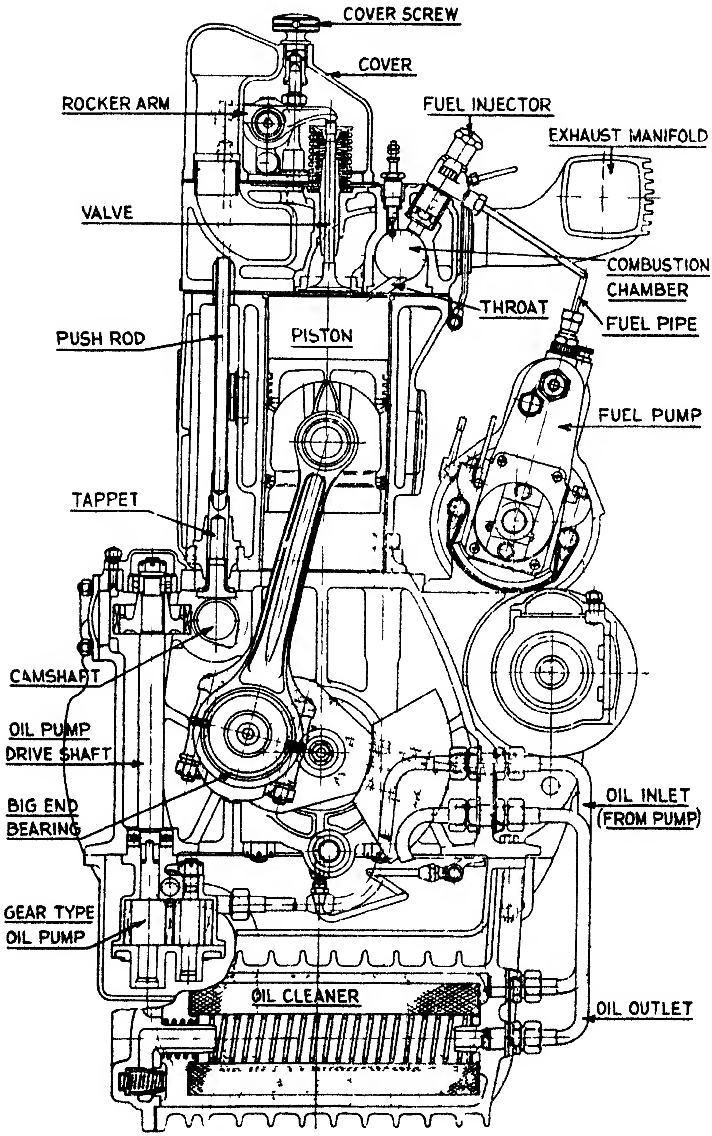

FIG 28 —Sectional view of A E C Engine, showing Lubrication System and Principal Components

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CHAPTER III

THE GENERAL MAINTENANCE OF C.I. ENGINES

IN most respects the care, upkeep and repair of the C.I. engine resembles that of the petrol engine. Thus, in the matter of the valves, pistons, cylinders, connecting-rods, crankshafts, camshafts and lubrication arrangements, the maintenance practice is very much the same for the two engine types.

The important differences, however, are due to the substitution of the fuel pump and injection nozzles for the carburettor, magneto and sparking plugs of the petrol engine. Whilst, therefore, the engine items that are common to the two types of engine will briefly be considered, more detailed instructions will be given in regard to the parts that apply solely to the C.I. engine; notably, the fuel injection system components, fuel filters, feed pumps and glow plugs.

The External Components

The principal components of a modern automobile engine are illustrated in Figs. 26, 27 and 28, in the case of the A.E.C. high speed C.I. engine. The latter illustration shows the near side of this particular engine. Here, it may be added that the majority of modern British C.I. engines have somewhat similar external dispositions of the components. It will generally be found that those parts requiring occasional or periodical attention are *grouped on the near side of the engine*, i.e., they are accessible from the pavement side when the vehicle is drawn up on the left-hand side of the road in the usual traffic direction.

The near side accessible parts include the *Fuel Injection Pump*, *Injectors*, *Oil Filler for Crankcase*, *Dynamo*, *Water Pump*, *Exhauster for Vacuum Brakes*, *Oil Level Dip Stick*, *Fuel Filter*, *Oil Filter* (occasionally) and *Fan Belt Adjustment*. In most cases the valve clearances are arranged to be readily accessible for adjustment from the near side.

Maintenance Procedure

Although it is not possible to lay down any very rigid procedure, it is possible to suggest, as the result of experience, a good system whereby C.I. engines can be maintained as efficiently and economically as possible with the minimum risk of breakdown whilst in service. The method to be outlined is equally applicable to the individual engine or to engines of a fleet of motor vehicles, although the detailed procedure will, of course, be different in these two extreme cases; the maintenance and repair equipment will also be different in the two examples mentioned.

The recommended maintenance procedure includes: (1) *Inspection*; (2) *Routine Attention*; (3) *Running Repairs*; and (4) *Periodical General Overhaul.*

(1) INSPECTION. The chief object of this is to detect minor faults, defects or inefficient running of the engine, so that the necessary attention can be given before anything serious can develop. The inspection process requires the attention of a skilled mechanic or engineer familiar with the design features and running of the particular make of engine.

He should be able to detect such items as *Loss of Compression, Incorrect Valve Clearances, Sticky Valve Stems, Bad Valve Seatings, Broken Valve Springs, Piston Slap, Small and Big End Knock, Main Bearing Wear Effects, Faulty Injectors, Partial Stoppage of Fuel Flow, Defective Pipe Joints, Faulty Fuel Pump, Incorrect Fuel Injection Timing* and other likely faults.

The first essential in the inspection process is that of *cleanliness.* Every exposed part of the engine should be kept in a state of thorough cleanliness. Here, it may be mentioned, by way of a parallel, that the L.G.O.C. insist that the steering gear drop arms shall be kept polished so that any flaws or cracks can readily be detected. All externally located machined faces of the engine should, for a similar reason, be kept clean.

The regular use of a paraffin-saturated rag, or a stiff brush dipped into paraffin, on the parts in question, followed by a rubbing with a dry cloth will ensure that the engine is always in a fit condition, externally, for inspection at any time.

The first duty of the person inspecting an engine that is in regular service should be a superficial examination of the minor items, including the various nuts and bolts, split-pins (for slackness or loss), water pump gland and water pipe connections (for leakages), exhaust manifold joints (for "blow-outs" or leakages), fuel pipes and unions (for fuel leakages) crankcase covers and joints (for oil leakages), fan belt (for undue slackness) and so on. The early detection and remedying of such defects will invariably save much trouble and expense later on.

Operators' and Inspectors' Reports

The driver or operator of the engine should be instructed to report upon its running daily, and to point out at once the development of any more serious defect, e.g., *engine knocks, loss of power, smoky exhaust, erratic behaviour, excessive fuel consumption*, and so on. If the engine is one of a fleet series, in regular service, then the driver should be provided with specially printed forms for entering his daily returns.

At regular intervals also the engine should be inspected by a competent mechanic or engineer for the more important defects previously mentioned.

Each engine should have its own log sheet or book, giving its type, engine number, date of purchase or manufacture, and similar particulars. In it should be kept a record of the various faults found and rectified, with the dates of occurrence and number of hours run since the last overhaul. The dates and periods (in hours) of the top and major overhauls should also be logged in a similar manner, each entry being signed or initialled by the person responsible. Details of any new material or parts fitted, and any relevant information on the condition of the engine at the date of its repair or overhaul should be entered.

In cases where the engine operator or driver is capable of carrying out minor or major repairs himself, these should be entered in his report book.

As a result of the inspector's report—which should, of course, be submitted each time to the maintenance engineer—any items of attention by the workshop staff, whether marked " immediate " or otherwise, can be put in hand.

In the instance of the engines of a fleet of commercial vehicles it is usual to keep a Driver's Report Book for each vehicle in which are entered the engine and chassis number, name of manufacturer and date of manufacture. The driver fills in the engine, chassis and body repairs required, with his signature and the date. The workshop staff afterwards note down the actual repairs carried out, the fitter's signature, time and date. The driver, in such cases is then concerned only with the driving of his vehicle and does not normally do any repairs.

(2) ROUTINE ATTENTION.—It is important for the maintenance engineer to draw up in brief form a schedule of engine items requiring routine or regular attention on the part of the driver or motor mechanic responsible for this work. If the engine is of the stationary class it occupies the whole schedule ; otherwise, in the case of automobiles, rail cars, marine craft, etc., it forms part of a more general schedule which includes other items of routine attention, e.g., the lubrication of the transmission members or chassis parts.

With modern high speed C.I. engines the usual routine attention consists in lubricating the working parts according to the manufacturers instructions. Thus, the *oil in the engine's sump* should be maintained at the proper level as indicated by the dip-stick or float gauge ; *the water pump shaft bearing, dynamo and motor bearings* lubricated, any *operating lever ball or pin joints, and cooling fan bearings* lubricated, radiator water replenished, and so on.

At regular intervals *the engine oil filter should be cleaned* ;[1] this is generally done when the sump is drained and fresh oil put in. If the lubricating system is furnished with *an oil cleaner* of the felt filter type, the latter should be removed at 6,000 to 10,000 miles (or the equivalent number of hours for engine types other than automobile ones) and replaced with a new one ; it scarcely pays to attempt to clean the dirty filters, for the new ones are quite cheap.

The inlet and exhaust valve stems should be checked for correct clearances every 2,000 to 3,000 miles. In some cases it is advisable to check more frequently. In other cases, e.g., the engines of commercial vehicle fleets, the valve clearances are sometimes only re-set when the valves are re-ground. The *valves themselves should be re-ground* when the engine is *decarbonised.* The period for this varies with different makes of engine ; it may be as short as 150 hours (or about 3,000 miles) or as long as 600 hours (12,000 miles) according to the type and nature of its duties.

It should here again be emphasized that a record, with dates and times, should be kept of the principal routine items such as oil, sump drainage, filter changing, valve clearance re-setting, decarbonizing and valve grinding.

In regard to *the fuel injection equipment* the items of routine attention include the following, viz., regular replenishment of oil in the base of fuel pump chamber, the checking at longer

[1] See also p. 43.

intervals of the injection timing, inspection of fuel pipe unions, regular testing of the injection nozzles for spraying pressure, presence of carbon on nozzle tips, wear of plungers, etc., and cleaning of fuel filters. It may also be necessary to check the adjustment of the governor springs for the correct maximum and minimum engine speeds. All of these main points of routine attention are dealt with in later chapters of this book.

(3) Running Repairs.—These include repairs and adjustments usually of an unforeseen or unexpected nature which occur between the general overhauls of the engine. These may include, for example, a choked injection nozzle, faulty fuel pipe or union, broken valve spring, worn injector or pump plunger due to ingress of solid matter in the fuel, or some other trouble of infrequent occurrence.

If the repairs in question are not of a major nature they can be undertaken by a mechanic and put right in a relatively short time. If, for example, the trouble is due to a broken part such as a valve spring or to a choked nozzle the repair is effected by *the process of replacement with a spare part.* This method enables the engine to be serviced in the minimum of time.

Although the fuel pump seldom gives any trouble, should any unsatisfactory or erratic running of the engine be traceable to the fuel pump it is generally advisable to remove the latter and substitute another new or re-conditioned pump. This method is invariably followed by firms running a number of C.I. engines of the same make. The defective injector or fuel pump can then be overhauled by skilled mechanics and afterwards tested on the bench for performance; if it passes the latter test it is appropriately labelled, logged in a ledger kept for the purpose and placed in store ready for use as a replacement part.

Any more serious mechanical troubles, such as broken valves, pistons, crankshafts, scored or " run " big-end or main bearings, cylinder casting fractures, etc., will necessitate placing the engine out of service for a relatively long period. In such cases it will probably be better to treat it as a general overhaul or re-conditioning job. Where a large number of similar types of engine are in regular service, it is usual to replace the defective engine with a re-conditioned one.

(4) Periodical General Overhaul. Assuming that an engine has been properly maintained in the matter of regular inspection and routine attention it should be given what is

known as a "top overhaul," after about 400 to 600 hours running; this, in the case of a heavy automobile engine corresponds to about 8,000 to 12,000 miles of road service. Actually, this top overhaul may be regarded as a matter of routine attention, for it necessitates such operations as *valve grinding* and *re-seating, decarbonising, changing the sump oil* and *filter cartridge, checking the working of the fuel injectors* and *fuel pump, its timing and governed speeds*, etc., at pre-stated intervals.

Some manufacturers, however, prefer to carry out these top overhaul operations at different intervals, cleaning the injectors at 2,000 to 4,000-mile periods, decarbonising the cylinders at 8,000 to 10,000 miles, grinding in the valves at 15,000 to 20,000 miles (or longer mileages for stellited seatings and special nickel-chrome steel valves) and so on.

If, however, the engine is given a top overhaul at 8,000 to 12,000 miles it will be unnecessary to give it a general examination and overhaul of the bearings, pistons, etc. Modern engines can be run for 70,000 to 90,000 miles before a complete overhaul, involving dismantling of the whole engine and crankshaft grinding becomes necessary.

The normal procedure is to strip the engine down completely, the component parts being cleaned in a caustic soda or special chemical bath (known as a "degreasing bath"). After cleaning they are inspected and measured carefully in order to ascertain the amount of wear. The *piston rings, pistons, cylinder barrels, valves, valve-seatings, camshafts, big-end* and *main bearings* are usually found to be the principal items requiring replacement or re-conditioning.

In some cases the fitting of a new set of piston rings and the taking up of play in the big-end and main bearings will be found sufficient to give the engine a further lease of life before cylinder re-boring and new pistons become necessary.

Where C.I. engines have been in more or less continuous heavy service it will often be found necessary with plain cast iron cylinders after 30,000 to 40,000 miles to re-bore the cylinders and replace the pistons. The general practice, however, is to fit *hardened alloy cast iron cylinder liners*, such as chromium and nickel-chromium, or nitrogen-hardened alloy cast iron ones.

With these, the wear figure is reduced considerably, so that it is possible to obtain from 70,000 to 100,000 miles running before they require replacement or re-grinding; with nitrogen-hardened liners a further 50,000 miles is possible after re-grinding.

The more recent *heat-treated aluminium alloy pistons* are found to have excellent wearing properties and may be run from 120,000 to 150,000 miles after which there is a danger of failure due to fatigue.

The cams on the camshaft often require building up by welding on alloy steel and then re-grinding to the correct profile. Similarly, badly-worn valve seats must be built up by welding on metal of a suitable composition.

The timing gear chain should be inspected for wear ; also the chain sprockets. It is seldom, however, that new chains are required under 40,000 to 50,000 miles. The chain tensioning device may require adjustment at intervals of about 20,000 miles, however. The fuel pump should be given an overhaul and check test at these intervals. Similarly fuel injectors should be stripped, cleaned and reassembled. Valve springs should be checked, against standard or new springs for tension and if necessary replaced. The valve stems and guides should also be checked for excessive wear ; and the exhaust valve ports for carbon formation.

The crankpins should be checked for uneven wear and the main journals also. It is usually advisable to fit new bearings or linings if these are of white metal.

If, however, lead bronze bearings are used then it will only be a matter of taking up the wear and scraping down until a proper bearing fit is obtained ; these bearings seldom require replacement under 60,000 miles and in many cases will run for 80,000 to 100,000 miles before this is necessary.

After all of the necessary components have been re-conditioned and the engine re-assembled, the engine should be "run-in," by means of an electric motor, or dynamometer for a few hours. It is advisable to use a dynamometer of the convertible electric motor-dynamo type and to continue the motoring of the re-conditioned engine until the power required to drive the engine falls to a predetermined "safe" value as given by the ammeter.

In some cases, however, the engine is run in under its own power at a low speed, using a dynamo or hydraulic brake (such as the Froude type) for a load. Following this running-in period, during which a liberal supply of oil is provided for the bearings, etc., the oil sump is emptied and the oil examined for sludge or solid matter. After replenishing the sump, the engine is then given a series of runs at increasing loads and speeds, taking careful note of its general running and performance. If these are satisfactory it is given a full load or " overload " test, and if this is passed it is considered to have been re-conditioned properly.

Engine Overhaul Intervals

Whilst the previous information relating to the recommended time intervals for routine, top overhaul and general overhaul may be taken as an approximate guide, it should be pointed out that the periods in the working life of an engine when such attention is necessary must, of necessity, vary according to the design, materials and nature of the duties performed by the particular engine. In this respect certain types that run under more or less constant loads will require less frequent intervals between overhauls than those subjected to heavy and intermittent loads, e.g., the engines of fully laden commercial vehicles operating on hilly routes or on bad roads. The design of the engine in regard to the compression and maximum pressures, engine speeds, type of piston, nature of cylinder wall surface (whether alloy, cast-iron or nitrided steel liners are fitted) bearing pressure valves, use or otherwise of insert valve seatings and special alloy steel valves, etc., will also have an important influence upon the rate of wear.

It will often be found, when examining the recommended maintenance instructions of various C.I. engine manufacturers, that whereas one firm recommends the adjustment of the valve tappets every 1,000 miles, another will give 2,000 or 3,000 miles. Similarly, the periods given for valve grinding will be found to vary from about 10,000 to 30,000 miles. In regard to cylinder wear effects some engines require re-boring at intervals of 30,000 to 40,000 miles, whilst others, fitted with centrifugally cast alloy-iron or nitrided steel liners only require replacement at intervals of 70,000 to 100,000 miles.

Although the C.I. engine *will nearly always continue to operate more or less satisfactorily* over appreciably longer periods than those indicated in the earlier part of this section, it is seldom good economy to allow them to do so. Thus, cases have come to our notice of commercial vehicle engines which have been kept in service for periods of 40,000 to 100,000 miles without being decarbonised, the valves re-ground or the piston rings, pistons and cylinders, etc., having received any attention, i.e., without the cylinder heads having been removed.

It is generally found, however, that the rates of wear in such cases are much higher for a given mileage than for engines that have been overhauled at shorter intervals; moreover, during the later stages of the engines running, the risk of a breakdown due to mechanical failure of some component is much greater than for the well-maintained engine. On the other hand, with the modern C.I. engine there is no object in reducing the normal periods between general overhauls, since this will result in higher maintenance costs and necessitate the engine being out of commission longer than is strictly necessary during its useful working life.

If there is any doubt, however, regarding the appropriate times for top or major overhauls it is always a wise plan to err on the side of the shorter intervals, than to risk possible damage, excessive wear or breakdown by leaving these overhauls for longer periods. The skilled engineer will usually be able to ascertain from an inspection of the engine, its general performance and its running sounds, when it is necessary to overhaul it.

Examples of Servicing Periods

From records kept of the performance and maintenance attention in the case of C.I. engines used in commercial motor vehicles some useful information has been elicited on the subject of the correct servicing periods to give the longest engine life and most economical maintenance costs. A few typical examples will be given of such servicing periods.

The first is the instance of two A.E.C. oil engines of the A.E.C. Ricardo type fitted to "Mammoth" six-wheel vehicles used by a haulage contractor. These had already completed 135,000 miles of regular service work without an involuntary stop; the average fuel consumption was 9.6 m.p.g.

Every 1,000 miles the tappets were adjusted and the fuel and lubricating oil filters cleaned. At every 3,000 miles the engine sump was drained of its oil and re-filled. The fuel injectors were cleaned and the fuel pressures adjusted at 5,000 miles intervals. At 15,000 miles periods the cylinders were decarbonised and the valves re-ground.

At 50,000 miles one of the engines was stripped for routine examination. This revealed that the upper halves of the main bearings were fit for further service, although the white metalled pressure halves were found to be slightly granulated, and were replaced by lead bronze shells. The big-end shells of the same alloy were in perfect condition, and were replaced untouched. None of the crankshaft journals showed wear of more than ·001 in.

The cylinder bores were in remarkably good condition, the valves and seats showed no signs of burning or pocketing, and the fuel pump, returned to the makers for re-calibration, was replaced on the engine with its original plungers and barrels.

Another Welsh bus company, running a fleet of 30 A.E.C. 130 h.p. oil engine vehicles at an average speed of 9.4 m.p.h. including stops, after having checked and, where necessary, improved the fuel consumption, makes a regular rule of cleaning the injection nozzles every 5,000 miles. The engine sump oil is changed at 4,000 mile intervals, when the filter is removed and cleaned in paraffin. Between 20,000 and 25,000 miles the engine sump is dropped and the pistons removed, the rings and grooves being cleaned and examined; new rings are fitted where necessary. It was found that the cylinders showed a wear of 0·014 in. at 20,000 miles just at the top, but at 30,000 miles no additional wear appeared to have occurred. Engines which had done 90,000 miles showed only 0·022 in. at the same place.

In the case of engines fitted with the Comet combustion head it is recommended that the fuel injectors be removed and cleaned every 2,000 miles; the valves re-ground at 20,000 miles; the valve tappet clearances checked or adjusted every 800 to 1,000 miles; the engine oil changed *before* 5,000 miles and the timing chains renewed at 50,000 to 60,000 miles.

The following are the servicing instructions for a well-known make of stationary and rail-car high speed C.I. engine, the average daily working period being from 8 to 10 hours:

Daily attention.—Lubricate valve rocker gear shaft bearings. Lubricate fuel pump and governor. Lubricate joints of operating levers and controls.

Weekly attention.—Clean fuel filter. Clean engine lubricating oil filter. Remove and test fuel injectors. Check valve tappet clearances.

Monthly attention.—Empty engine sump and re-fill with fresh oil.

Quarterly attention.—Decarbonise combustion chamber. Re-grind and adjust valves. Clean valve ports and air filter.

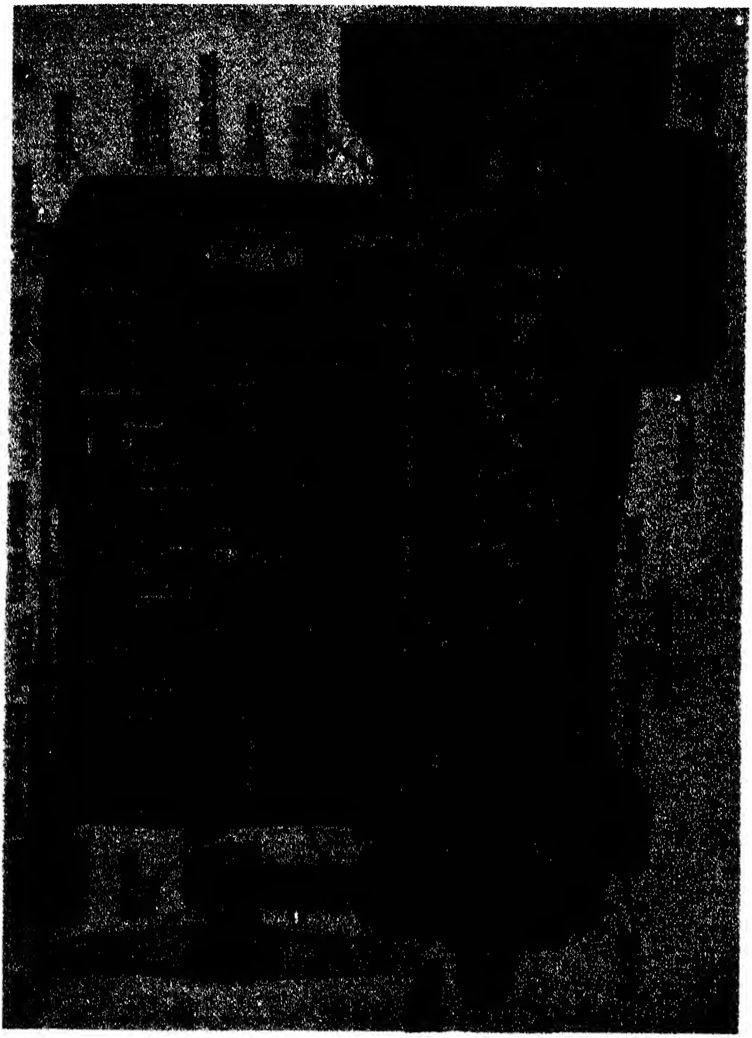

FIG. 29.—Sectional view of Six-Cylinder A E C Engine

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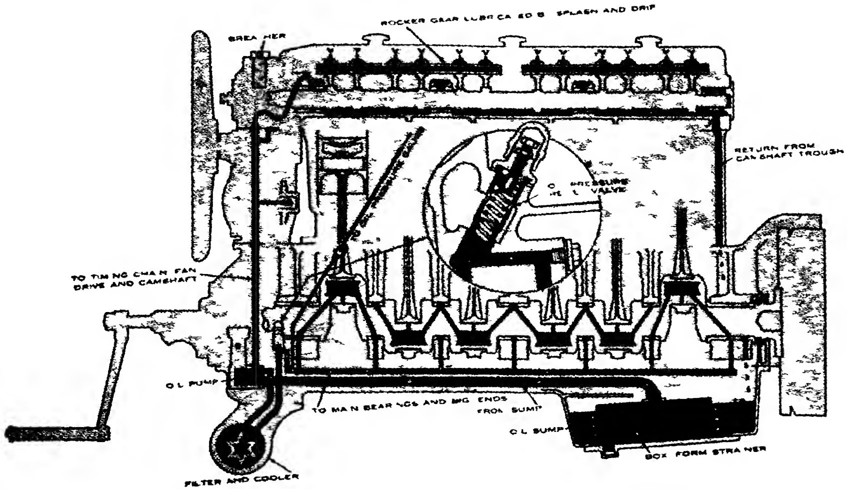

FIG 31 —The Leyland Engine Lubrication System

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Clean piston tops. Clean lubricating oil pump. Check bearings for wear effects.

Yearly.—General overhaul, engine to be stripped down and re-conditioned where necessary.

The Comet Combustion Chamber

In connection with this popular form of combustion head, it is important to observe that the lower half should not protrude

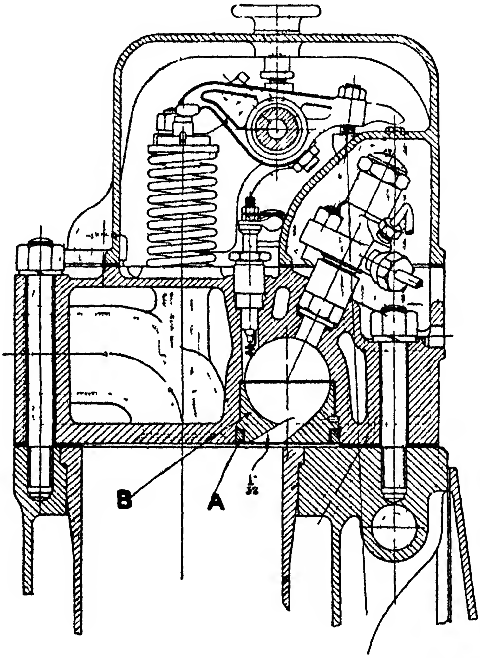

FIG. 30.—The Crossley Cylinder Head, showing "Comet" Combustion Chamber.

below the level of the cylinder face or it may foul the piston when the latter is on its top centre.

Fig. 30 shows the Crossley cylinder head in sectional view. With regard to the nut *A* which secures the detachable lower half of the combustion chamber, it is important that after the half combustion chamber *B* has been removed and when replacing, the nut *A* should be screwed home until it is approximately $\frac{1}{32}$ in. below the cylinder face.

Maintenance of Lubrication System

The majority of high speed oil engines employ a similar lubricating system to that used on commercial petrol engines.

Fig. 31 illustrates a typical system, namely, that of the Leyland oil engine; the arrowed black passages denote the oil flow pipes and channels.

In this arrangement the gear type oil pump draws its supply from the oil sump through a box form strainer and delivers

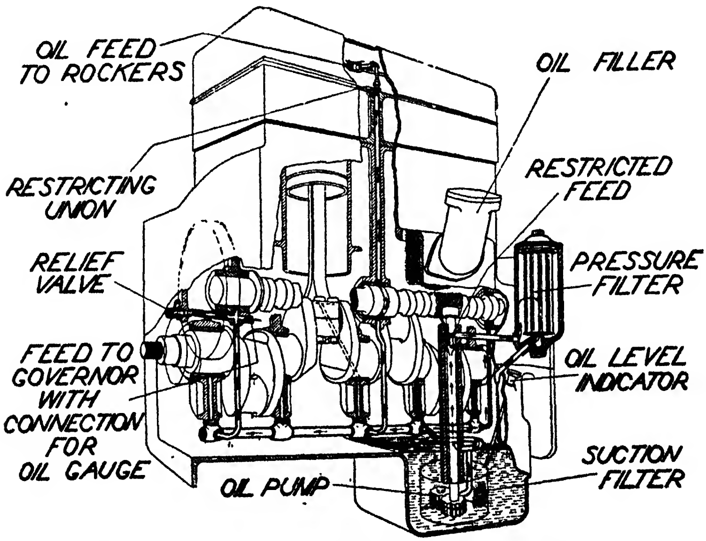

FIG. 36.—The Dorman Engine Lubrication System.

it first to an oil filter and cooler, whence it flows under pressure to (*a*) The main crankshaft bearings, through the hollow crankshaft and out through holes in the crank pins in order to lubricate the big-end bearings. (*b*) Up the vertical pipe, shown on the left-hand side, to the overhead rocker gear, afterwards returning down the oil passage on the right-hand side, leading from the camshaft trough to the top of right-hand main bearing whence it drips down into the sump. (*c*) To the oil pressure gauge on the driver's instrument panel and (*d*) To the pressure release valve—an enlarged view of which is shown in the centre of the illustration (Fig. 31).

In the Leyland engine all oil pipes are of mild steel clipped to the crankcase, the branch pipes to the main bearings being connected by unions to the main delivery pipe.

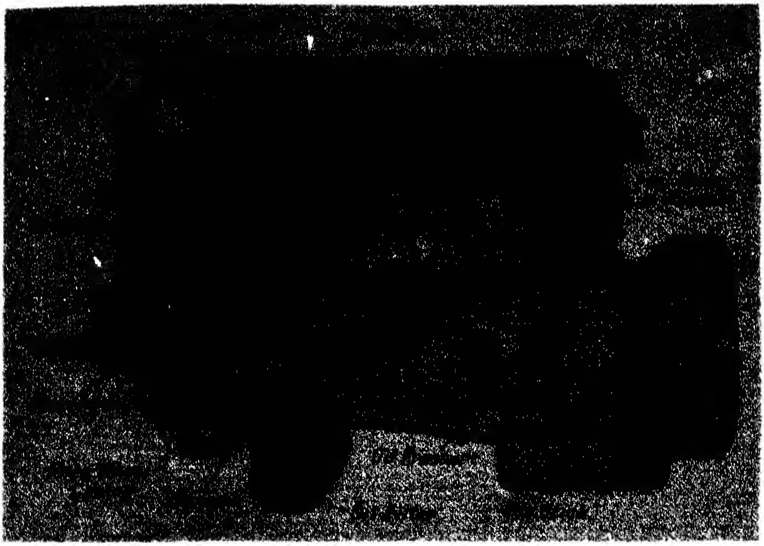

FIG 32 —Showing near side view of A E C Engine upon which most of the components are arranged

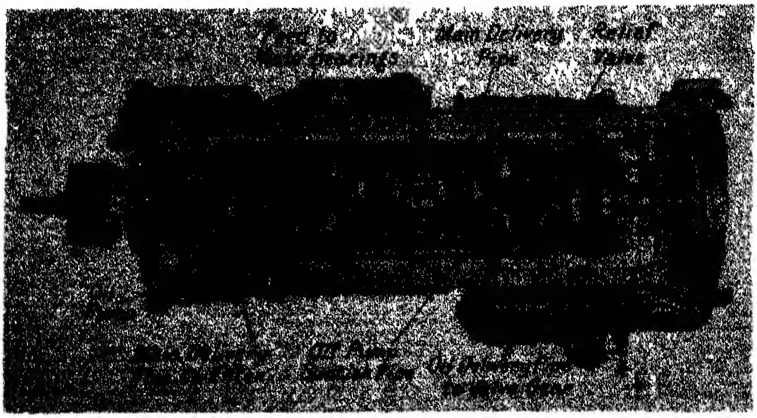

FIG 33 —Underside of A E C Engine, showing Oil Pipe arrangements (Sump has been removed)

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FIG 34—Showing Lubricating Oil Filter Element of A E C Engine

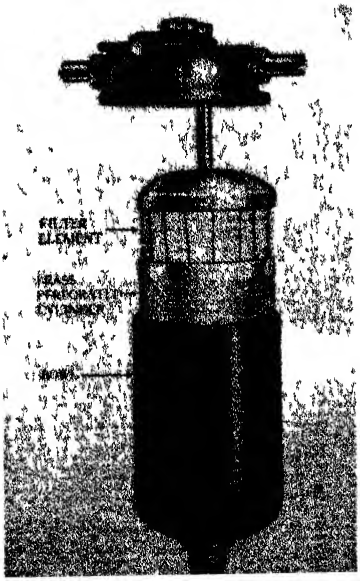

FIG 35
The C A V -Bosch Oil Filter, shown partly dissembled.

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The principal maintenance points of a high speed oil engine lubrication system may be summarized, briefly, as follows :

(1) Oil Replenishment.—The crankcase sump is furnished with an oil level gauge—usually of the dipstick pattern—for the purpose of maintaining the oil level at the recommended height in the sump.

The oil level gauge should be checked every 100 to 200 miles, or before the commencement of a long run.

(2) Crankcase Draining.—Many manufacturers recommend draining the crankcase sump at the end of the first 500 to 1,000 miles, when the engine is new, and thereafter at intervals of 5,000 to 7,000 miles—when oil filters or cleaners are employed ; otherwise, at intervals of 2,000 to 4,000 miles.

(3) Oil Filter Cleaning.—The oil filter should be removed and cleaned whenever the oil is changed in the sump. The felt type of oil filter, e.g. the Tecalemit, should be thoroughly scraped after removal to get rid of the thick deposit in the serrations of the star-shaped felt element ; it should then be cleaned in a petrol or paraffin bath. Before replacing it, squeeze out the felt to remove the surplus petrol and then soak it in clean lubricating oil before replacing it. The ends of the filter should be plugged with corks before washing it in petrol.

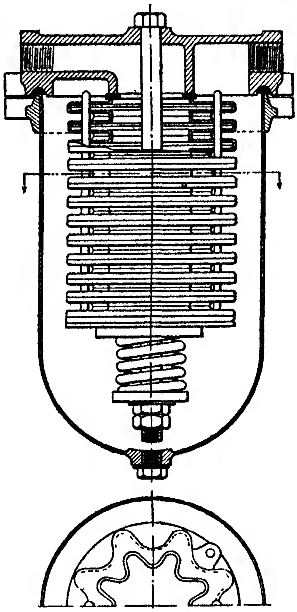

Fig. 37.
The Vokes Oil Cleaner.

After replacing a filter element of this type it is important that the chamber should be filled with new oil.

The felt cartridge type of filter should be replaced by a new one every 10,000 miles or so of road usage or, in the case of stationary engines after about 500 hours of use.

When oil filters of the metal pack edge-flow pattern are employed the necessity for renewing the filter element is, of course, avoided.

Fig. 37 illustrates the Vokes filter which has a filtering element made up of a number of star-shaped thin plates, to give a large total filtering area. The plates have ground faces on their beaded edges and they are held together by a compression spring, retaining rod and adjusting nuts for varying the pressure between the plates. With the oil flowing from inside to outside an increase of pressure due to the greater viscosity of the cold oil, when starting, causes the plates to spring apart slightly against the spring pressure. When the oil warms up the plates tend to close together, thus increasing the fineness of filtration.

(4) Oil Pressure Release Valve.—The purpose of this spring-loaded valve is to regulate the oil pressure in the lubrication system and to prevent excessive pressures occurring. The spring-loaded ball or cone valve opens at a certain oil pressure, predetermined by means of a screw adjustment which alters the compression load of the spring ; the overflow from the valve returns to the oil sump, but occasionally this surplus oil is used to lubricate the timing gears or some other moving part.

If the oil pressure requires regulation this can be effected by means of the adjustment screw on the oil pressure release valve.

(5) Oil Ways Cleaning.—When an engine is completely dismantled for general overhaul the oil passages and pipes should be *thoroughly* cleaned right through. In particular, the oil passages in the crankshaft must be cleaned, since dirt is almost certain to collect in certain of the passages, owing to centrifugal action.

Flushing Out the Oil Sump

It is a good plan periodically to flush out the oil sump. In this connection one well-known user of high speed oil engines has fitted up a ramp upon which vehicles are run for sump flushing purposes. A flexible pipe connects a stand type of oil pump run by an electric motor with the tank containing the flushing oil and the engine sump. About 50 gallons of oil are required for 100 large commercial vehicles. The oil is forced into the sump and crankcase, where it dislodges and removes whatever sludge may be present. Every engine is flushed out in this manner at 5,000 miles, when the lubricating oil is changed and oil fillers cleaned. When the sumps are dropped for annual overhaul they are cleaned thoroughly in a chemical degreasing plant, such as the I.C.I. one. It is interesting to note the experience of the London Traffic Pool with oil-engined buses, in connection with engine lubricants. It has been found that the quantity of carbon which accumulates in the oil is practically proportional to the mileage, i.e. an average of 0·7 per cent. per 1,000 miles up to a maximum of 2 per cent. The *effect of this carbon is to thicken the oil* and to necessitate the use of lower viscosity oils in the first instance.

Lubrication Troubles and their Causes

Although lubrication troubles, with properly maintained systems are the exception, when these do occur they are apt to prove somewhat difficult to diagnose quickly. For this reason the following classification of possible causes of lubrication troubles may be found helpful:

A. No Oil Pressure Reading. Engine Running.—*Probable Cause:*

(1) No oil in engine sump.
(2) Oil gauge pipe restricted or broken.
(3) Oil release valve stuck open.
(4) Weak or broken oil release valve spring.
(5) Faulty oil pressure gauge.
(6) Oil pump not working.

B. Low Oil Pressure Indicated.—*Probable Cause:*

(1) Oil pressure regulator not operating satisfactorily.
(2) Leakage from pressure system (external or internal).
(3) Slack main or big-end bearings.
(4) Oil pump not operating correctly, owing to wear effects, etc.
(5) Oil filter choked with dirt; no by-pass fitted.

C. No Oil to Valve Rockers.—*Probable Cause:*

Restriction tube or passage from pump delivery to overhead gear choked.

D. Excessive Oil Consumption.—*Probable Cause:*

(1) External leakage from crankcase to clutch-pit; from sump to ground *via* oil plug or through one of the crankcase joints.
(2) Gummed up piston rings or excessive wear of piston rings or cylinder walls, allowing oil leakage past piston into combustion chamber. Indicated by continuous smoky exhaust.

(3) Leakage from timing gear case joints or external bearings, e.g. fuel pump or dynamo drive shafts.
(4) Use of unsuitable grade of lubricating oil.
(5) Oil return holes in scraper ring slots stopped with carbon.

E. Dilution of Oil in Crankcase.—*The causes include:*

(1) Stuck or worn piston rings.
(2) Excessive fuel injection due to dirt on valve seating or to sticking nozzle valve plunger.
(3) Incorrect fuel quantity, i.e. injection of more fuel than the air in combustion chamber will burn.
(4) Insufficient spring tension on nozzle plunger.
(5) Incorrect injection timing.
(6) Vacuum in crankcase caused by tight cap on crankcase breather.
(7) Use of unsuitable fuel or lubricating oil.
(8) Engine temperature consistently too high.

Selection of Suitable Lubricating Oils

The use of the correct grade of oil is important and, generally, the advice of the engine manufacturers should be sought.

In some circles the use of a somewhat heavy body oil is recommended on the ground that crankcase dilution must occur and thus thin it down in service. This, however, is not the experience of many leading manufacturers, notably, Messrs. A.E.C. Ltd., who find that in practice the lubricating oil actually tends to thicken, so that to start with a thicker grade of oil is inadvisable.

The use of an engine oil containing a fatty compound is recommended, for the reasons that mineral oil alone has a lower heat resistance and tends to burn away at high temperatures, whereas fatty oils continue to lubricate at these temperatures. At the cold starting temperatures, however, mineral oils have excellent lubricating properties and do not " gum " up, whereas if fatty oils alone were used, difficulty in starting—owing to gumming—would be experienced.

Further, when cold the fatty oils offer a better safeguard against cylinder corrosion, since they are less soluble in fuel oils than mineral lubricating oils and, therefore, are less liable to wash off the upper cylinder walls and to expose the latter to the corrosive influence of the combustion products.

The compound lubricating oils—of which Prices Motorines are typical examples—are to be recommended for high speed oil engines.

It should be remembered when selecting a suitable grade of engine oil that engines operating under wintry conditions require a lighter grade than when used during the summer, whilst for special " Arctic " or " Tropical " conditions abroad, special grades of oil will be required.

The manufacturers of the A.E.C. oil engines issue a lubricating oil specification to the leading oil firms any of whom can recommend a grade of oil to confirm to this specification at a reasonable price. The following is the A.E.C. Oil Specification:

Description.—To be a pure hydrocarbon oil, thoroughly filtered to remove all solid matter, and to be entirely free from water, dirt, fibrous particles or any other impurities. The cylinder oil used in the blend to be of the filtered variety.

Free Acid.—The oil not to contain more than a trace of mineral acid, and organic acid not to exceed the equivalent of ·01 gms. KOH per 100 gms. of oil.

Specific Gravity.—At 60° F.: Not to be below ·900 not to exceed ·901.

Closed Flash Point.—Not to be below 395° F. (determined on either a Pensky Marten's or Gray's apparatus).

Viscosity.—At 140° F.: Not to be below 160-secs. nor to exceed 175-secs.; at 200° F.: not to be below 60-secs. (Both determinations to be carried out on the standard Redwood No. 1 Viscometer.)

Asphalt.—Not to exceed 0·010 per cent. (To be determined by the method described in the Appendix hereto.)

Ash.—Not to exceed 0·010 per cent.

Cold Test.—Pour point not to exceed 15° F. (To be determined by the I.P.T. Method G.O.11, Standard Methods, 1st Edition.)

Oxidation Test.—After blowing for 12 hours, the viscosity of the oil at 140° F. shall not be greater than 2·0 times the original viscosity at the same temperature. After blowing for 12 hours the asphalt content of the oil shall not exceed 2·2 per cent. (The test referred to in the first paragraph is that known as the Air Board Oxidation Test, whilst asphalt in the oxidised oil is to be estimated by the method given in the Appendix hereto.)

APPENDIX.—*Method for determination of Asphalt.*—A suitable weight of the oil to be diluted with 40 times its volume of light petroleum spirit, free from aromatic hydrocarbons, and completely distilling between 40° C. and 60° C. The solution after standing at least 18 hours in a stoppered bottle, in the dark, at room temperature, to be shaken and poured through a No. 40 Whatman's filter paper and the paper washed with petroleum spirit, as specified above, until free from oil. The residue on the filter paper then to be dissolved by pouring hot benzene (free from thiophene) through the filter paper, collecting the solution in a suitable weighed vessel, the vessel to be reweighed after evaporating off the solvent and drying.

A.E.C. Lubrication System

The lubrication system of the A.E.C. engine depends upon the supply of oil to all the main and crankpin bearings under pressure. The pistons and gudgeon pins are supplied by splash.

The requisite quantity of oil for the camshaft and timing gears is bled from the oil pump by means of a patented device.

The oil pump, which is of the usual gear type, is mounted directly beneath the front main bearing, and is driven from the crankshaft by a pair of spur gears.

To feed the camshaft and timing gears, the spindle for the driven pump wheel is made hollow with a small hole which faces towards the delivery side of the mump, drilled radially through to the inside. A second small hole is drilled between two of the teeth of the driven pump wheel. The two holes are arranged to coincide once per revolution, and a small quantity of oil is thus forced into the interior of the spindle. By means of a copper pipe (Fig. 33) connected to the pump cover, this oil after passing through the filter (see later) is led to a passage drilled in the crankcase and leading up through the timing case to the cylinder head, where part is fed over the timing gears and chain and part to the camshaft trough. The chain tensioner is lubricated from this system.

The oil filter (Fig. 34) consists of a felt cylinder (Fig. 35) and is carried in a chamber partitioned off from the sump. Into this chamber the oil to the camshaft is fed, and passes radially inwards through the felt cylinder, the cleaned oil then being fed to the cylinder head.

To guard against any interruption in the supply to the cylinder head, should the filter become choked owing to neglect, a by-pass valve is fitted to allow the oil to pass directly to the cylinder head if the resistance offered by the filter exceeds a pre-determined amount. The filter can be withdrawn from the crankcase by removing the cover on the off-side of the latter. The filter is cleaned by first scraping the outer gauze and then washing in petrol; the felt should be squeezed to remove most of the petrol before replacing and then soaked in a container of clean oil. There is a strainer on the pump suction side to prevent the passage of solid matter to the pump; *this strainer should be cleaned whenever the crankcase oil is changed, say, every* 3,000 *to* 4,000 *miles.*

Radiator Maintenance

The radiator and cooling system of an oil engine require a certain amount of regular attention to ensure a constant free circulation of the cooling water and freedom from leakages.

After a vehicle has been in service for some appreciable time a certain amount of sedimentary matter may enter the cooling system. It is advisable, therefore, to clean the cooling system about every 4,000 miles or so as follows:—Drain out the water and insert a hose nozzle into the filler cap orifice. Then turn on the water from a main supply and regulate it so that there is a steady flow through the system. When the issuing water from the base of radiator is quite clean the flow can be stopped.

Afterwards, refill the cooling system with softened tap water or with clean rain water.

After long periods of service the radiator water passages may become partly furred owing to the deposits from hard water used for replenishing it during its previous service.

If there are no aluminium parts in the cooling system, e.g. aluminium cylinder head or water pump casing, the water should be drained out and the system refilled with a strong soda solution, made by dissolving about $\frac{1}{2}$ lb. of soda ash in each 2 gallons of water. The engine should be used, normally for a day or two with this solution in the cooling system. Afterwards, drain out the soda solution and flush through thoroughly with clean water.

One commercial vehicle manufacturer advocates filling the cooling system with paraffin, leaving this for several hours. Afterwards, the paraffin is drained off and a solution consisting of $\frac{1}{2}$ lb. of soda ash and $\frac{1}{2}$ oz. of water-glass (sodium silicate) to each 2 gallons of water is poured into the cooling system. The vehicle is then run for several days on its normal routine work, with this solution in the cooling system. The solution is then drained away and the system flushed through with plenty of clean water; this treatment is claimed to be effective in removing hard deposits.

The use of mains supply water which has passed through a water softener is advocated as the best means of preventing furring of the radiator passages.

Leakage in Cooling System

Water leakages are readily indicated by the frequent necessity of replenishing the radiator water. The most probable causes of these leakages are: (1) Leak in radiator core, due to damaged fins, faulty soldering or accidental causes. (2) Leaks at water hose connections. (3) Leaks along water pump spindle past gland. (4) Defective cylinder head gasket. (5) Leaks at top or bottom water tank seams or pipe junctions. (6) Overheating of engine causing occasional boiling.

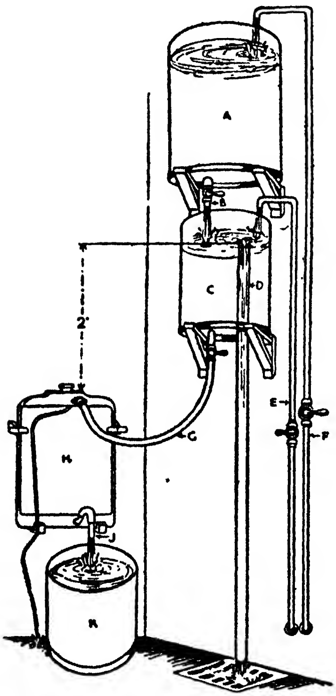

FIG. 38.—Method of Flow Testing a Radiator.

Water Temperatures

Normally, the high speed oil engine tends to run cooler than the corresponding type of petrol engine. It is important, however —from the point of view of engine efficiency—to maintain the cooling water at the correct temperature advocated by the manufacturers. Thus, in the case of the Leyland air-turbulence engines the makers recommend a water temperature of 180° F. as tested by a thermometer in the water-filled filling orifice. The manufacturers of the Perkins engines recommend that their engines should be run on the cool side, but that the temperature should not fall below 140° F. at the outlet side. In practice the radiator water temperature can be increased by blanking off part of the radiator or setting the fan blades—if of the sheet metal type—to a finer pitch, i.e. reducing the angle made by the blade with the plane of rotation.

Radiator Flow Tests

Radiators which have been in service for some appreciable periods should be tested for obstructions in the water spaces by ascertaining the rate of flow of water through them under a given pressure or head. Comparison with figures for a new radiator give a fairly accurate check on the state of the used radiator. A method used by the makers of the Bedford vehicles is illustrated in Fig. 38. The radiators in question have capacities of about 1·6 gallons.

The flow test plant can be made by utilizing three oil drums for the tanks *A*, *C* and *K*. The tank *C* has a capacity of 5 gallons. From the bottom of this tank a 1½ in. internal diameter stop cock controls the flow of water through the rubber hose *G* (of the same internal diameter) to the top of radiator *H* under test.

An overflow pipe *D* should be fitted to the tank *C*; this can be made from a length of exhaust pipe, with open top just below top of tank *C*.

Water can be led into *C* either from the 10 gallon supply tank *A* from the mains tap *F* or direct from the other mains tap *E*. The former method is used for districts where water is supplied under high pressure. The water flowing from radiator is led from the hose *J* to the third oil drum *K*, which is of 5 gallons capacity.

To carry out a flow test the water level in *C* is kept constant at the overflow height and the time is noted for the vessel *K* to fill. For the new 1·6 gallon radiator the time should lie between 20 and 30 seconds.

Testing for Leaks

A radiator can readily be tested for leaks by plugging up the inlet, outlet and filler cap orifices and connecting a tyre pump to the overflow pipe. On immersing the radiator in a water bath air bubbles will reveal any leakages (Fig. 39).

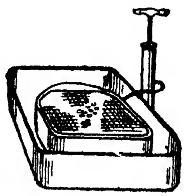

FIG. 39. Testing Radiator for Leakages.

Water Pump Maintenance

The centrifugal type of water pump needs very little attention, beyond the regular greasing of the impeller shaft—through the greaser provided—and the occasional tightening of the pump gland. When the latter has reached the limit of its adjustment, or when persistent leakage occurs, the gland should be repacked with special gland packing such as Cresswells, or with asbestos string smeared with motor grease. When draining an engine to prevent the water freezing in the cooling system the drain tap on the water pump should be opened—or the pump casing may crack as a result of freezing of the trapped water.

Some engines, notably the A.E.C. ones, are fitted with water pumps having carbon block packings (Fig. 40); these do not require the usual gland adjustment attention. The pump packing in this case is replaced by a special sealing made of carbon against which runs a shoulder formed integral with the pump spindle. Positive contact between the two is assured by a coil spring placed between the end of the spindle and the drive

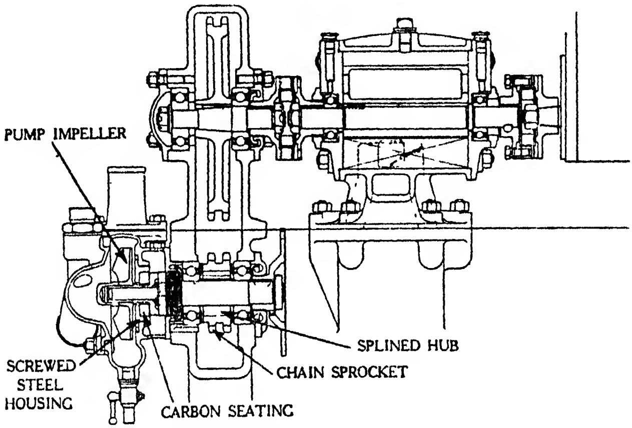

FIG. 40.—The A.E.C. Cooling Water Pump.

shaft; in the A.E.C. engine the pump spindle is of stainless steel.

When it is necessary to fit a new carbon seating the following is the procedure.

Unscrew the steel sleeve which carries the carbon seating and heat in oil until the old seating becomes easily removable. Do not attempt to chip out the old seating, as this will damage the recess, which is machined to very accurate limits.

Carefully clean out the recess and heat sleeve over a gas ring until it turns a pale straw colour, when the new seating should be dropped in and pushed up home against the back of the recess. Allow the sleeve to cool in air and the seating will be tightly held in the recess. Screw the sleeve back into the pump body and fit the pump spindle. The seating is made slightly convex so that an even marking all round will quickly be obtained. A good seating $\frac{1}{8}$ in. wide all round will make an efficient gland, and as wear takes place the width of the seating increases.

Care should be taken when fitting the spindle that the inner edges of the carbon seating are not chipped. Should chipping occur, it will be necessary to renew the seating.

When replacing the water pump on the engine, make sure that the spring is inserted in the hollow spindle.

CHAPTER IV

THE ENGINE COMPONENTS: CYLINDERS

WHILST to a large extent the maintenance of the components common to both petrol and oil engines is very similar, there are certain items in the latter type which necessitate special attention. It will be assumed, in what follows, that the reader is familiar with ordinary petrol engine design and upkeep, so that it will not be necessary to go fully into any detailed explanations of the features common to the two types of engines, but rather to emphasize the special points of attention in the case of the C.I. engine.

The main differences between the petrol and C.I. engines, from the maintenance point of view, arise in consequence of the different working cycle and they relate in particular to the combustion producing arrangements and the higher compression and maximum pressures employed.

In connection with the engine itself as apart from the fuel injection plant, the bearing pressures are usually higher and the rate at which these pressures vary (or are applied to the moving parts) is higher than for the petrol engine.

Here, it is of interest to point out another important difference between the two types, concerning the idling, cruising and full load conditions.

Under normal running conditions, for commercial vehicle engines the average load on the engine is about 33 per cent. of the full load, i.e., the greater part of its time the engine works at about one-third full load.

Now, in the case of the petrol engine, the mixture is throttled down to give one-third of the maximum effort, or torque. Under these circumstances the maximum cylinder pressure *is much lower than the value* for full torque. With the C.I. engine, however, the fact that it is necessary for ignition of the fuel to maintain the high compression pressure indicates that under one-third (or, indeed, any other load conditions) the cylinder pressures will always be above the compression pressure value; the latter is considerably higher than the part load highest pressures of the petrol engine. Moreover, the rapidity of the pressure rise during the fuel ignition process tends to subject the small, big-end and main bearings to impact shocks. Even when the C.I. engine is idling the maximum pressure on the connecting-rod bearings is higher than for the petrol engine running at its maximum load, whilst the pressure rises at a higher rate.

Big End Bearing Failure

The much more severe character of the loads upon the bearings has, in the past, been the cause of a certain amount of trouble with the material of the bearings ; this is shown by the relatively early development of cracks in white metal big-end bearings. At one period about 50 per cent. of the oil engines manufactured at home and abroad suffered from cracked white metal bearing linings. Usually, after a certain period in service, small cracks appeared in the white metal lining of the top half of the connecting-rod bearing, right in the centre and immediately under the shank of the rod ; these cracks spread gradually and multiplied until the whole surface became a kind of mosaic. Finally, the bearing broke down when a piece of the mosaic detached itself and attempted to climb over its neighbours.

This trouble was eventually overcome by substituting special alloy bearing metals of a stronger nature for the white metal, notably, lead-bronze bearing metal.

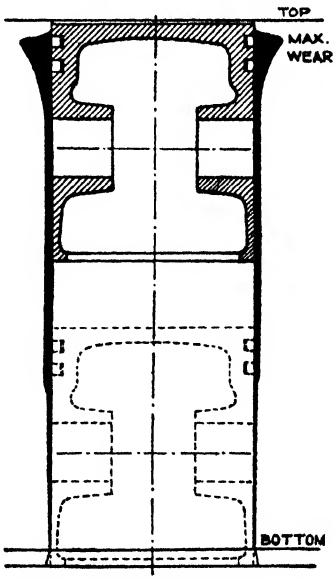

FIG. 41.—Showing manner in which the Cylinder wears. Position of Piston at Bottom of its Stroke is shown Dotted.

The Cylinder Wear

Owing, principally, to the higher loading conditions and possibly also to certain enhanced corrosion conditions, it has been found that the cylinders of the high speed C.I. engine wear at a greater rate than those of a petrol engine of similar power output and cylinder metal. *The rate of wear* in the case of the

C.I. engine is, roughly, from 50 to 75 per cent. greater than for the petrol engine. The practical outcome of this is the necessity for re-grinding, or replacing the liners of the C.I. engine at shorter intervals.

From an analysis of various types of commercial petrol engines, Ricardo deduced the rate of cylinder wear, measured at the point reached by the top piston ring to be approximately $\frac{3}{1000}$ to $\frac{4}{1000}$ in. for each 1,000 hours of running, using ordinary cylinder irons.

For the C.I. engine, the rate of wear is approximately $\frac{5}{1000}$ to $\frac{7}{1000}$ in. per 1,000 hours.

It is often convenient to consider cylinder wear in terms of the total distances travelled by motor vehicles. In such cases, in order to be able to make true comparisons it is necessary to know the gear ratios used and the periods of such use. If the cylinder wear is expressed in terms of engine revolutions we have a better standard of comparison.

Thus, for petrol engines of the motor bus type, the engine revolutions per 1,000 in. of cylinder wear were found to range from 690,000 to 780,000 ; for the C.I. engine one would anticipate reduced revolutions of about 55 to 70 per cent. of these values.

In regard to commercial vehicle C.I. engines, the following information has been collected from firms engaged in haulage and passenger service work over long distances.

In the case of one motor bus service, the average wear per 1,000 miles worked out at 0·00035 in.

In another example the cylinder wear was 0·008 in. for 60,000 miles on large C.I. engine haulage vehicles.

For a fleet of the earlier type of engines using ordinary cast-iron cylinders the wear was 0·015 in. for a period of 35,000 miles.

In all of the above instances the cylinder wear relates to that at the top of the cylinder, i.e., at the top-ring's highest position.

The manner in which the high speed C.I. engine cylinder wears along its length is illustrated in Fig. 41. It will be observed that immediately opposite the top ring's highest position the cylinder wear is a maximum. The next place of high wear occurs opposite the piston ring's lowest position.

Apart from this characteristic mode of wear along the length of the cylinder barrel, there is also a differential wear, at any given distance along the barrel. It is found that the cylinder wears more on the thrust faces than on the sides. This fact is clearly shown by the graphs reproduced[1] in Fig. 42. They show the amount of cylinder wear at right angles to the crankshaft and parallel with the latter, in an engine of 4 in bore, after 100,000 miles of running. Whilst there is a fairly marked increase in wear on the piston thrust faces, near the top end, the differences are not so marked further down the barrel; thus near the top, the cylinder wears oval, but is practically cylindrical lower down.

It is important, from the maintenance viewpoint, to note that just above the upper position of the top piston ring the cylinder barrel remains practically unworn. Most motor

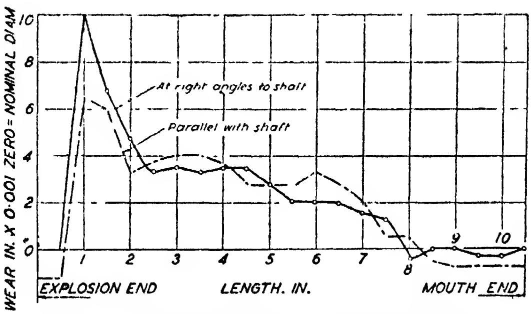

FIG. 42.—Showing nature of Cylinder Wear.

engineers will be familiar with this *ridge at the top of the cylinder* and of the necessity for removing it before new rings can satisfactorily be fitted.

Cylinder Wear Factors

According to deductions made by Ricardo, from statistics of a large number of different types of engines it has been found that

(1) The rate of cylinder wear is practically *independent of the engine or piston speed*, under similar pressure and fuel conditions.

(2) *The material of the piston*, whether cast-iron or aluminium, has no influence on the rate of wear, providing the piston rings are free in their slots and in good condition.

[1] "Resistance to Wear of Nitrogen-Hardened Cast Iron." J. E. Hurst. Proc. Iron and Steel Inst. 1934.

(3) *The grade of fuel* used in C.I. engines has an important bearing on the rate of wear. It increases with fuels of high ignition temperature.
(4) The rate of wear is not, apparently, influenced by *the nature of the service* for which the engine is employed.
(5) *In sleeve-valve engines* the rate of wear is only about one-tenth of that of an engine with a fixed cylinder liner.
(6) Within very wide limits the rate of wear appears to be *independent* of the oil consumption.

The reason put forward for the greater part of the cylinder wear observed is not one of abrasion, or frictional wear, but of corrosion of the bare metal which is scraped clean by the piston rings, the partially burnt gases being the corrosive agents.

It is believed that a good deal of this corrosion occurs *when the cylinder walls are relatively cool,* as when the engine is started up and during the warming-up period ; this suggests that the engine should not be run slowly for long periods soon after starting up, but as soon as the oil has become sufficiently warm to circulate, the engine should be speeded up in order to raise the temperature of the cylinder walls to their working value as quickly as possible.

Cylinder Wear and Mileage Run

A fact, of interest to maintenance engineers, which has already been referred to, is that *the rate of wear of the cylinder when new is much higher than after it has been in service* for some appreciable time. Thus, in the case of a motor bus engine, the average wear per 1,000 miles when the engine had run the equivalent of 5,000 miles, since new, was ·0008 in. After 10,000 miles the rate of wear was reduced to ·0007 in. ; after 20,000 miles, to ·0005 in. and after 40,000 miles, to ·0004 in. ; thereafter the wearing rate was still falling.

The greater wear in the initial stages was due, no doubt, to the bedding-down of the wearing surface, for the initial state of the cylinder surface is invariably rougher, by comparison, than the normal working surface after several thousands of miles running.

When to Re-bore or Re-line Cylinders

Having considered the various facts and experimental data relating to cylinder wear, the practical outcome of this information involves the question of cylinder life and, incidentally, the means to prolong the latter as far as possible.

The maintenance engineer, as a rule, is guided by the general behaviour of an engine as its service continues. He must also take into account the total hours (or mileage) of service since the engine was new, was last re-bored, or had new liners fitted. If he is dealing with one particular make over an extensive period, previous experience will indicate fairly definitely the number of hours operation before the cylinders require such reconditioning. Otherwise, he must examine the engine for symptoms which indicate when this work is necessary.

The principal signs of excessive cylinder and piston wear are as follows:

(1) Excessive lubricating oil consumption.

(2) Progressive falling-off in performance.

(3) Loss of compression.

(4) Imperfect combustion. Pungent and smoky exhaust not attributable to faulty atomizer but to insufficient combustion heat, due, in turn, to reduced compression.

(5) Noisy operation. Knocking due to big-ends or piston slap.

(6) Constant blowing of fumes through crankcase breather. This is an indication of combustion charge leakage past piston and rings.

If any or all of these effects are observed it is advisable to remove the cylinder head and crankcase sump. One of the pistons and corresponding connecting-rod should be removed for examination. The piston rings should first be tested, in turn, in the working part of the cylinder barrel, and their gaps checked against the maker's recommended clearances.

The diameters of the piston and cylinder bore should be measured accurately with a micrometer or dial gauge, and the maximum clearances deduced. If these are excessive, this is a sure indication that the cylinders require re-boring, or if cylinder liners are fitted, new liners required.

Otherwise, it may only be found necessary to fit a new set of piston rings. If, however, the cylinder measurements show that the bore is irregular even to the extent of $\frac{2}{1000}$ or $\frac{3}{1000}$ inch it is advisable to re-bore the barrels or re-line.

Here, it is of interest to note the practice of one leading C.I. engine manufacturer making four and six-cylinder motor vehicle engines. The cylinder bore in each case is 114·3 mm. The makers recommend that the cylinders should be re-ground or lined when the maximum diameter exceeds + ·015 in. (0·4 mm.) at the top or + ·006 in. (0·15 mm.) midway down the stroke.

Alloy Cast Iron Cylinders

Tests made by a leading passenger service company have shown that cylinders made of chromium and nickel-chromium cast-irons offer a greater resistance to wear than straight-run irons.

Thus, it was found that the average rate of cylinder wear for a straight run cast-iron containing 2·7 to 3·5 per cent. total carbon (0.5 to 0·8 combined) was ·00031 in. per 1000 miles. For a chromium iron containing ·3 to ·5 per cent. chromium, the corresponding figure was ·00022 in., and for nickel-chromium iron having ·3 to ·5 per cent. chromium and 1·0 to 1·25 per cent. nickel it was ·00024 in.

In regard to the use of nitrogen-hardened alloy cast-irons, such as Centrard, the much greater wear resistance of this material over ordinary and chromium irons is shown by the following results of tests carried out on stationary and motor vehicle engines.[1]

COMPARATIVE WEAR TEST RESULTS (HURST)

Material.	Total Mileage.	Wear. Miles per 0.001 in.	Total Mileage.	Wear. Miles per 0.001 in.
Stationary Engine Tests.				
Centrifugal cast iron, standard to B.S.I. Spec. 4*K*6	30,000	12,000	...	...
Chromium alloy cast iron, centrifugally cast	30,000	9,250	40,000	12,300
Nitrogen-hardened cast iron	30,000	24,000	40,000	32,000
Road Tests.				
Centrifugally-cast chromium cast iron, hardened and tempered	...	...	40,000	4,520
Centrifugally-cast nickel-chromium cast iron, hardened and tempered	10,000	3,220	...	...
Nitrogen-hardened cast iron	10,000	19,020	40,000	10,100

[1] Ibid p. 57.

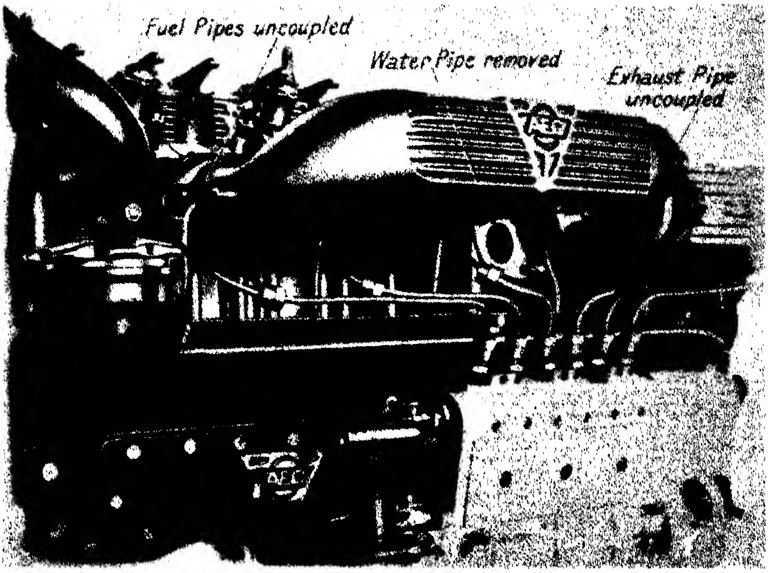

FIG. 43.—Illustrating method of dismantling Cylinder Components.

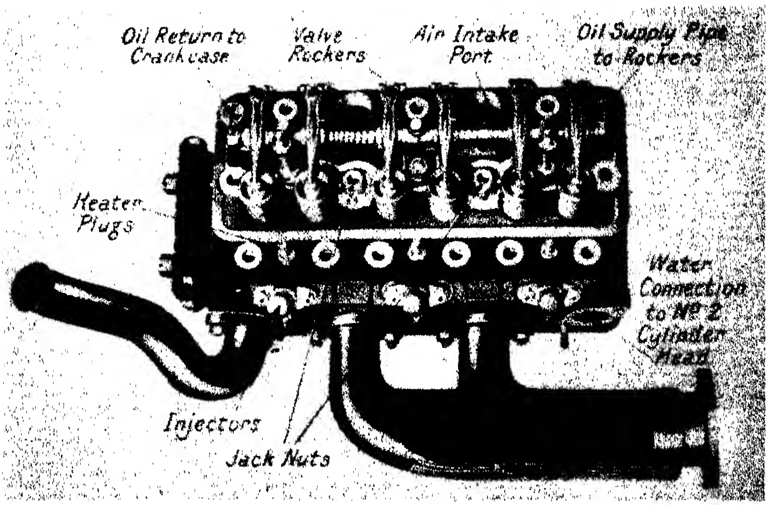

FIG. 44.—Showing Cylinder Head of A.E.C. Engine.

[*To face page* 61.

Dismantling the Engine

The examination of the cylinder, piston, piston rings, connecting-rod, camshaft and main bearings, etc., necessitates an almost complete stripping down of the engine. Whilst the general procedure is practically the same for most normal designs of C.I. engine, it sometimes happens that certain types require special methods of dismantling; in such cases the manufacturer's particular instructions should be followed.

The following instructions, taken from the A.E.C. engine practice, will serve as a general example for the basic type of C.I. engine which it represents. The A.E.C. engine shown in Figs. 26, 27 and 28 is a six-cylinder one with overhead valves operated by push-rods and rocker arms from a camshaft in the crankcase.

The camshaft is driven from the crankshaft by a chain which also forms the drive to the fan, the water pump, the dynamo, the vacuum exhauster and the fuel pump. The latter two are mounted in tandem on the nearside of the engine, whilst the water pump, which is mounted on the forward side of the crankcase, is driven by an extension of the dynamo drive shaft. The water pump is fitted with a special graphite packing which requires no attention, and this eliminates the constant nuisance of repacking the spindle.

Three point suspension is provided for the engine unit, the front of the engine being carried by a removable cross member bolted to the dumb irons and fixing to a bracket on the front of the crankcase which carries the starting handle.

The cylinder heads are in two units, each one covering three cylinders; they are interchangeable. The valve gear mechanism is carried in the head and the valve seatings are of a special bronze alloy, screwed into the cylinder; these have an angle of 30°.

The first step in dismantling is to disconnect all externally connected fittings and parts. These include the water pipes to the radiator, the exhaust pipe, driver's controls, electrical connections, etc.

The cylinder heads are removed separately as follows: Remove the cylinder head cover. Disconnect the top water pipe; it is usually found easier to break the flanged joint on the cylinder head than to disturb the rubber connection. Remove the boss bar from the glow plug and disconnect the fuel injector pipes by unscrewing the unions on the injectors. It is best to remove the pipes bodily by undoing the fuel pump and unions, in order to avoid accidental damage to these pipes; the individual pipes should be labelled or scratched with their appropriate cylinder numbers before dismantling. Next, disconnect the exhaust pipe flange and uncouple the two halves of the exhaust manifold where it is joined in the centre. Remove the water pipe coupling the two heads together at the nearside of the engine, remove the rockers and brackets and, for convenience, lift out the push-rods operating the valves.

The cylinder heads are each provided with two special jack nuts to assist in their removal; they are so arranged that as they are unscrewed they will lift the head clear of the cylinder. They are, of course, only used *after* all the other cylinder head nuts have been taken off. Referring to Fig. 45, the jack nuts are shown at *A*13 and *A*12.

Removing Tight Cylinder Heads

An effective method of removing tight cylinder heads on A.E.C. oil engines is illustrated in Fig. 43, in which one of the cylinder heads is shown lifted off the cylinder block as far as possible, by unscrewing the jack nuts. By using the two set screws shown, screwed into the jack nuts themselves, it is possible to lift the cylinder head into such a position that it is easily removable. This is accomplished by holding the jack nuts stationary with one spanner and screwing home the set screws, which, passing through the jack nuts, take a bearing on the top of the jack nut studs. It is absolutely essential that before using the two set screws, the jack nuts must be completely free of their studs as otherwise binding will be unavoidable. If by any chance the jack nut thread has become stripped, this procedure can still be adopted after fitting a new jack nut. The actual set screws themselves should be $\frac{9}{16}$ in. diameter B.S.F. and should be $4\frac{1}{2}$ ins. long under the head.

Removing the Pistons and Con.-Rods

The cylinder heads must first be removed, thus exposing the piston tops. The latter should each, in turn, be brought to its top centre and the carbon deposit removed by scraping or with a wire brush of the end-bristle type rotated by means of an electric motor through a flexible shaft. After cleaning the piston tops thoroughly—taking care not to remove any metal by scraping, or otherwise—examine each of them in

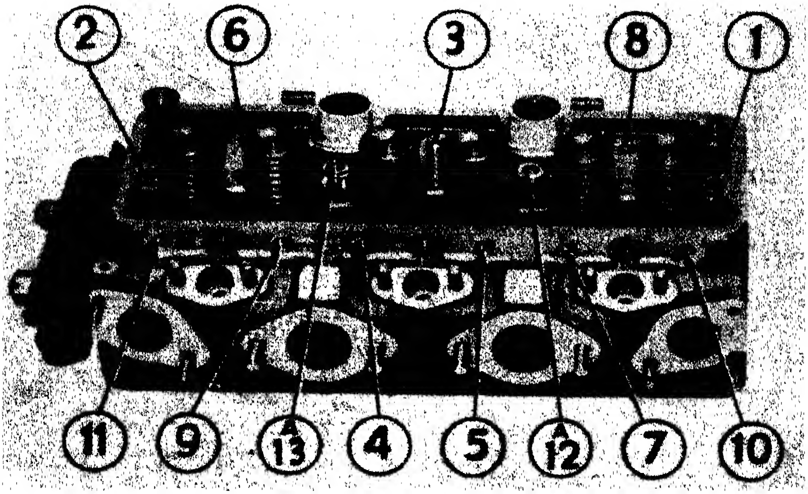

FIG. 45.—Holding-down Stud Holes of A.E.C. Cylinder Head and Jack-nuts.

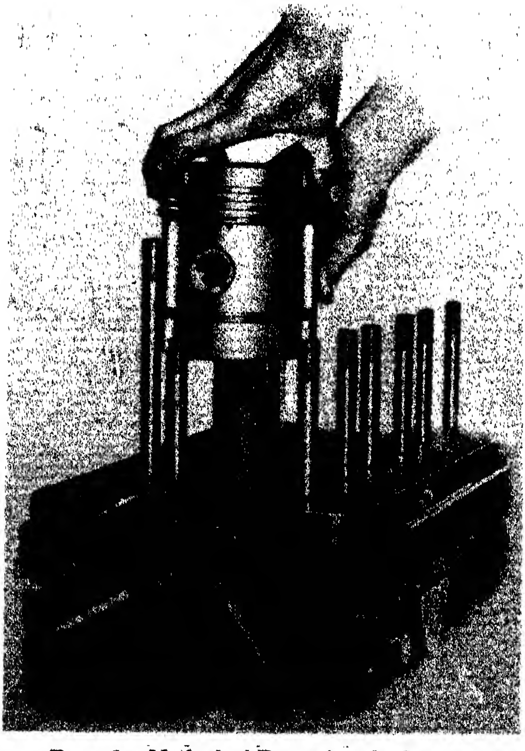

FIG. 46.—Method of Removing the Pistons

order to check that they are properly numbered. If no numbers are found, lightly stamp each piston top with a number stamp, commencing with No. 1 nearest the radiator, and numbering them consecutively 1, 2, 3, 4, etc.

It is important to mark all of the pistons near the same edge, such as the injector or fuel pump side, to ensure that they are re-assembled in the correct manner. Whilst this is not so important with symmetrical designs, it becomes essential with non-symmetrical ones, such as cavity-head pistons.

Incidentally, when the connecting-rods are removed see that each rod has its proper cylinder number; further, observe that the *front*, or near-side, of each rod and its cap is also clearly marked. The rod and bearing cap are invariably marked, to show which way they go together.

The procedure for removing the pistons is, first to obtain access to the big-end bearing bolts and their castle nuts. In some engines special doors or covers are provided on the sides of the crankcases to provide access to these bolts and nuts. In other cases the oil sump has to be removed before they can be reached.

The split-pins are removed from each castle nut, and the latter unscrewed. The big-end bearing cap can then be removed; care should be taken not to lose any of the liners or shims from between the two halves of the bearings during this operation. It will be found more convenient to have the piston on its bottom dead centre when removing its connecting-rod bearing cap, except where crankcase covers are fitted.

Having taken off the caps, slowly turn the crankshaft so as to move the connecting-rod and piston upwards to the top centre, when, on turning the crankshaft farther, the connecting-rod will be left at its top position. It can then be pushed right up, by hand, so that, with the piston, it can be withdrawn from the top. Care should be taken that the connecting-rod does not score the cylinder when passing through it.

If, as sometimes happens, in the case of the smaller bore engines, the big-end portion of the connecting-rod will not pass through the cylinder, it will be necessary to remove the gudgeon pin first. The piston can be pushed sufficiently above the cylinder top to enable this to be done. Afterwards the piston can be removed from above and the connecting-rod from below the cylinder.

The Gudgeon Pin

The gudgeon pin is often of the floating type in both the piston and connecting-rod, being secured endwise by means of spring clips, such as Seegar or Circlips. To remove these rings a special pair of pliers is required, having circular jaws; in some cases ordinary round-nosed pliers can be used.

The gudgeon pin can then be pushed out, using the thumb or fingers. Immediately each piston is removed its gudgeon pin should be wiped clean and replaced in it for identification reasons. In cases where the gudgeon pin is a tight fit in the piston bosses and a bearing fit in the small end bearing of the connecting-rod, a screw press or copper drift should be used, making certain, however, that the pin is driven out in the correct direction; this is necessary, as it sometimes happens that the ends of the pin are tapered one way.

In certain designs of aluminium piston the gudgeon pin is fitted by the *thermal method*, whereby the piston is heated in a special jig, having an electrical resistance heating coil, and, when it has attained the proper temperature the connecting-rod small end is placed in position and the cold gudgeon pin tapped lightly into place.

Otherwise, if the piston is inserted in a vessel of boiling hot water up to the level of the gudgeon pin bosses—so that the latter are not submerged—in a few minutes the piston will expand sufficiently to allow the gudgeon pins to be inserted.

A short heating of the piston is also useful for removing the gudgeon pins, but the heat should not be applied for a sufficient period to actually heat the pins themselves.

When new gudgeon pins are to be fitted they should first be tested for bearing fit in the small-end bearing. If of the full-floating type they should not, of course, be forced into the piston bosses, or small end bearing, but selected so as to be a proper floating fit in all of these parts; on no account should reaming of the holes be employed to ensure a correct fit, except in special instances where the holes have worn out of truth; oversize gudgeon pins will then be required.

Reconditioning the Cylinders

When the pistons and cylinder bores have been thoroughly cleaned they should be measured at various places for diameter, in order to check for maximum wear and irregularity of wear.

The cylinders should be measured with an inside bar or

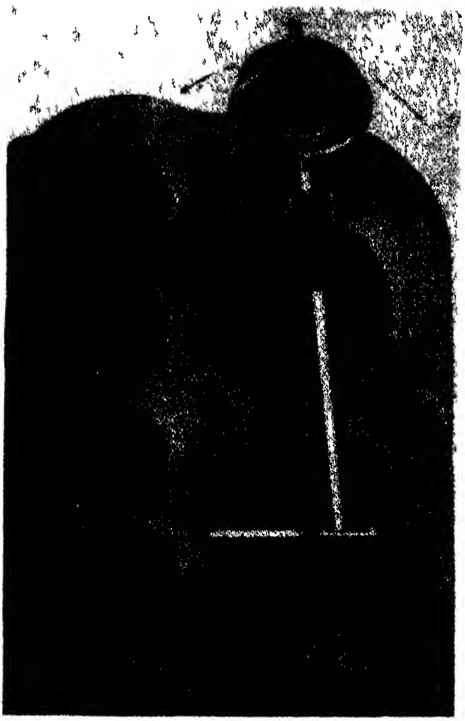

FIG 49 —The Mercer Cylinder Measuring Gauge

[*To face page* 65.

FIG. 47.—Decarbonising Cylinder Head with Wire Brush driven by Portable Electric Drill.

dial type micrometer. The Starrett type shown in Fig. 48 is suitable for this purpose.

A convenient dial gauge is the Mercer one[1] shown in Fig. 49. This has a relatively long stem, arranged at right angles to the micrometer bar which is inserted into the cylinder bore, whilst the dial is mounted at the other end in a position that is easy to observe.

The method of using the gauge is first to place it squarely in the cylinder and then rocking it slowly to and fro in the plane of the dial; the maximum reading shown on the dial is then taken. It is possible to obtain readings to $\frac{1}{4}$ of $\frac{1}{1000}$ in. and to measure taper and ovality as well as to detect scored cylinder walls; it has a range of 2 to 6 inches.

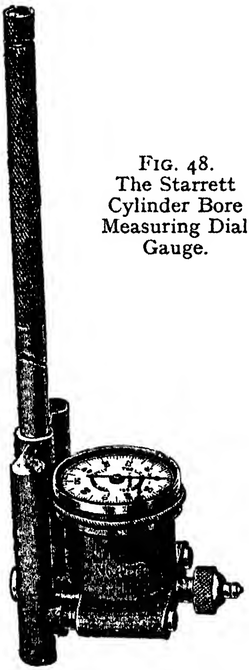

FIG. 48. The Starrett Cylinder Bore Measuring Dial Gauge.

If this wear is found to exceed the limits previously referred to the cylinders will need re-boring and new pistons fitted. If, from the general running of the engine, its length of service or any other reasons it has previously been decided that reconditioning of the cylinders is necessary, it is usual with the engines of a fleet of vehicles to remove the engine bodily from the chassis and transport it to an engine or bench stand, where it can be worked upon more conveniently.

In single instances, however, it is often possible to re-bore the cylinders

[1] J. E. Baty & Co., 39, Victoria St., London, S.W 1.

with the engine in place on the chassis, but special care must be taken to prevent chips, abrasive parts or dust from getting into the main bearings and other working parts.

The multiple-stone cylinder hone, operated through a universally jointed shaft drive from an overhead portable electric motor on a stand having a vertical feed arrangement, is generally used for cylinder re-boring *in situ*.

There are three principal methods of cylinder reconditioning in use in motor engineering workshops and repair garages, viz., as follows :

(1) *The Grinding Wheel*; (2) *The Honing*; and (3) *The Boring Bar Methods*.

(1) THE GRINDING WHEEL METHOD.—In this case the surplus metal is removed by means of a high speed grinding wheel, the axis of which is also given a slow eccentric motion as it is fed into the cylinder, in order to grind all of the cylinder barrel. As this is also the method employed when manufacturing cylinder, it can be claimed to give most satisfactory results.

The cylinder grinding machines employed for this purpose, of which the Churchill and Heald are typical examples, are of massive construction and capable of turning out work of high precision in the hands of skilled operators.

The machine is provided with a vertical " table," on which the cylinder casting is bolted, so that the machined face of the cylinder block affords a satisfactory locating face; this ensures the axis of the re-bored cylinder being accurately at right angles to this face.

The grinding wheel shaft runs in another shaft eccentrically, the two shafts rotating, the outer one concentrically and at a relatively low speed, whilst the inner shaft carrying the grinding wheel is eccentric and rotates at a high speed. The feed, or cut, is adjusted by the amount that the high speed shaft is set eccentrically in relation to the main bar; the cylinder block is held stationary in the machine during the grinding operation.

The grinding wheels used are of carborundum, aloxite, etc., and they give a good surface finish. Although this is by no means a mirror finish, it can be improved appreciably by finishing the surface with another composite wheel of finer grit, with a light cut.

Grinding Speeds.—For internal grinding the speeds are lower than for external work and usually range from 2,000 to 4,000 ft.

per min. Speeds of 2,000 to 3,000 ft. per min. are commonly used. It is essential to have very rigid spindles and mountings for accurate results.

The speed of a 1 in. diam. wheel running at 3,000 ft. per min. will be about 11,500 r.p.m.; for a 2 in. wheel, 5,750 r.p.m. and for a 3 in. wheel, 3,800 r.p.m.

The wheel diameter should be made as large as possible, taking into account the cylinder bore and spindle diameter; usually it is made from half to three-quarter the diameter of the cylinder bore; the larger size of wheel gives the longer wearing life.

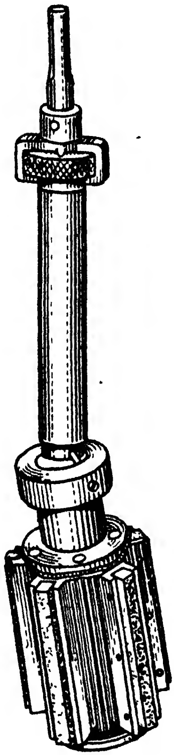

FIG. 50.
The Ammco Cylinder Hone.

In regard to the speed of traverse of the concentric spindle, this, as previously stated, is relatively slow. In practice this speed should lie between 100 and 200 ft. per min.; thus for a 3 in. cylinder bore the outer spindle should rotate at about 10 to 20 r.p.m. The advantages of the grinding method lie in the accurate results obtained, both in regard to concentricity, parallelism of the bore and true alignment in relation to the cylinder head machined face. The chief drawback of the method, from the maintenance engineer's point of view; is the costliness of the grinding machines and the necessity for removing the cylinder block from the chassis. Moreover, the grinding and finishing processes require more time than with some of the other methods in use; this increases the cost of the work.

(2) THE CYLINDER HONING METHOD.—In this method a number of approximately rectangular section parallel stones of an abrasive composition, e.g., carborundum or aloxite, are located by means of holders held in a central member, so that they are all at the same radial distances from the centre. The hones, as they are termed, can be adjusted radially, within certain limits so as to suit cylinders of different diameters; usually a micrometer adjustment is provided for radial adjustment and feed purposes. The complete multi-stone unit is usually rotated at its appropriate cutting speed, through a univer-

sally-jointed shaft from an electric motor of the portable type; the object of the jointed shaft is to allow the hones to align themselves without any external constraint due to the driving shaft. The motor is generally mounted on a vertical stand, the base of which is located by and affixed to the machined top face of the cylinder block. A hand feed is provided for giving the hones a vertical "stroking" movement whilst they rotate; vertical adjustment of the whole unit is also provided.

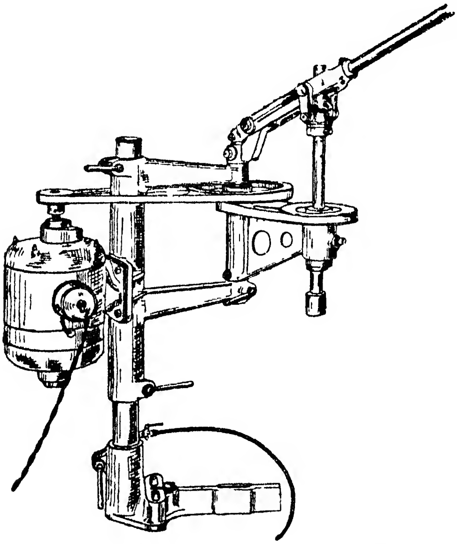

FIG. 51.—A Special Cylinder Head Machine for use with Cylinder Hones.

It is essential, for accurate work, to have a micrometer adjustment capable of giving diametrical adjustments of $\frac{1}{1000}$ in., with a dial and indicator to show the position of this adjustment. This is necessary, since, with a multi-cylinder engine, all of the cylinders should be honed to the same final diameter. It is usual to measure each of the cylinders beforehand and to select the largest bore for the first honing operation. When finished this bore acts as the standard dimension for all of the other finished bores.

The commercial cylinder hones usually have five or six stones. The Ammco (Fig. 50) and Newton-Hartridge hones have five equally spaced stones. The latter are generally supplied in several grades; thus the Ammco stones are available in the extra coarse, coarse, medium and fine grades, suitable for various operations from roughing to finishing.

The radial adjustment provided in commercial cylinder honing machines is such that the same model is suitable for cylinder bores ranging from about 2 in. to 4 in. or 2½ in. to 5½ in. diameter.

The cylinder hone provides a relatively inexpensive method of reconditioning and it is convenient to use in place on the cylinder block without having to remove the latter from the chassis.

The hone must, however, locate itself from the existing bore, so that if the latter is initially incorrect in relation to the crankshaft axis or top cylinder block face the finished bore will also be incorrectly located. On the other hand it is usual to start the honing process from the bottom—or least worn—part of the cylinder bore, so that the finished result is located from this and is within fairly accurate limits, vertical.

Occasionally, however, the garage engineer finds that although every precaution has been taken, the finished bore is definitely off the vertical. It is difficult to account for this result, but it is possibly due to initial inequalities in the bore or to non-alignment of the hone with the machined top face of the cylinder block. A criticism which has often been levelled at the honing method is that it results in abrasive particles being left in the engine. Whilst there is a possibility of such a detrimental result, due to insufficient cleaning of the engine after honing, the exercise of a reasonable amount of care in cleaning the surfaces will obviate this possibility.

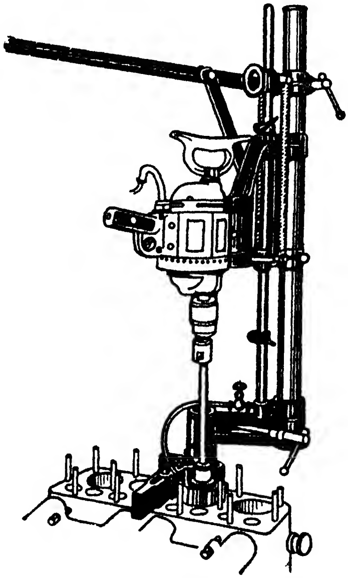

Fig. 52.—Showing Method of using a Cylinder Hone.

As regards the finish given to the surface after honing, if the final operation be done with a fine grade of stone an excellent result will be obtained; it is advisable to continue the final honing several times without altering the feed in order to allow any " spring " of the hone to apply the finishing feed.

Dry honing is employed with coarse or medium grades of stones in cases where an appreciable amount of metal has to be removed, as for roughing and semi-finishing operations.

Wet honing, using a fine grade of stone, with paraffin will give a polished glass-like finish which is considered very satisfactory for cylinder bores. A still higher degree of surface finish approaching a mirror effect is obtainable by lapping the bore, after fine wet honing, with a copper or lead lap impregnated with very fine abrasive powder, crocus powder or rouge.

(3) The Boring Bar Method.—In this method, the cylinder bore is trued with a single or multiple cutter, similar to that employed for lathe boring work. The cutters used are now of the tungsten carbide alloy type ; these are considerably harder than ordinary tool steel and will retain their cutting edges over relatively long periods before resharpening becomes necessary. It is thus possible to true a worn cylinder bore to final dimensions with a single cut, the tool being fed spirally downwards into the cylinder. The finish obtained, whilst showing a definite spiral "tool-mark" is considered satisfactory for most purposes ; it is not, however, so good as that obtained by the finer grades of grinding wheel or finishing hones.

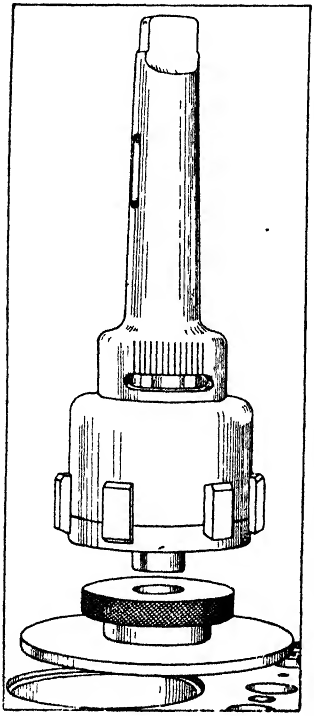

Fig. 53.
The "Durable" Cutter Head for Cylinder Re-boring.

It is unnecessary with modern cylinder boring machines to remove the engine from the chassis, but only to take off the cylinder head and sump and remove the pistons, connecting rods and valves.

The boring bar machine is fixed to the top of the cylinder block, using the cylinder head studs and nuts for holding it down. The cutter, or cutters, are accurately located, or centred, in the cylinder bores by means of a centring device incorporated in the machine. The radius of the cutter is set to the desired dimension by a micrometer or dial-gauge fixture. It is possible to take cuts ranging from $\frac{1}{1000}$ to about $\frac{80}{1000}$ in. in the average size of cylinder, with a smooth finish.

Most of the single tungsten carbide cutter machines on the market are provided with a sharpening device consisting of a diamond dust impregnated disc, driven from the electric motor providing the power for driving the boring bar, for sharpening the cutter on the machine itself.

The average time occupied in traversing the cylinder bore of a commercial vehicle engine cylinder is from 10 to 12 mins.; the usual time for a four-cylinder block, including setting up averaging about 2 to 2½ hrs.

Fig. 53 illustrates the "Durable" cutter head which is used on the larger stationary machines for finish boring cylinders. It is of the multiple tungsten carbide cutter pattern, but a single cutter model is also made. The radial setting of the blades is controlled through the opening shown. A small tommy bar is inserted into one of the slots and by the simple operation of turning to the right or left the blades can either be contracted or expanded. The cutter head is provided with a cylindrical spigot below for engagement with the centre setting gauge shown underneath it. The gauge itself fits the cylinder bore, so that the cutter is thus accurately located. Incidentally, in the case of worn cylinders it is almost invariably found that there is *an unworn ridge* at the top of the barrel between the top piston ring position on T.D.C. and the machined face of the cylinder block; this ridge is useful for location purposes.

Commercial Machines

The type of single- or multiple-cutter cylinder re-boring machines used in the works of manufacturing firms concerned with the reconditioning of a relatively large number of C.I. engines of similar type is the relatively massive vertical boring machine having an extremely rigid frame and boring head, with micrometer or dial gauge device for quickly setting the cutters to the desired size. A suitable machine for this purpose is made by Messrs. Asquith Ltd.

It is usual for one operator to look after two or three machines at the same time, since the boring process is sufficiently long to enable this to be done efficiently; moreover, automatic devices can be fitted for stopping the machine when the cutter has cleared the bottom of the cylinder barrel.

Machines designed for re-boring cylinders *in situ* on the chassis or bedplate include the "Storm" models made by the Messrs. Buma Engineering Co. Ltd., Newcastle-on-Tyne; the K.B. Electric Cylinder Boring Bar, made by Messrs. Mansions Motor Co. Ltd., London, S.W.19; the Hall Fly Cutter Boring Bar, supplied by Messrs. Brown Bros. Ltd., London, E.C.2, and the Van Norman "Per-fect-o," supplied by Messrs. E. P. Barrus Ltd., London, E.C.4.

The Storm model B.N.S. is illustrated in Fig. 54, the various features indicated by the letters being described in the caption below.

The special features include an independent electric motor

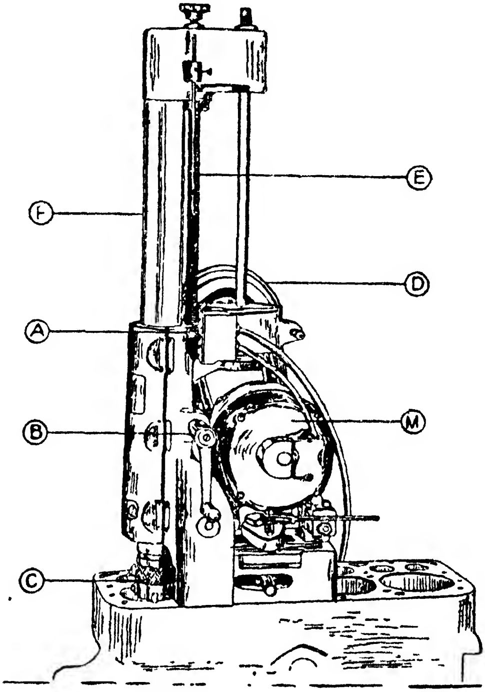

FIG 54 —The Storm Cylinder Re-boring Machine.

A Automatic Stop Switch; *B* Quick Return for Cutter by Rack and Pinion; *C* Cutter Head, *D* Diamond Sharpening Disc for Sharpening Cutters; *E* Screw Feed for Cutter Head; *F* Massive Main Bar, hardened and ground very accurately; *M* Electric Motor for Driving Cutter, Diamond Disc, etc.

of ¼ h.p., 50 cycle, single phase; main boring bar 2⅛ in. diameter hardened and ground; single tungsten carbide cutter; diamond lap for sharpening the cutter, belt-driven from the motor; cutter adjustment for cylinders of 2·2 in. to 4·2 in. diameter; two centring heads; special micrometer for setting the cutter in its head; positive screw feed for cutter with engaging and disengaging eccentrically-operated split nut; rack and pinion for quick return of cutter after reaching bottom of cylinder barrel; long adjustable main bearings to give ample support to the bar; helical cut gearing; special clamping device operating on cylinder adjacent to that being re-bored and an automatic stop switch for stopping machine when cutter has traversed cylinder barrel. The machine will take cuts up to $\frac{60}{1000}$ in. with a smooth finish.

The K.B. portable boring machine used by several large motor service depots has a single tungsten carbide cutter and anti-chatter boring head. It is provided with a novel hydraulic variable feed for the cutter, operating under a steady oil pressure of 20 lbs. per sq. in. It has a range of 2·2 in. to 4·5 in. and is electrically driven from a $\frac{1}{4}$ h.p. constant speed universal motor. This particular machine weighs only 60 lbs., it being about the lightest in commercial use.

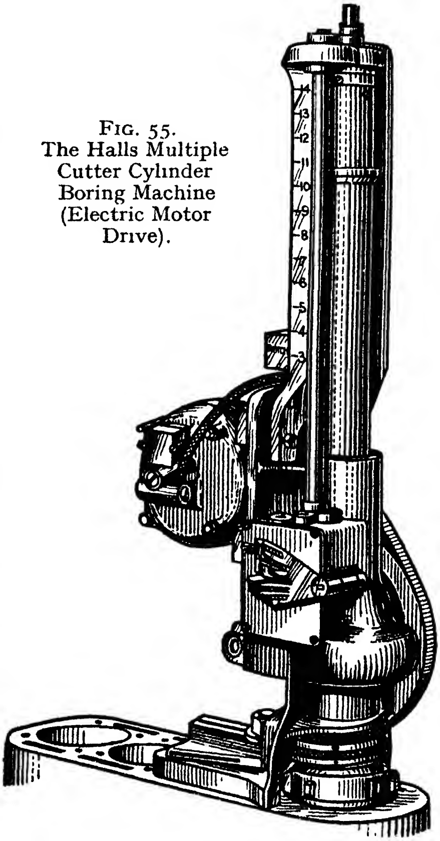

FIG. 55.
The Halls Multiple Cutter Cylinder Boring Machine (Electric Motor Drive).

The machine is also available with an alternative motor drive consisting of a $\frac{1}{4}$ h.p. electric motor driving through a flexible shaft to a Holroyd worm gear mounted on the top of the boring spindle; a three-speed pulley drive is incorporated so that three different speeds are available to cover different cylinder bore requirements.

The Halls cylinder reboring machine shown in Fig. 55 has a six-bladed cutter, with a convenient expanding mechanism. It is electrically operated from the motor shown on the left. An ingenious device is embodied for sharpening the cutters without removing the cutter head from the machine.

The speed is 35 r.p.m., with two speeds, viz., ·020 in. per rev. and ·030 in. per rev. It has an automatic device for stopping the feed and a hand-operated reverse motion.

The capacity, using four cutter head sizes, is from $2\frac{1}{16}$ in. to $4\frac{3}{4}$ in.

Cutting Speeds and Feeds

The cutting speed recommended for the most efficient results is 400 ft. per min. for tungsten-carbide cutters. The usual range of cutter bar speeds is from 300 to 400 r.p.m.

The rate of feed per revolution of the average size of bar is from $\frac{2}{1000}$ to $\frac{6}{1000}$ in., and the maximum depth of cut about $\frac{60}{1000}$ in.

In the case of the Van Norman "Per-fect-o" boring bar the cutter moves down the cylinder at the rate of $1\frac{3}{4}$ in. per min.; this is claimed to be the fastest cutting machine on the market.

As the bar itself has to traverse its guide during the feeding operation, it is necessary to employ a hardened surface; for this reason the bar is generally of Nitralloy steel or of case-hardened alloy steel.

In cases where an appreciable amount of metal has to be removed it is usual to take a roughing cut with a cut of $\frac{50}{1000}$ to $\frac{60}{1000}$ in., followed by a finishing cut of $\frac{2}{1000}$ to $\frac{3}{1000}$ in., with a fine feed.

Improving the Cylinder Bore

The surface left after finish boring with a single or multiple cutter, if examined under a medium power lens, will be found to be somewhat uneven, the ridge marks left by the tool being clearly apparent. Similarly, when cylinders are ground in the ordinary manner, surface irregularities will be seen. It is a well-known fact that these imperfections cause a higher rate of initial wear than would otherwise be the case, but mass-production methods will not usually permit of more refined methods for improving the texture of the surface. (Fig. 56.)

For the best results after boring or grinding, the surface should be lapped to a mirror finish, using a copper or lead lap made practically a running fit in the cylinder. The lap is charged with a wetted mixture of very fine carborundum powder.

Honing is a quicker but less effective method of removing tool or grinding marks and leaving the barrel in a semi-polished condition; if a fine grade of honing stone is used with paraffin, a very good surface finish will be obtained. It is, therefore,

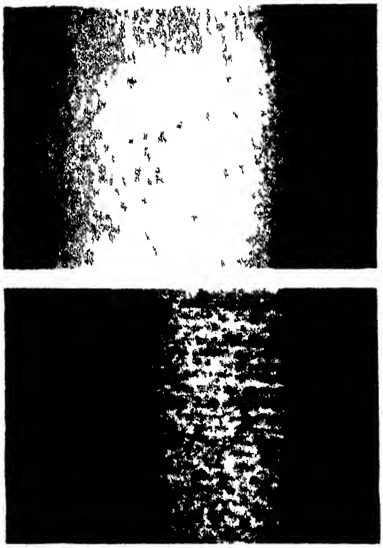

FIG 56 —Showing appearances of Cylinder Bore Surface (Below) As finished by Boring Bar (Above) By Boring Bar with subsequent Honing

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the practice of manufacturers of high grade engines to first bore the cylinders with tungsten-carbide cutters and then to finish by honing.

Cylinder Liners or Sleeves

Many engines are now fitted with separate cylinder liners which can be removed after having reached the allowable wear limits and replaced with new liners, often of suitable internal dimensions, to enable the old pistons to be employed

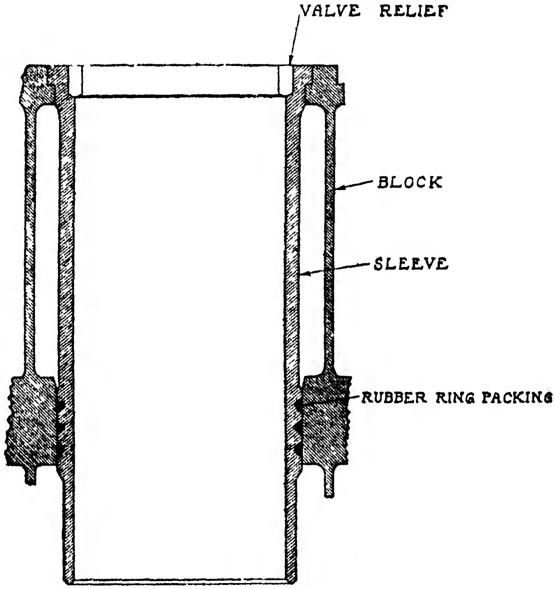

FIG. 57.—The Wet Type of Cylinder Liner, showing method of making Water Joint.

after truing up. These liners are made of a much better grade of cast-iron than is possible for the lower grade most suitable for the complicated cylinder block casting. Thus, by using a chromium or nickel-chromium cast-iron, cast into cylindrical form by the centrifugal process, a much harder and better wearing quality of metal is obtained. The centrifugal method of casting ensures freedom from inclusions or air cavities and results in a somewhat denser metal.

The use of alloy iron liners results in reduced maintenance costs, for not only are worn cylinder blocks obviated but a lower rate of liner wear results.

Thus, in the case of some cylinder liners employed by a large motor bus company, these contained 1·0 to 1·25 per cent. of nickel; 0·3 to 0·5 per cent. of chromium and 3·0 to 3·5 per cent. total carbon, of which 0·5 to 0·8 per cent. was in the combined form. The wear of the cylinders fitted with these liners was at the rate of ·00019 in. per 1,000 miles, whereas for the unlined straight run cast-iron cylinders it was ·00035 in. per 1,000 miles; the former, therefore, showed an improvement of 45 per cent.

Cylinder liners are of two general types, viz., the *wet* and *dry* ones. In the former case (Fig. 57) the outer surface of the liner is in contact with the cooling water, whereas in the latter case the liner is fitted inside the cylinder barrel and is not, therefore, in contact with the water. The wet type of liner is of appreciably greater thickness than the dry type, and requires a carefully designed water joint at its lower end.

The dry pattern cylinder liner is sometimes fitted by forcing it into position by means of an hydraulic press or slow-pitch screw and nut device. More recently, however, the much quicker method of first shrinking the liner in liquid carbon-dioxide or oxygen and then dropping it into place in the cylinder block has come into favour.

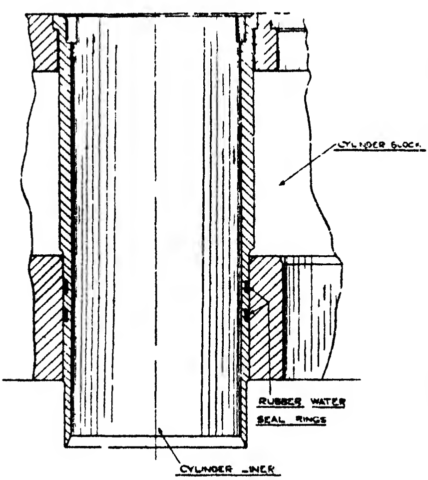

Fig. 59.
The Crossley Wet Cylinder Liner.

The Drikold process of Messrs. Imperial Chemical Industries Ltd., London, consists in the immersion of the cylinder liner in a tank containing a liquid which does not freeze down to minus 110° Fah. The tank is surrounded by an outer shell, having a non-conducting material to prevent heat interchange between the cooling medium—which is solid carbon-dioxide—and the surrounding air. The contractional effect thus obtained amounts to $\frac{1}{1000}$ in. per in. diameter, in the case of cast-iron.

The method employed by Messrs. A.E.C. Ltd. is to immerse

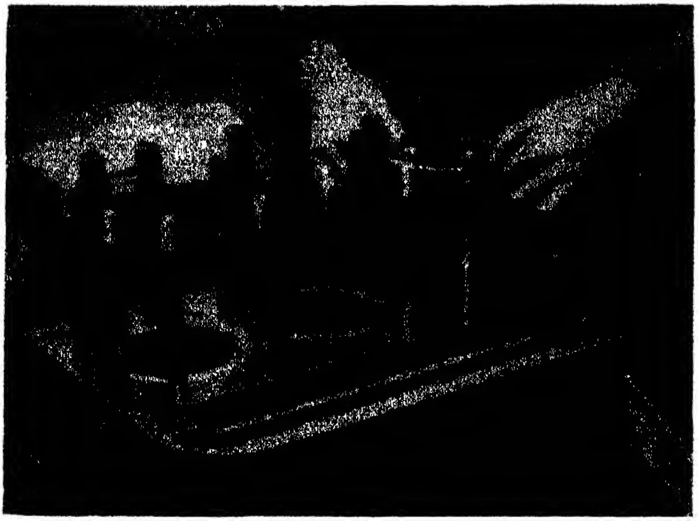

Fig. 58.—Inserting a Wet-type Liner into Cylinder Block. (Fowler.)

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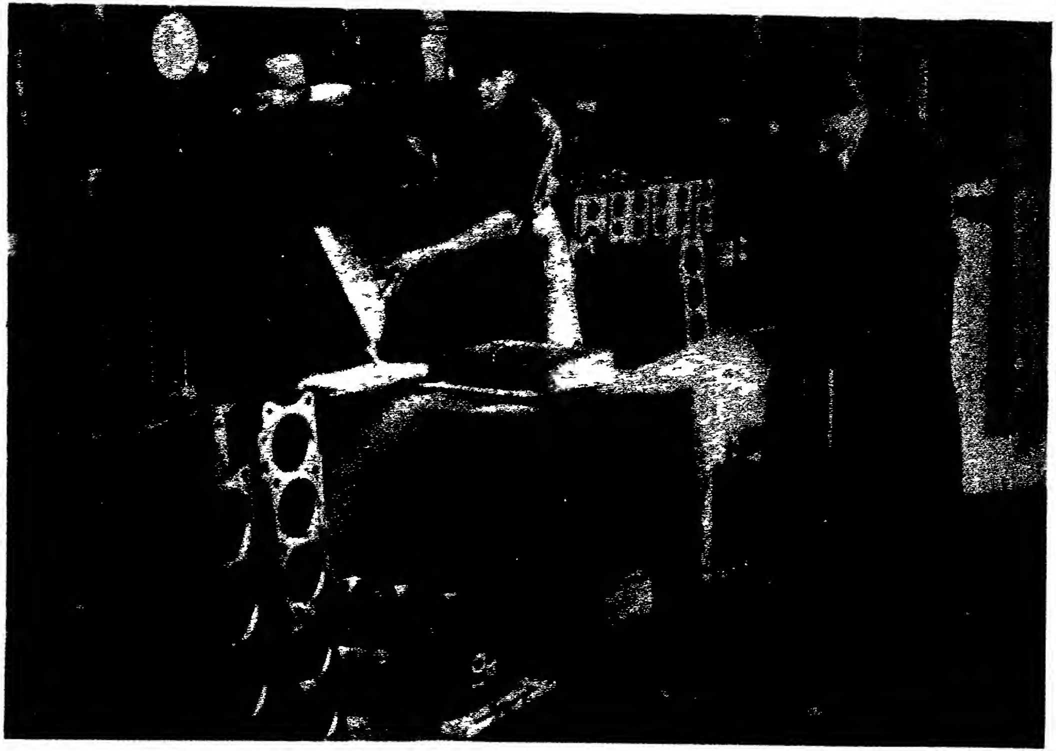

FIG 60 —Illustrating the "Freezing" method employed by Messrs A E C Ltd for fitting Cylinder Liners

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each liner in a well-insulated box into which liquid oxygen is released from a tipping container at about minus 182° Fah. The liner shrinks to the extent of $\frac{8}{1000}$ in. Using padded asbestos gloves the operator removes and quickly transfers the liner into the appropriate barrel of the cylinder block, taking care not to touch the sides of the cylinder bore. Expansion occurs directly the liner is in place; this method, whilst dispensing with the need of hydraulic pressure obviates distortion. The lined cylinder barrels are finally honed to size.

When hydraulic pressure is used to force the liner into place a force of 4 to 8 tons, depending on the size of cylinder is used; usually, this pressure is progressive so that it is applied proportionately to the increasing resistance of the inserted liner.

In connection with the fitting of wet-type liners, the following method of removing and fitting new liners to the Crossley high speed C.I. engine as used on commercial vehicles may be of interest. The liners (Fig. 59) are removed from the cylinders by carefully tapping with a piece of wood on the bottom edge of the liners.

When fitting the new liners, new water seal rubber rings (obtained from a Crossley Agent) should be used. These should be smeared all over with soft soap before fitting to the liner. Thoroughly clean the cylinder and then fit the liners by hand pressure alone. They must now be withdrawn and the rubber rings inspected to see if they have been making contact all round. If the rubber rings show a good reading for a water-tight joint, press the liners back again into the cylinder.

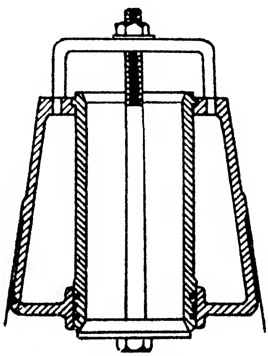


Fig. 61.—Showing method of removing Cylinder Liner by means of Nut and Screw device.

The top flange of the liner should be ·003 in. to ·004 in. above the top face of the cylinder after fitting.

The bores of the Armstrong Saurer oil engine cylinders are fitted with centrifugally-cast iron dry liners, the replacement of which is a simple operation, when necessary, i.e., after about 50,000 to 60,000 miles. The new cylinder liner dimensions when new are 110 mm. plus ·05 to ·07 mm. bore.

The maximum permissible wear before replacing the liners is 0·3 mm. or about ·012 in.

Sleeve Press Tools

Special tools are now available for inserting and withdrawing cylinder liners. These are generally made adjustable for a range of liner sizes.

The Buma liner insertion tool shown in Fig. 63 belongs to the ratchet and pawl operated screw press class, with ball thrust race between the rotating and fixed members near the upper side. A stepped cone attachment is provided for centralising the liner, whilst the lower end has a pin-jointed stop member which engages with the lower face of cylinder block; it can be inserted from above, by virtue of the joint mentioned. This tool is also provided with attachments—as shown in Fig. 64—for removing cylinder liners. In this case a stepped cylindrical member engages with the lower face of the liner, and centralising conical member with the upper

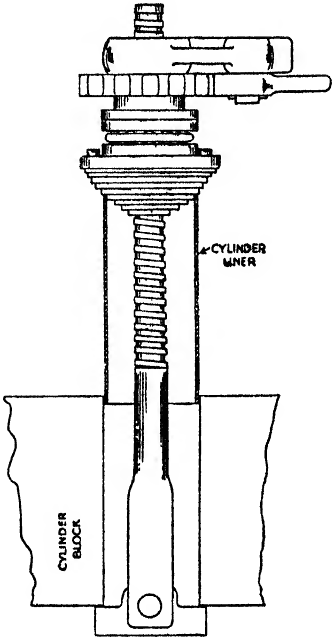


FIG. 63—Inserting Cylinder Liner, with Buma Tool

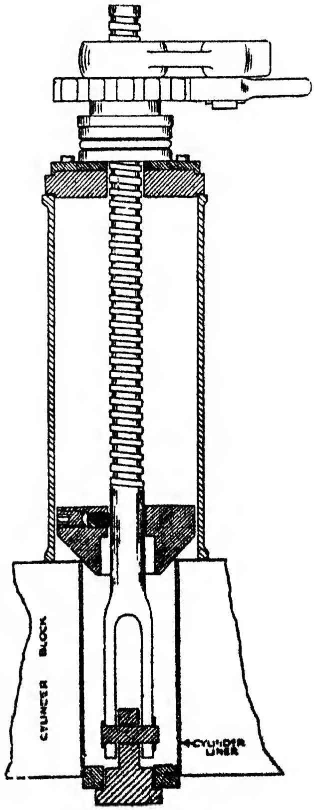


FIG. 64.—Removing Cylinder Liner with Buma Tool.

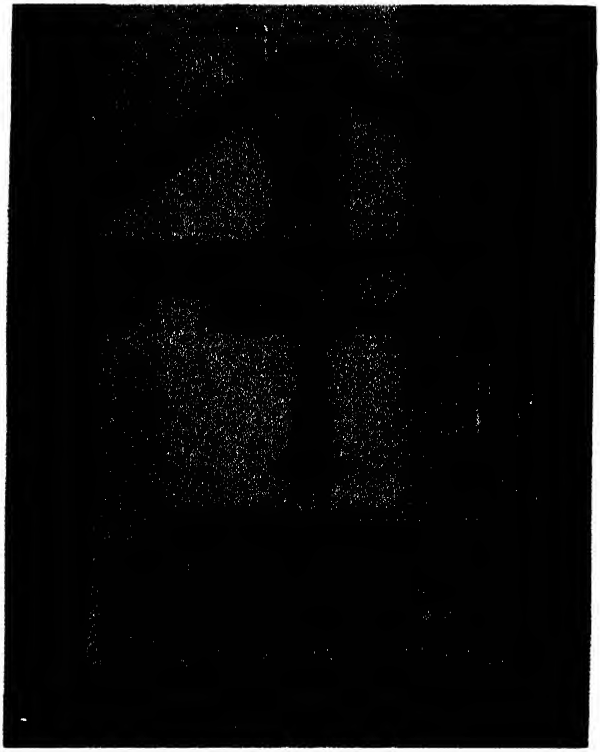


FIG. 62.—An Hydraulic Press for Inserting Cylinder Liners.

[*To face page 78.*

face. The ratchet operated square-threaded nut and screw then exert the necessary upward thrust to force the liner upwards.

A convenient tool known as the Ohio Sleeve Press, for inserting and removing cylinder sleeves or liners is illustrated in Figs. 65, 66 and 67. It consists of a Tee-ended yoke with a long screw-threaded rod and a special nut unit for applying the pressure. The actual nut is operated through a worm and worm-wheel gear by means of a squared shaft. It is designed for use with an ½ in. electric drill, or by hand, using a cranked wrench of the carpenter's brace pattern.

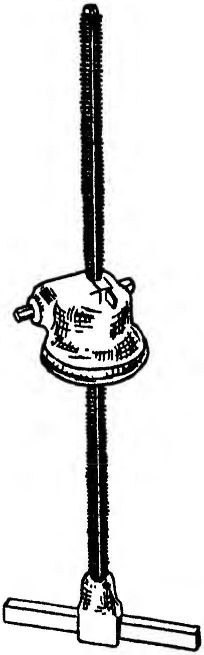


FIG. 65.
Ohio Cylinder Liner Tool.

The cylinder liner is inserted by placing the square bar below the cylinder block (Fig. 66) and the nut member above the block; the top of the liner engages with a cylindrical machined face on the lower side of the nut member.

In order to allow for quick adjustment of the nut, without the gearing previously mentioned, the latter is placed out of action by removing a key in the nut (Fig. 59).

To extract a cylinder liner (Fig. 67), it is necessary to use another sleeve, larger in diameter than the liner, and a bar or disc below, slightly smaller than the outside diameter of the liner. This bar or disc engages with the lower edge of the liner and, by means of the nut and screw device above, pulls the liner upwards. The tool in question is made in two sizes for sleeves up to 4 ins. diameter and for sleeves from 4 to 7 ins. diameter, respectively; it is marketed by E. P. Barrus Ltd., London.

The Cummins Sleeves

The sleeves used in the Cummins engine are of the wet type held in place by the cylinder head. They are made watertight at the bottom of the sleeve by three endless rubber rings. These sleeves are removed by taking off the cylinder head and extracting with a screw pulling tool. (Fig. 62.)

The sleeve should be tested in the cylinder block without its packing to ensure a suitable fit.

To prevent the rings from rolling when the sleeve is being forced into the cylinder block they should be well rubbed with cup-grease or soft soap. The sleeves in question have recesses for the valves, and so must be inserted in the correct position. It is not necessary to re-grind or replace the cylinder sleeves as long as the engine starts readily and does not show

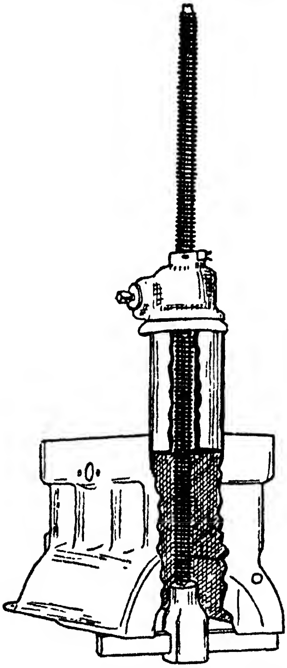


FIG. 66.—Illustrating method of inserting Cylinder Liner.

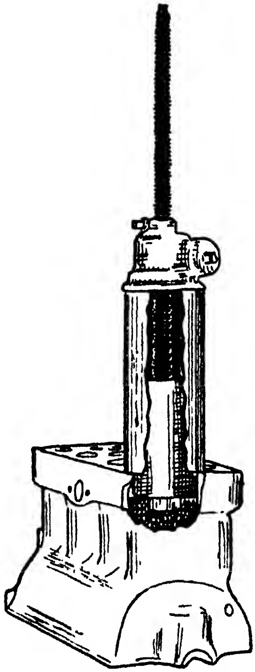


FIG. 67.—Method of removing a Liner.

any "blow by." Otherwise, when the cylinders have worn by about 0·010 in. they should be re-ground or replaced. Incidentally, stuck piston rings or worn rings should not be confused with cylinder wear.

Liner Dimensions, Clearances and Tolerances

The wall thickness of the commercial *wet liner* varies from $\frac{1}{4}$ to $\frac{3}{8}$ in., the usual thickness favoured being $\frac{5}{16}$ in.; for passenger car engines the wall thickness varies from $\frac{3}{16}$ to $\frac{1}{4}$ in. It is the practice to provide a flange at the top end, in order to obtain a better top seal. The lands on which the barrel is seated are usually of increased diameter so that the seats will not be detrimentally affected by the passage of more surface barrel than necessary.

In some cases, as previously mentioned, rubber rings are used to make the bottom seal; in others an interference fit of $\frac{2}{1000}$ to $\frac{4}{1000}$ in. is employed.

The wall thickness of the cast-iron dry liner is from $\frac{1}{16}$ to $\frac{3}{16}$ in., and it has a flanged head; steel liners can be made appreciably thinner.

The liner is made an interference or press fit in the cylinder barrel, the usual allowance being $\frac{1}{1000}$ in. per in. diameter with a maximum allowance of $\frac{4}{1000}$ in.; these allowances are for cylinders of 3 in. to 6 in. diameter. A slight lead is desirable on the entering end.

The liner should be *smeared with soft soap*, to act as a lubricant and seal during insertion.

Plain Liners

Plain cylinder liners of the dry type are often used in preference to stepped or flanged ones, as their fitting is simpler, there being no additional boring of the cylinder block. The plain liner is much used in the U.S.A.

Finishing Lined Cylinders

After the insertion of the liner the inside surface requires a slight truing, to correct for any distortion that may have occurred during its insertion. Usually it is found that only about $\frac{2}{1000}$ to $\frac{4}{1000}$ in. of metal requires to be removed. The method generally used is that of honing, and the final size must also be chosen with the object of utilizing the existing or new pistons of a given size.

Materials for Liners

Cylinder liners are now made in certain alloy irons by the process of centrifugal castings; ordinary "straight" irons are seldom used in modern engines. We have already referred to two alloy irons of chromium and nickel-chromium content, and shall now deal briefly with two or three other commercial alloys of particular suitable nature for cylinder liners intended for long lives. These alloys include Chromidium, Centrard and Durocyl.

Chromidium iron contains 3·1 to 3·3 per cent. total carbon; ·6 to ·8 per cent. combined; 2 to 2·2 per cent. silicon; ·15 to ·19 per cent. phosphorus; ·75 to 1 per cent. manganese and ·25 to ·45 per cent. chromium; the sulphur content is extremely low. The metal has a tensile strength of 20 to 23 tons per sq. in. and a Brinell hardness of 230 (unhardened).

Durocyl is a hardening alloy cast-iron with a hardness, in the heat-treated condition equal to that of oil-quenched nickel-chromium steel, viz., 475 to 525 Brinell.

The Chromidium liners show an appreciable gain in life as compared with ordinary "straight" cast-irons. The hardened Durocyl iron gives from three to four times the life of the ordinary cylinder iron.

Centrard liners [1] are made in a special alloy cast-iron which is capable of being hardened to a high degree by the nitrogen hardening process. The bore surface of the liners is ground and submitted to the action of dry ammonia gas for a certain period at the comparatively low temperature of 500° C. During the process nitrogen is absorbed from the ammonia and the exposed surface acquires an intense hardness, viz., of over 900 Brinell. The surface is so hard that hardened specimens of Centrard will readily scratch glass. The hardened layer extends to a depth of $\frac{15}{1000}$ in. to $\frac{20}{1000}$ in. The tensile strength of the Centrard iron, as cast by the centrifugal process, is 25 to 30 tons per sq. in.

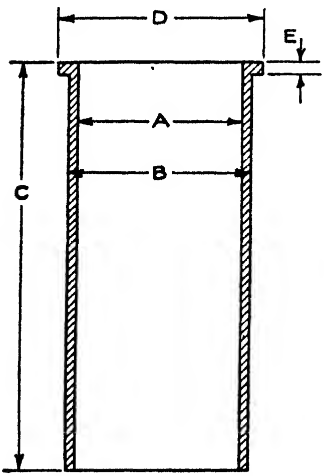


FIG. 68.—Centrard Cylinder Liner Dimensions.

Liners made of Centrard iron have been submitted to lengthy tests in commercial vehicle engines. Data thus obtained shows in many cases a mileage, measured in the position of maximum wear, of over 20,000 per $\frac{1}{1000}$ in. wear. The majority of results show mileages per $\frac{1}{1000}$ in. considerably in excess of this figure even for the first 5,000 miles run. Centrard liners are ground accurately to close limits and provided with an allowance of $\frac{1}{1000}$ to $\frac{35}{10000}$ in. in the bore to enable them

[1] Made by Sheepbridge Stokes Co. Ltd., Chesterfield.

to be finished to size after insertion in the bored out cylinders.

The following are the *fitting instructions* for Centrard cylinder liners of the stepped type illustrated in Fig. 68; the letters *A*, *B*, *C*, *D*, and *E* on this diagram are referred to in the following instructions:

(1) The outside diameter *B* of flanged liners is ground slightly larger $\left\{\begin{array}{l}\text{B plus } \cdot 001 \text{ in.}\\ \quad \text{plus } \cdot 0025 \text{ in.}\end{array}\right\}$ according to diameter

The flange diameter *D* is ground $\left\{\begin{array}{l}\text{D minus } \cdot 003 \text{ in.}\\ \quad \text{minus } \cdot 005 \text{ in.}\end{array}\right\}$

The flange depth *E* is ground $\left\{\begin{array}{l}\text{E plus } \cdot 000 \text{ in.}\\ \quad \text{minus } \cdot 002 \text{ in.}\end{array}\right\}$

(2) For Centrard (nitrogen hardened) Liners the bores *A* are provided with an allowance of ·001 in. to ·0035 in. for finishing after insertion of the liner.

(3) The preliminary boring operation of the block should finish at $\left\{\begin{array}{l}\text{B plus } \cdot 0000 \text{ in.}\\ \text{B minus } \cdot 0005 \text{ in.}\end{array}\right\}$

(4) The recess in the Cylinder Block to receive the flange of the liner should be bored to $\left\{\begin{array}{l}\text{D plus } \cdot 001 \text{ in.}\\ \quad \text{plus } \cdot 002 \text{ in.}\end{array}\right\}$

with the depth $\left\{\begin{array}{l}\text{E plus } \cdot 0005 \text{ in.}\\ \text{minus } \cdot 0005 \text{ in.}\end{array}\right\}$

The liners are provided with a radius approximately $\frac{1}{32}$ in. under the flange and a radius or chamfer of approximately $\frac{1}{16}$ in. should be provided at the corresponding place in the cylinder block.

(5) Centrard liners are left unhardened in the bores for a length of 2 in. from the end opposite to the flange: this is to enable con-rod clearances and chamfer to be cut, if necessary, after fitment.

The Listard Process

The life of a cylinder liner, whether of plain or alloy cast iron, can be extended appreciably by treating it before being placed into service, to a chromium plating process, known as the Listard[1] (Van der Horst patent). The surface obtained is much harder than that of hardened alloy cast iron or hardened steel.

Owing to its hardness the usual Brinell test cannot be applied, but there are two alternative methods of testing. The first is by scratching the surface under a given pressure with a diamond and measuring the scratch. The other is to apply an abrasive object at a given speed and under a given pressure for a given time period. With the latter method a hardened 1·25 % carbon steel has a wear value of 166, whilst the chromium surface is 500. With the first method the relative wear values are 333 and 624.

The results of actual road tests made with different types of cylinder liners give the following comparative figures :

Cast iron	1,500 hours or	30,000 miles
Hardened cast iron . .	3,000 ,,	60,000 ,,
Listard treated cast iron . .	6,000 ,,	120,000 ,,

These figures are based upon a total wear of $\frac{10}{1000}$ to $\frac{12}{1000}$ in. for the hard cast iron liners and $\frac{6}{1000}$ for the Listard ones. The results of wear measurements taken down the top three inches of a cylinder barrel, for hard cast iron and Listard treated cast iron that at the position of greatest wear, viz. at about $\frac{5}{8}$ inch from the top of the liner, the plain cast iron wear was ·011 in. and the Listard liner, ·0025 in.

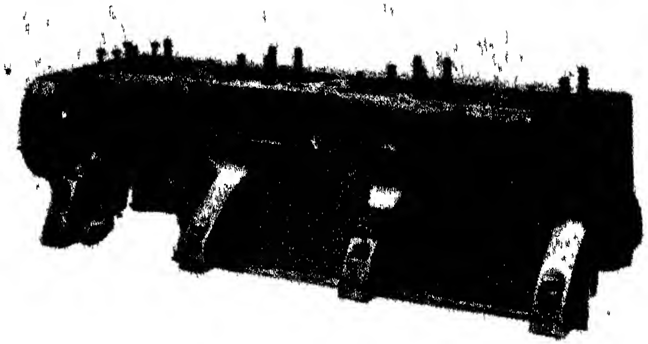
Cylinder Repairs

Apart from the work of reconditioning cylinder bores or fitting new liners, high speed C.I. engine cylinders occasionally require repairs by the welding process. In this connection the experience of the well-known firm of welding specialists, Messrs. Barimar Ltd., London, may be of particular interest.

In addition to the fitting of cylinder liners made from a special corrosion-resistant grade of iron, repairs have to be executed to cracked cylinders. The cracks may be due to frost in winter time, to latent strains in the casting, to distortion set up by the heat of the engine, to uneven bolting down of cylinder heads, manifolds and other fittings, or to the radiator being filled up with cold water while the engine was still hot. (Fig. 69.)

The latter is a very prevalent cause of trouble, and it is significant that cylinder heads are frequently received with

[1] Messrs. R. A. Lister Ltd., Dursley, Gloucester.



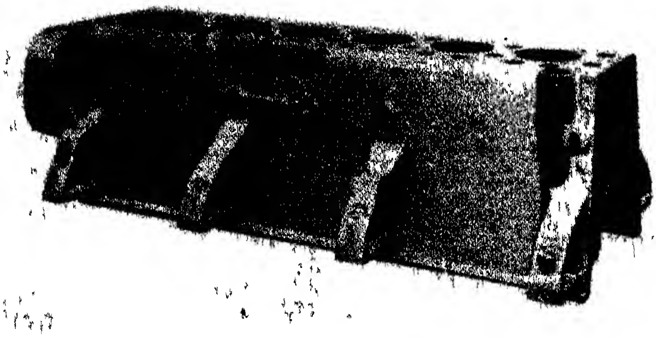


FIG 69.—(Above) Fractured Diesel Cylinder Block (Below) The same Block after Repair by the Welding Process (Barimar)

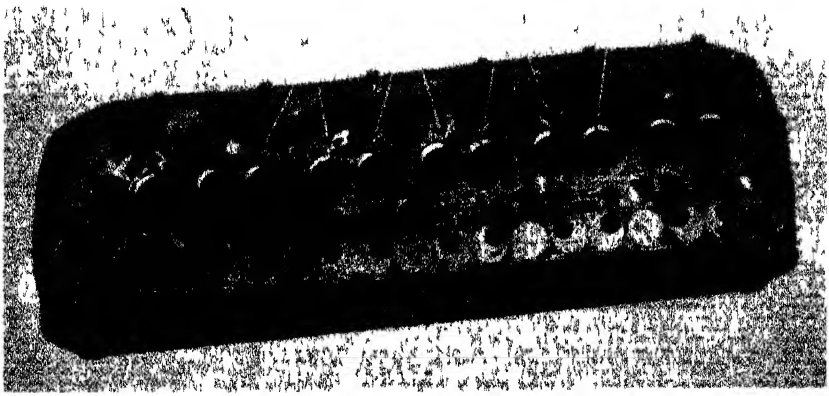


FIG 70.—Diesel Engine Cylinder Head, showing valve seating cracks that were satisfactorily repaired by welding (Barimar).

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cracks just at the place where cold water from the radiator first impinges on the casting. When a considerable amount of water has been lost from a radiator it is most desirable to allow the engine to become almost cold before the radiator is filled up again. It must be remembered that although the external parts of the engine may lose their heat fairly rapidly, the internal parts do not cool so quickly.

Valve seat wear is fairly rapid in the heads of high speed C.I. engines belonging to motor vehicles, due no doubt to the great heat that is generated in this type of engine and to the powerful valve springs that are used. It is by no means unusual for all the valve seatings in a C.I. cylinder head to be cracked. These can be built up by welding just as successfully as those of a petrol engine. It is frequently not sufficient to weld a crack or build up a worn place. The "burnt" metal in the vicinity of the defective area must be cut right out and new metal welded in. (Fig. 70.)

It is found that cylinder wear in particular is more rapid in the case of a C.I. engine fitted in a vehicle in service requiring frequent stopping and starting. This is an indication that so long as the temperature can be maintained reasonably high there is little opportunity for cylinder corrosion. In further support of this conclusion is the fact that marine C.I. engines are more prone to wear than any other type. It is not suggested that this is due to constant stoppage and starting, for in marine service full load running for long periods is usual, but in this case the wear is caused by over-cooling from the over-abundant supply of cold water in the cylinder jackets. Wear in other respects is about the same and the oil coolers which are almost invariably fitted to high speed marine C.I. engines are undoubtedly instrumental in prolonging the life of the main bearings, big-ends and other wearing surfaces.

On some types of C.I. engines cracks develop in the water jacket, and as this occurs at all seasons of the year, the trouble is not due always to frost. The explanation appears to be that the load on the cylinder head studs is transmitted to the comparatively thin outer wall of the cylinder jacket, which is not strong enough to stand the extra stresses set up by the high compression ratio of C.I. engines. It has even been suggested that it is wise not to make the cylinder head studs of too great a strength, because it is not so serious for a cylinder head stud to give way as for the main body of the casting to be cracked.

Replacing the Cylinder Head

After the cylinder head has been decarbonised and the valves ground in and replaced, with their springs and collars, the head can be put back upon the cylinder block.

The machined face of the head should be quite clean and any edge burrs removed with a smooth file. See that the water passage holes are quite free from obstruction before the head is replaced. Examine the copper-asbestos gasket;

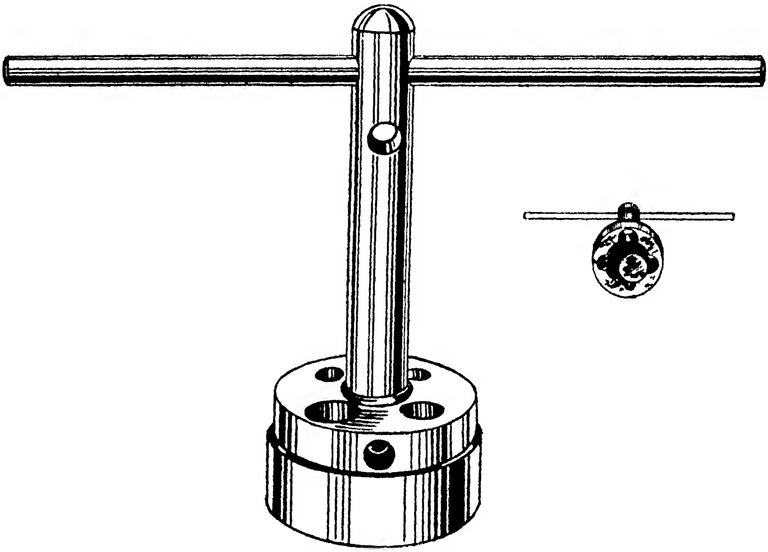

FIG. 71.—The B. and T. Stud Extractor.

if it is not damaged in any way it can be used on more than one occasion, otherwise it should be replaced by a new one.

The studs in the cylinder head should also be cleaned, as any dirt present will be scraped off on to the gasket when the cylinder head is replaced. It is best to clean all burnt oil and adhering dirt off with a scraper, afterwards wiping off all traces left with a paraffin-soaked rag.

The machined face of the cylinder head and the upper one of the gasket (when the latter is used again) should be lightly smeared with a cylinder-jointing composition such as Osotite; ordinary gold size, linseed oil or coach varnish can be used with satisfactory results, however.

In the case of cylinders having jack nuts, the head should be lowered carefully over the studs until it comes to rest on these nuts. These hold it about half-an-inch above the cylinder, in the instance of the A.E.C. engine (*vide* Fig. 40). The head must be kept parallel with the cylinder, giving each jack nut a few turns alternately with the spanner, so as to bring the two together. After the head is down on to the gasket give each nut a slight turn, working spirally outwards from the centre nut in order to avoid any distortion. If, as is usual, there are three parallel rows of nuts, tighten the centre row first, working spirally outwards from the centre; then tighten both of the outside rows in a similar manner, again working spirally outwards. The nuts should be tightened up in at least three stages, the first time lightly, the next time with a medium pull on the spanner and, finally, pulling them up hard.

After the engine has been run for a sufficient period to warm it thoroughly, the cylinder head nuts should be once again checked for tightness; any leakages at the gasket edges should be noted and, if possible, rectified. It is advisable, also, to check the cylinder nuts for tightness after the vehicle has run about 50 miles on the road.

In the event of cylinder studs requiring extraction they can readily be removed with a stud extractor of the type illustrated in Fig. 71. This is more convenient and quicker in action than the usual lock-nut method. Other proprietory makes of stud extractor are the Newton and Buma ones.

CHAPTER V

THE PISTONS AND PISTON RINGS

The Pistons

PISTONS of C I. engines differ in design from petrol engine types, on account of the higher maximum and compression pressures that occur in the former type In order to provide for these higher pressures the pistons are made longer, in relation to their diameter, whilst to minimise leakage of the charge a greater number of piston rings is provided.

The length of the piston is usually from 1·3 to 1·5 times its diameter and the number of rings five in all. There may be three pressure and two oil-control rings, or four pressure and one oil-control rings Aluminium alloys, such as the " Y " and " R.R." alloys are often used for C.I. engine pistons. The gudgeon pins are of case-hardened carbon or alloy steel and float in both the piston bosses and small-end connecting-rod bearings, being retained by spring clips, such as Seegar Circlips.

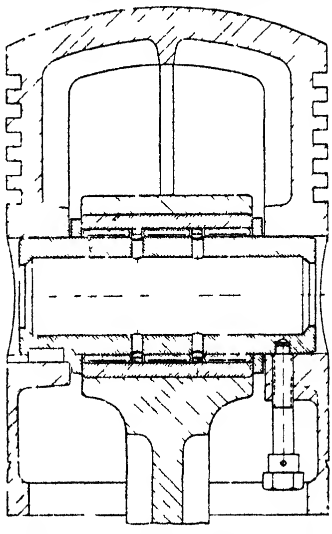

FIG 72 —Diesel Piston with Needle Bearings for the Connecting Rod Small End.

In the Leyland C.I. engine the gudgeon pin is a *light* push fit in the small-end connecting-rod bearing when cold, and a *tight* push fit in the piston bosses.

The gudgeon pins on the Armstrong-Saurer engine, whilst not strictly so, may be termed " fully floating " in the piston bosses and phosphor-bronze bushed small-end bearing. They are positioned by Circlips. To remove the gudgeon pin, the Circlips are detached and the piston is heated in an oil bath

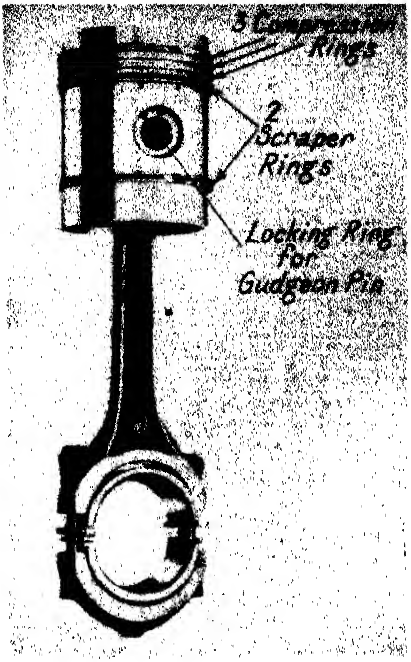

Fig. 73.—The A.E.C. Diesel Piston.

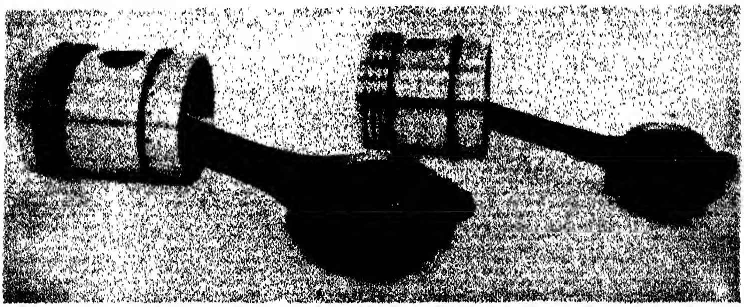

Fig. 74.—Showing A.E.C. Diesel Piston Assembly (left) and Petrol Engine one (right).

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to 375° F. The pin can then be removed by means of a piece of wood placed on its end and tapped with a hammer. If the pin does not come out with a slight tapping this indicates that it has not been heated sufficiently. The gudgeon pin is also replaced by a similar oil bath heating process, tapping it with a piece of wood, using a hammer. Incidentally, a total of 3 mm. (about 0·12 in.) side float is allowed between the gudgeon pin bosses and the sides of the small-end connecting-rod bearing.

Typical examples of C.I. engine pistons are shown in Figs. 73 and 74. In the former case the A.E.C. piston illustrated has three pressure and two oil control rings of the perforated

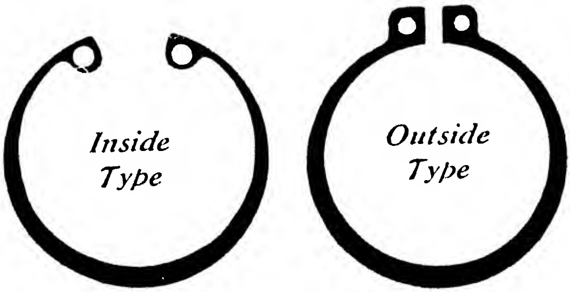


FIG. 75.
Circlips for fixing the Gudgeon Pins in Piston Bosses.

channel section type, one above and one below the gudgeon pin. The clearance at the skirt of the piston, when new, is $\frac{8}{1000}$ in. The pistons and rods are numbered in sequence counting from the front end (No. 1) and they should always be fitted to their respective cylinders when re-assembling.

The method of removal of the piston has already been described. *To replace this type of piston* it is important to ensure that the piston rings should enter the cylinder bore without any constraint. For this purpose a special guide (Fig. 76) is supplied by the makers as part of the tool kit. This guide should be well smeared with engine oil and passed over the piston before the connecting-rod is dropped down into the cylinder barrel.

The motor garage accessory firms, e.g., Messrs. Brown Bros. Ltd., London, East London Rubber Co. Ltd., Bradbury Ltd., etc., supply special piston ring compressing clips to facilitate the insertion of the pistons into their cylinders; the use of these clips saves a good deal of time and obviates any risk of breaking the rings.

It is a fairly simple matter to make a satisfactory design of ring compressing clip from a strip of brass or steel. The clip is compressed by means of a wing-nut and screw. It should have two or three equally spaced lugs on the cylinder face side to ensure that the rings enter the bore normally.

In some designs of C.I. engine *cavity, or non-symmetrical crown type pistons* are employed ; in such cases it is important to ensure the correct dispositions of these pistons when they are re-assembled ; they should be suitably marked for this purpose before dissembling. Thus, with the Leyland engine the piston cups are offset towards the nozzle side and they must always be fitted in this position.

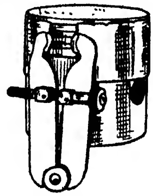


FIG. 77. A convenient Piston Ring Compression Clip (Brown Bros. Ltd.).

Piston Maintenance

During its normal life the piston requires but little attention, it being necessary only to decarbonise the crown portion when the cylinder head is decarbonised, and to clean out the piston ring slots at stated intervals—usually every 15,000 to 20,000 miles.

Some manufacturers recommend that this should be done *at alternate valve-grinding periods.*

Special tools are sometimes employed for cleaning the piston ring grooves. The piston crowns are usually decarbonised with a rotating wire brush of the end " bristle " type, operated by means of a small electric motor and flexible drive. After cleaning in this manner they should be wiped with a paraffin soaked cloth and dried off with a clean cloth.

It is necessary, when decarbonising with a steel scraper, to avoid removing any of the relatively soft aluminium alloy from the piston crown.

Further, the interior of the piston should be examined for any carbon formation.

The drilled holes in the oil-control ring grooves should be kept clear of any carbon when the piston is receiving maintenance attention. Finally, when thoroughly cleaned the surface of the piston should be examined for defects such as cracks.

When replacing pistons in the cylinders the bores of the latter should be smeared with perfectly clean engine lubricating oil. After re-assembling all the pistons and connecting-rods

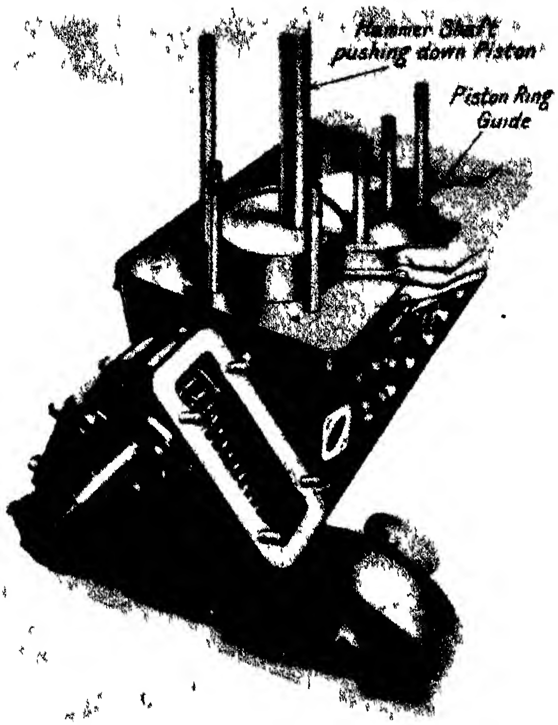


FIG 76 —Replacing the Pistons on A E C Engine

the engine should be cranked over by hand for several turns and any surplus oil wiped off the cylinder and piston tops.

Replacing Pistons in Reconditioned Cylinders

When cylinders are re-bored it is necessary to employ new pistons; the latter are usually made in standard oversizes so that the most suitable size can be selected, or the cylinders bored to suit the available oversize pistons.

When new liners are fitted to C.I. engines designed for this type of cylinder barrel, the old pistons can often be used again, provided that their ring grooves are not worn appreciably or the skirts scored in any way. It is possible in some cases to select liner sizes so that the pistons can be given a light skim for truing purposes before re-fitting; tungsten-carbide or diamond-tipped tools are recommended for the latter purpose.

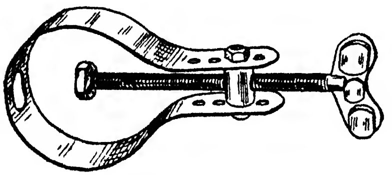


FIG. 78.—A useful Device for forcing Out Gudgeon Pins.

A Method of Piston Maintenance Economy

In one or two instances provision is made by the manufacturers of C.I. engines to use the pistons of one type of engine in the cylinders of a practically similar type after the cylinders have been re-bored. In such cases an engine having a nominal cylinder bore of, say, 100 mm. will be made in three very nearly similar sizes with bores of 99, 100 and 101 mm. or 99.5, 100 and 100.5 mm. When the cylinders of the two smaller size engines are re-bored the pistons of the two larger sizes are used, with or without a truing up, for these re-bored cylinders; this method results in an appreciable saving in maintenance costs.

Piston Skirt Clearances

After the engine has been in use for some appreciable time it is advisable to measure the clearances at different parts of the piston, between the latter and the cylinder, and to compare these clearances with the new values as given by the manufacturers.

With the aluminium alloy pistons now universally employed on high speed C.I. engines the skirt clearances depend upon the diameter of the piston and upon the particular design and alloy used.

As a general rule the clearances allowed for aluminium alloy pistons of the plain skirt type are ·0015 in. per in. diameter; thus a 4 in. diameter piston would have a skirt clearance of ·006 in.; in some cases, where five piston rings in all are used, rather greater clearances are often given. Thus the A.E.C. oil engine piston of 4·53 in. diameter has a (new) clearance of ·008 in.

The usual *piston ring land clearances* for a 4 in. piston are as follows, viz., Top, or First Land, ·020 in.; Second and Third Lands, ·014 in. and Fourth Land, ·006 in. These clearances increase slightly with the diameter, except in the case of the fourth land, the clearance of which is constant for pistons from 3 in. to 5 in. diameter. The other land clearances increase at the rate of about ·005 in. per inch of diameter, increase.

In the case of the Armstrong-Saurer aluminium pistons, the dimensions, when new, are:

On the second and third lands, 109·53 mm.
,, ,, lower 50 mm. of skirt, 109.78 mm.

The maximum clearances of the piston when in its cylinder sleeve at the above two places are, respectively, 0·54 mm. (or ·021 in) and 0·39 mm. (or ·016 in.).

In the case of the Cummins piston and connecting-rod assembly shown in Fig. 79, the piston is of a special alloy iron and carries four compression and one scraper ring, suitable oil drain holes being arranged for the latter.

The gudgeon pin is given a clearance of 0·0005 in. or until it can be pushed in with the fingers. After the lock screw is in place the pin should be able to turn with the piston.

The big-end bearing clearance is 0·0035 in. This clearance should be maintained at all times and care should be taken when tightening up the lock-nuts to obtain this clearance; *the castle nuts should not be backed* off to obtain the proper line for the split-pins. It will be observed that connecting-rod is drilled through its length to supply oil to the small-end bearing.

The side clearance of the big-end bearings is 0·008 to 0·010 in. The main bearing clearances are each 0·0035 in.

Piston Troubles

The following is a brief account of the principal piston troubles likely to occur in high speed C.I. engines:

(1) PISTON SLAP.—This is a regular mechanical noise caused by the piston rocking or moving from one side of the cylinder to the other. Excessive clearance is the usual cause.

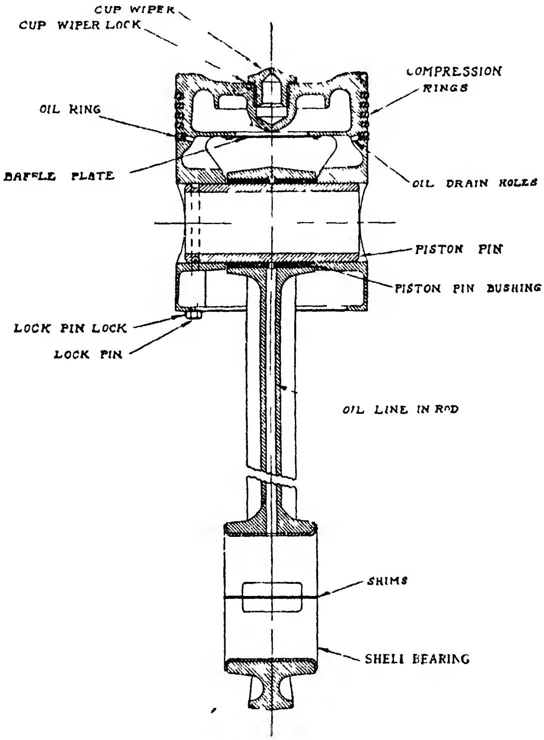


FIG. 79.—The Cummins Piston Assembly.

This may be due to faulty design in the case of aluminium alloy pistons or to excessive wear. In some designs of such pistons the excessive clearance is given to take into account the higher thermal expansion of aluminium over cast-iron. If, however, the former type is properly designed it can be given the same clearance as cast-iron.

In other cases the initial clearance, when the engine is cold, is taken up as the engine attains its proper working temperature; the piston slap then disappears.

Piston slap can be recognised by the method of listening with a stethoscope or rod, one end of which is held against the cylinder block—at different places—and the other to the ear.

(2) Seizing of Piston.—This may be due to several causes, including, (*a*) Lack of lubricating oil. (*b*) Lack of water in the cylinder jackets. (*c*) Too small a clearance between the piston and cylinder. (*d*) Dirt in the lubricating oil.

The results of seizing for cast-iron pistons are usually serious, for the cylinder walls are generally badly scored. With aluminium alloy pistons, however, the cylinder wall is seldom affected.

(3) Oil Pumping.—This expression is applied to the passage of oil past the piston, from the crankcase to the combustion chamber. If the piston or cylinder are worn oil pumping will occur. The result will be excessive oil consumption and more rapid carbon formation, with a smoky exhaust.

The piston rings are, however, the most frequent cause of oil pumping since their purpose is to seal the joint between the piston and the walls. In such cases the piston rings should be examined for wear in their grooves, excessive end clearance, and lack of elasticity or low ring pressure.

(4) Excessive Wear of Piston.—This may be due to the use of an unsuitable grade of lubricating oil, viz., one that is too "thin" at working temperature to maintain an effective oil film between the piston and cylinder walls. Dirty oil is another cause of excessive piston wear. Similarly, dusty air drawn in through the inlet valve for charging purposes will cause increased wear.

In both cases the *use of efficient filters for extracting the dirt* is strongly recommended.

We have already referred to the effect of failure of the oiling system but here may mention the fact that a partial starvation of oil to the cylinder walls, due either to inadequate supply or to scraper rings exerting excessive wall pressure, will also cause excessive wear, whilst promoting conditions favourable to seizure.

Piston Rings

As stated previously there are two kinds of piston ring fitted ; one for pressure maintenance and the other for keeping the oil consumption to a minimum whilst allowing adequate lubrication of the cylinder walls.

The compression rings are of the narrow type, and are made to give as uniform a radial pressure as possible. As turned and ground this pressure is seldom uniform so that the desired uniformity is obtained by "peening" or hammering the ring on the inside. This ensures that the rings shall have proper contact with the cylinder walls and will wear uniformly. The hammered type of piston ring can be identified, readily, from the peening hammer marks or "dots" inside the rings.

Piston rings are usually made of a high grade straight or alloy iron cast by the centrifugal process. The material for cast-iron piston rings is specified in the British Standard Piston Ring Specifications 5004 (Automobile) and 4.K.6. (Aircraft). The amount of combined carbon is between 0·45 and

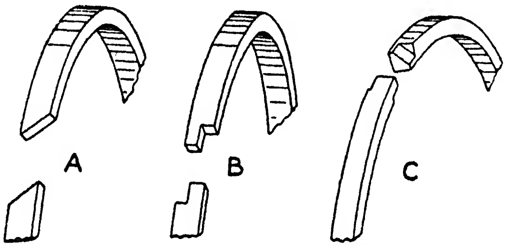


FIG. 80.—Types of Piston Ring.

0·80 per cent.; the total carbon, not more than 3.5 per cent., and sibion, between 1·8 and 2·3 per cent.

It is usual to make piston rings to Standard Specification dimensions, as regards *width, thickness* and clearances.

The British Piston Ring Company recommend as the best ring thickness value, *one-thirtieth* of the diameter and the usual tolerance plus ·008 in. with a free gap of three to four times the thickness. These dimensions will give a minimum pressure of about 9 lbs. per sq. in. for sand-cast rings and about 10½ lbs. per sq. in for centrifugally cast ones.

The narrow type of piston ring is now favoured in preference to the wide one as it usually reduces piston friction, is more flexible in regard to distortion of the cylinder, causes less wear in the groves (owing to the smaller inertia forces) and, if more of them are used than the wider rings, provide a, bet- ıne baffle against gas leakage. of America,

There are three principal types of piston ring the Angle, Step and Step Seal Joint. These are ill Fig. 80, at *A*, *B* and *C*, respectively.

The Angle type of ring is made with a 45° angle, and is designated *Right* or *Left*-handed according to which way the joint slopes (Fig. 81).

When fitting three angle rings, the centre one should, preferably, be of a different " hand " to the two outer ones;

FIG 81.—Types of Piston Ring Joints.

this gives a " crooked " instead of a " straight " leakage path, should the three ring joints move into line.

The angle type of ring is generally employed for pistons having a larger number of relatively narrow rings.

The Step type of ring is supposed to provide a greater barrier to leakage of the gases past the ring, since the faces of the step are kept in contact, so that there is no free path as with the angle type; it must not be forgotten, however, that the gases can escape round the back of the ring and out past the lower half-slot; the leakage path in this case is a longer one than for the angle type.

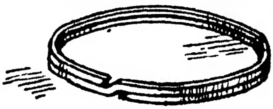
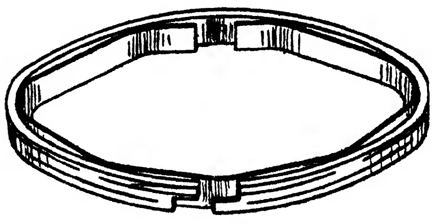


FIG. 82.
The Clupet Compound Piston Ring.

One disadvantage of the step type of ring is the risk of damage to the smaller stepped end when fitting or removing it from the piston.

The Step Seal ring is a one-piece ring in which one leg of the joint is triangular in section and the other pentagonal. The ring should be installed with the small triangular part of the joint away from the pressure, to obviate pressure loss through the joint. This type gives a very good joint seal and is considered one of the most efficient rings to prevent



Pıston . .
FIG. 83.
As statec lworthy Spring Piston Ring.

fitted; one t' of the gases; its use, however, is generally
the oil consu the larger sizes of engine.
lubrication of the ty of ring used in new and also reconditioned

engines is the Clupet (Fig. 82). This provides a long leakage path for the gases. It is, however, rather more difficult to fit than the plain pattern and is more liable, in certain types of engines, to gum up. It is recommended for use in worn engines that are to be run over a longer period before reboring.

The Wellworthy ring (Fig. 83) is particularly useful for use in slightly worn cylinders. The inner steel expansion ring gives a uniform pressure enabling the ring to adapt itself to some extent to cylinder irregularities.

Ring Clearances

Since the parallel, or concentric pattern of ring is now favoured instead of the eccentric type, the following remarks are intended to apply primarily to the former.

The ring gap, when the piston ring is in the working part of the cylinder, must be sufficient to allow for expansion of the ring, but not enough to permit blow-by. In this connection the practice of the British Piston Ring Company is to employ *a standard tolerance* for *clearance at the joints* when the ring is placed in a gauge of nominal diameter, of ·005 in. on rings up to 6 in. diameter and for larger rings of ·007 to ·010 in. *The actual clearance* at the joint when fitted in the cylinder is ·002 in. to ·003 in. per inch diameter, for water-cooled engines; for air-cooled types it is ·004 to ·005 in.

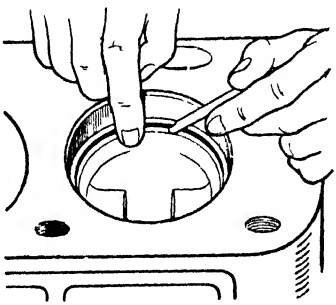


FIG. 84.—Method of measuring Piston Ring Gap Clearance.

It is best to err on the side of giving too large, rather than too small a gap, since in the former case the only ill-effect will be a very slight increase in oil consumption. If, on the other hand, the gap is too small, the ring, owing to its expansion, may jamb and cause excessive friction and wear of the cylinder or it may eventually fracture.

In regard to gap clearances, the following table gives the values recommended by the Aluminium Company of America, in connection with aluminium alloy pistons:

Cylinder Diameter in Inches.	Ring Gap in Inches. Step Cut.	Ring Gap in Inches. 45° Cut.
3·00	0·007	0·005
3·50	0·009	0·007
4·00	0·012	0·009
4·50	0·015	0·011
5·00	0·019	0·014

The gap should always be measured with the ring in the *least worn* part of the cylinder, namely, at the bottom end.

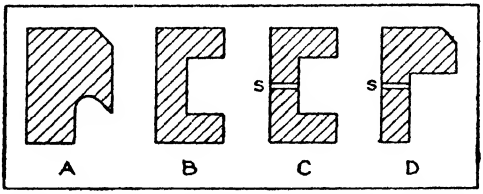


FIG. 85.—Sections of typical Oil Scraper Rings.

The side clearance of the ring in the piston groove is ·0015 in. on rings up to 6 in. diameter and ·002 in. for diameters of over 6 in. to 12 in. in the case of *cast-iron* pistons ; for aluminium alloy pistons these clearances are, respectively, ·002 to ·003 and ·003 to ·004 in.

The fit of a ring in its groove is often considered correct when the ring will just drop to the bottom of its groove when the piston is held horizontal.

The practice in the case of the A.E.C. oil engines is to allow side clearances of ·003 to ·0045 in. The joint clearances are ·008 in. In this case the aluminium alloy pistons have a diameter of about 4·6 in.

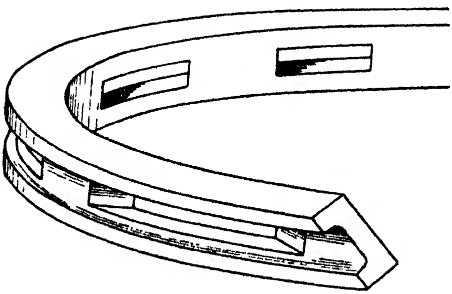


FIG. 88.—A Slotted Type of Piston Ring, with Angle Joint.

Messrs. Leyland recommend a side clearance in the piston grooves of ·003 in. to ·005 in. The ring gap clearance is ·007 in. to ·009 in. when new.

Scraper or Oil Control Rings

As previously mentioned, the purpose of these rings is to

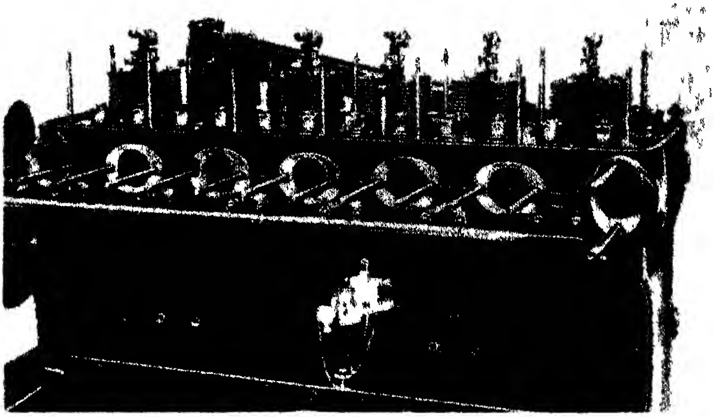


FIG. 86.—The Armstrong Saurer Dual Turbulence Cylinder Head. This has four Valves per Cylinder.

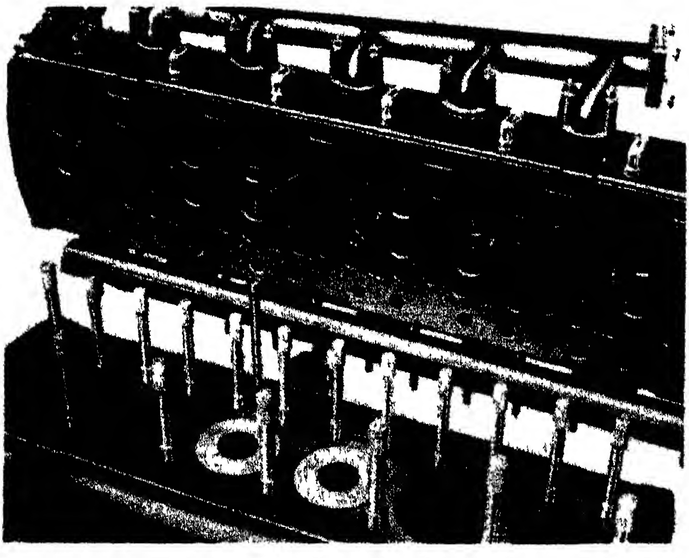


FIG. 87.—Showing Valves in Cylinder Head and two Cavity Pistons of Armstrong Saurer Dual Turbulence Engine.

[To face page 98

minimise oil consumption by scraping off from the cylinder walls the surplus oil. It also reduces the formation of carbon in the cylinder head.

The principle of the scraper ring is to ride over the oil layer on the cylinder wall during the upward piston stroke, but to scrape off any surplus oil, whilst leaving a sufficient film for lubrication, during the downward stroke. *The oil scraping edge is, therefore, the lower one on scraper rings.*

To obtain this scraping action, the outer edges of the rings are usually made narrower than standard pressure rings, so as to obtain a higher pressure per square inch against the cylinder walls; in this case, therefore, the same expansion

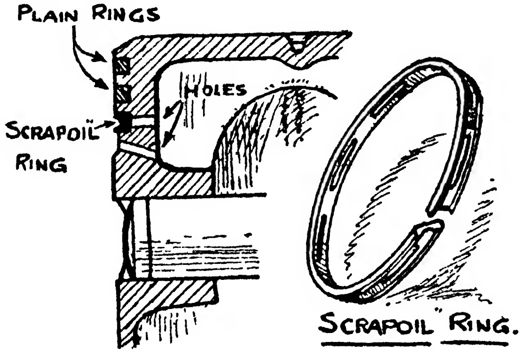


FIG. 89.
Method of using Oil Scraper, or Control Ring.

force—tending to press the ring against the cylinder—acts on a smaller area.

Fig. 85[1] shows four typical designs of scraper ring. Those shown at *A* and *B* obtain their increased wall pressure effect by the turning of a bevel or step, so as to reduce the width of the bearing surface on the cylinder wall; if the width is reduced to one-half the pressure per square inch will be doubled.

It is important to note, with all scraper rings, that a free passage must be provided for the surplus oil to be removed; this is effected by means of small holes drilled through the wall of the piston opposite or below the ring grooves.

When scraper rings have to be fitted, or replaced it is important to *clean out any carbon* that may have formed in the oil return holes in the ring grooves.

Diagram C, Fig. 85, shows the ventilated, or slotted type

[1] British Piston Ring Co., Ltd.

of ring, which has a series of slots S cut right through, at the bottom of a central groove turned in the ring. The slots allow the oil to pass through and thence to the inside of the piston, through the holes drilled for this purpose. This type requires a wider piston slot than the other two shown at A and B. As it usually exerts little more pressure than an ordinary compression ring it has a longer life than the high pressure type scraper ring.

The drilled wide slot type of ring shown at D (Fig. 85) gives a bigger oil reservoir and a stronger construction, since the holes cause less weakening than the slots in the example shown at C (Fig. 85).

Piston Ring Maintenance

When the pistons have been removed from the engine, the rings themselves should be taken off the piston. It is best to use three strips of tin or bronze for this purpose; special piston ring opening and removing tools are, however, now available. (Fig. 90.)

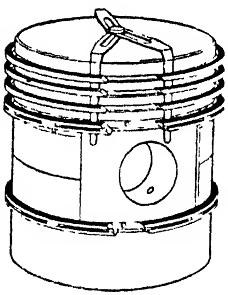


FIG. 90.—Method of removing, or replacing Piston Rings.

It is inadvisable to attempt to remove the rings by the fingers alone as this procedure often results in fractures of the rings.

Having removed the rings, they should be cleaned, all carbon on the inside surface being scraped off. The rings should be tried, in turn, in the corresponding slots for wear. If the clearance between the ring and slot exceeds about ·010 in. for the top ring and ·008 in. for the lower rings, the ring should be replaced with a new one.

If the slot clearances are satisfactory the rings should be tested for gap clearances by placing them, in turn, in the cylinder barrel—assuming the latter not to have worn appreciably. The gap clearances should be measured with a feeler gauge. If the clearances exceed ·020 to ·025 in. for a 4 in. piston, the rings should be replaced with new ones.

The latter should have the side and gap clearances as previously mentioned.

It will be necessary to clean up the piston slots by turning down the unworn ridges which may be found in the piston slot (Fig. 91). When ordering new piston rings the diameter of the ring should be measured with the ring compressed to give the existing slot clearance for the diameter of cylinder. The Brico measuring devices shown in Figs. 92 and 93 are very convenient for this purpose. In the former case the ring is placed in the Bricometer so that the space at the joint is the same as when the ring is in the working part of the cylinder barrel; a feeler gauge is used to check this clearance; the nearest next size larger should then be ordered. The diametrical gauge shown in Fig. 93 is rather more accurate; it is used by inserting the ring in the steel tape which is pulled taut by turning the pointer. The end of the latter shows the required diameter on a scale.

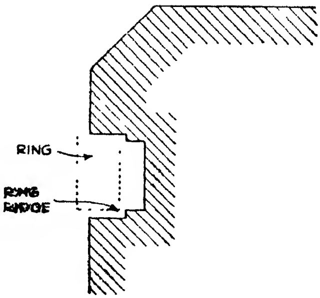


FIG. 91.
Showing (exaggerated) the wear in Piston Ring Slots.

When fitting new piston rings to C.I. engines the same methods are employed as for petrol engines.

There is one important point to remember, namely, that it is inadvisable to remove more than about $\frac{1}{32}$ in. off the sides of the joint, with well-made piston rings, otherwise, when fitted in the cylinder, they will tend to become elliptical, as shown in Fig. 94.

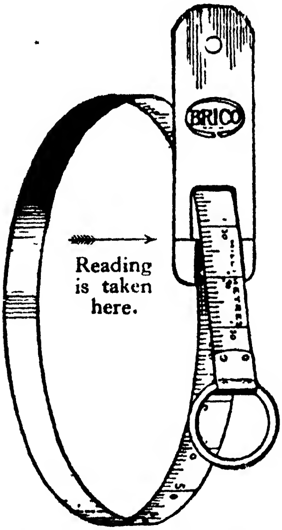


FIG. 92.—The Brico Ring Measuring Device.

The sides of the ring slot, or ends, can be filed down when it is necessary, slightly, to reduce their diameter. Where routine fitting of piston rings is employed—as with vehicle fleets—it is best to use a joint grinding machine or fitting, as this gives perfectly parallel joints for angle rings. Fig. 95 shows the Brico machine that has been designed for this purpose.

When replacing piston rings, it is advisable to use a ring assembly device, such as the one illustrated in Fig. 90. When the piston is put back into its cylinder, the slots of the rings should be spaced so as to afford the longest possible leakage path.

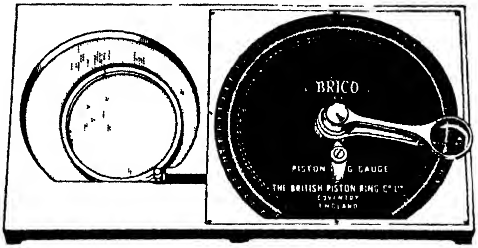


FIG. 93 —Another type of Ring Measuring Gauge.

Piston Ring Troubles

From the preceding remarks the more common causes of piston ring troubles will now be fairly evident. These may be summarized, briefly, as follows .

(1) *Excessive Gap Clearance.*—This results in loss of gas pressure.

(2) *Too small Gap Clearance.*—This causes excessive wall friction, oil scraping and frequent fracture of the ring itself, with risk of scoring the cylinder walls.

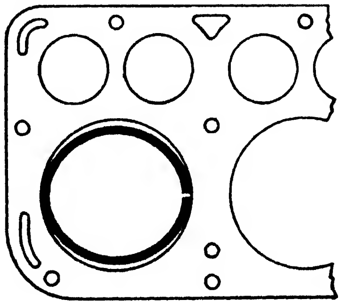


FIG. 94.
Illustrating Effect of Filing too much away from Ends of Ring.

(3) *Blow-by.*—Due to unequal bearing of ring on cylinder walls owing to faulty design or excessive wear.
If the ring is not round when in position in the cylinder, or its periphery is not square with the side faces, or if the side faces are not flat, blow-by and excessive oil consumption will be caused.

(4) *Gummed-up Rings.*—Due to carbon formation behind rings in their slots and caused by oil leakage past piston, the use of unsuitable oil or may result from overheated piston.

(5) *Rings Loose in Slots.*—This causes loss of pressure and noisy operation.

(6) *Piston Ring Click.*—Often caused by fitting the rings too tightly in piston grooves. Also by fitting new rings in worn piston grooves without turning away the

shoulder (Fig. 91); the rings then tend to become wedged in the slots.

(7) *Ring Breakage.*—Caused by faulty metal of ring, or excessive stretching of ring over piston to get into piston slots.

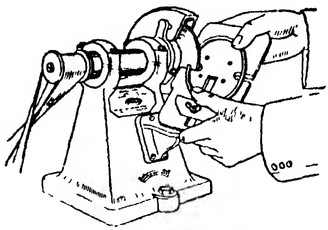


Fig. 95.—The Brico Piston Ring End Grinder.

Insufficient tension in the rings, also, will often cause the noise known as ring click, since this allows pressure to get between the ring and the cylinder wall, thus compressing the ring. The subsequent expansion of the ring causes a loud click.

If the rings are fitted with the correct clearance in the top of the cylinder where wear is greater, they will tend to produce clicks when in the lowest position.

Ring click may also be caused when new pistons or connecting-rods are fitted, due to the top piston ring projecting above the worn ridge near the top of the cylinder barrel.

The usual cure for ring click is to give more clearance to the rings in their grooves and with sufficient end clearance to avoid any possibility of the ends butting.

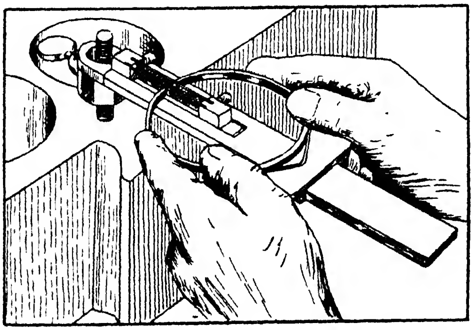


Fig. 96.—A Useful Device for Filing the Ends of Piston Rings.

Building Up Worn Engine Parts by Electrodeposition

An important aid in the reconditioning of oil engines is that of metal deposition by electrolytic methods, whereby worn parts can be built up and then machined or ground to their original or new dimensions.

The metals that have been used for this purpose include pure iron, nickel and chromium; the two latter metals are the more widely used ones.

Nickel can be deposited on steel parts in thicknesses up to at least half an inch. It is usually employed on parts, such as water pump impellers which are subject to corrosion. On the other hand the housings for ball-races which have become worn, small ends of connecting rods, valve guides and similar parts can also be reconditioned by nickel deposition.

Nickel as deposited by the Fescol process can be used for shafts running in bearings—similar to crankshafts and camshafts, but a slightly increased clearance should be used than for steel shafts in such cases. The nickel thus deposited is moderately hard, namely, about 300 Brinell, and it has a low coefficient of friction; moreover, the nickel is absolutely inter-

FIG. 97.—Example of Camshaft, showing surfaces at C which can be built up by the Chromium Plating Method.

locked with the steel base-metal so that it will not separate, even after severe bending has occurred.

Motor vehicle engine crankshafts which have worn oval on the crank pins and main journals can be reconditioned by nickel deposition and re-grinding. The average wear of such surfaces is at the rate of about ·0015 to ·002 in. per 15,000 miles. Cast iron, alloy iron or steel pistons which have become worn can be reconditioned by means of a layer of nickel.

The ball-races of the camshaft or timing gears that have worn loose in their bearings can also be reconditioned in a similar manner.

Cylinder walls that have become scored owing to loose gudgeon pins can be filled in with electrolytically deposited nickel.

In all cases where engine parts are subjected to severe wear or heavy working pressures, it is advisable in oil engine practice to employ chromium deposition for building up these when worn appreciably.

Chromium is considerably harder than nickel (or heat-treated alloy steels) so that it offers a correspondingly greater resistance to abrasive or wearing action; moreover, it is very resistant to most forms of chemical corrosion ; for these reasons chromium is now much used for coating the wearing surfaces of engineers' gauges and punching dies. It is, however, more expensive than nickel.

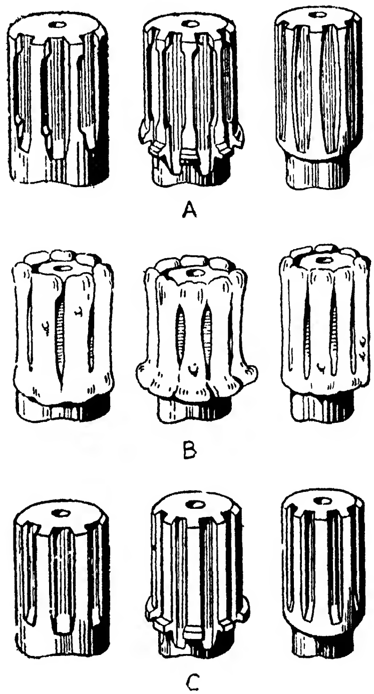


FIG. 98.—Castellated Shafts built up by Electrodeposition with nickel. A.—Worn Shafts. B.—As Nickel Deposited. C.—After Final Machining.

The parts that are subjected to severe wearing action in oil engines include the gudgeon pins, valve ends, rocker arm bearings and contact surfaces, push-rod ends, tappets, cams on the camshaft and the crank pins and main journals.

All of these parts can be given a coating of chromium of about ·010 to ·015 in. thickness so that they will offer a high resistance to wearing action ; the actual thickness of the chromium layer after grinding need not be more than a few thousandths of an inch. It is claimed that chromium plated gudgeon pins, camshafts and crankshafts have from 5 to 10 times the wear resistance of hardened alloy steel ones.

In regard to cylinder bores, reference is made on p. 83 to the Listard chromium plating process.

CHAPTER VI

THE VALVES AND VALVE SEATINGS

THE inlet and exhaust valves of high speed C.I. engines normally operate at rather lower temperatures than in the case of high speed petrol engines; moreover, the working speeds are lower in the former case so that there is more time available for getting rid of the heat.

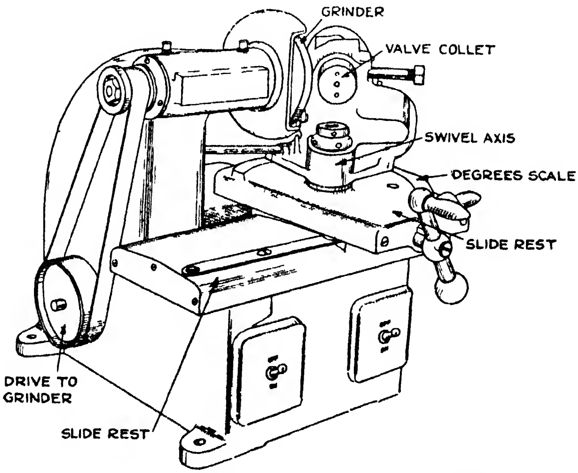


FIG. 99.—Electric Motor type Valve Truing Machine.

For this reason the valves do not require quite the same attention as for petrol engines. It is thus becoming the practice to recondition the valves about once every 15,000 to 20,000 miles of road service.

The valves themselves generally require re-grinding with a suitable abrasive paste in the usual manner. If the valve faces are found to be pitted or scored they should be trued up in the lathe or, where a number of such valves has to be reconditioned, in a valve face-grinding machine of the Black and Decker type; in this case the valve stem is held in a collet or chuck at its correct angle to the grinding face of an abrasive disc which is rotated at a fairly high speed to give the correct cutting velocity. The valve is rotated on its axis, slowly, whilst the face is ground. A note should be made of the *correct valve seating angle* when using a lathe or valve-facing machine, as this angle often varies from the value used in petrol engine practice. Thus, the Leyland and six-cylinder A.E.C. oil engines use a 30″ valve face angle. The four-cylinder A.E.C. engine valves have 45″ angle. The best method for setting the lathe slide-rest or facing wheel is to use a new valve in the chuck, in order to get the correct angle, afterwards replacing it with the one to be ground.

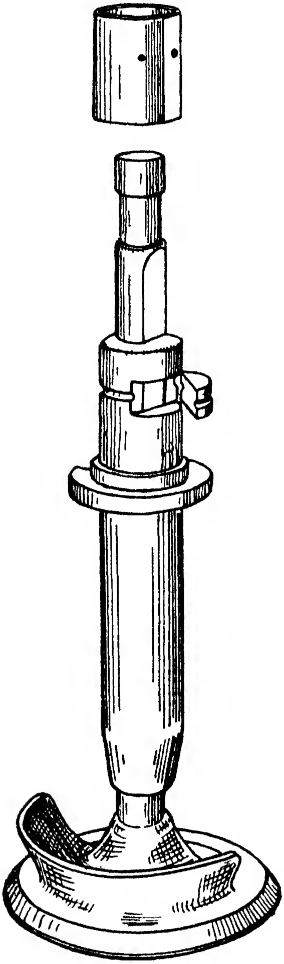


FIG. 100.
Leyland Engine Masked Valve.

The valve stems should be tested for excessive wear, after removal of the valve springs, by inserting them in their guides, or by measurement of the valve stems and guide holes with micrometers. After a long period of service it will be found necessary to renew both the valves and also their guides. Advantage should be taken of such an opportunity to fit valve guides made of hardened alloy cast-iron, such as centrifugally cast Bricromium iron.[1] The valve guides can be made from ground bar on automatic machines, the bar being fed through a collet ; if the guide has a large flange it can often be re-designed to be made from smaller diameter stock. If, however, valve guide castings are required these should be made from metal patterns to ensure accurate castings with the minimum machining allowance.

Masked Valves

In certain designs of turbulent head engine the inlet valves are provided with deflectors or masks under their heads, in

[1] The British Piston Ring Co., Ltd., Coventry.

order to divert the incoming air for the purpose of imparting a directional movement. In some cases this is a spiral or circular movement which persists throughout the induction and compression strokes. Typical examples of engines having masked valves are the Leyland cavity piston and the Saurer " dual turbulence " engine which also has a cavity piston.

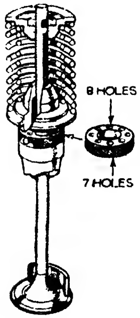


FIG. 101.

When fitting new inlet guides in engines having *masked valves*, such as the Leyland (Fig. 100), care must be taken to locate these properly. In the latter example, location is effected by means of pegs in the cylinder head and slots in the valve guide flanges. The inlet valves are keyed in their guides and cannot be withdrawn until their Circlips are removed. The valve keys must, of course, be replaced after valve grinding.

The Armstrong Saurer engine (Fig. 87) has two masked inlet valves and two plain exhaust valves; all are of the overhead pattern. The position of the mask on the inlet valve is shown in Fig. 101. The method of ensuring the correct location of the mask is also shown in the same diagram, which refers to the earlier engines having a vernier adjustment for the mask; the valve guides are marked to show the correct positions of the shrouds, by means of two chisel marks on the guide, directly opposite the slot in the lower spring seat.

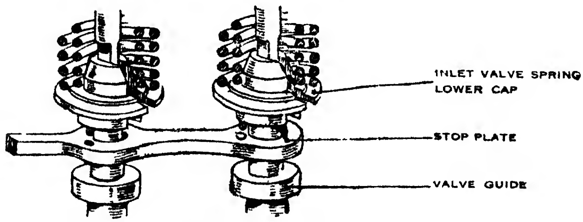


FIG. 102.—Locating the Masks on Inlet Valves.

On the later engines the vernier method is dispensed with and a special positioning plate (Fig. 102) is employed, so that the two inlet valves are located correctly at the same time. Each valve stem has a positioning flat machined on it; this flat also serves as an oil passage for the oil collecting on the top spring seat, so that the oil can run down the valve stem to lubricate it.

Straightening Valves

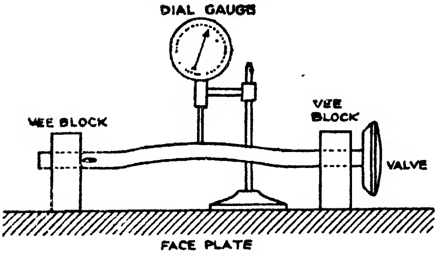


FIG. 102A.
Testing Valve Stem in Vee Blocks, using Dial Gauge to check straightness.

Before grinding-in a valve it is important to test it for stem straightness. This can either be done by centring in a lathe or by means of special collets holding the stem end. Any want of straightness can be rectified in a hand-press or by tapping with a hammer; the valve is held in a pair of Vee-blocks for this purpose (Fig. 103).

Valve Seatings

It is seldom that the valve seatings require special attention, although instances occasionally occur—as previously mentioned—where valve seatings have cracked or worn excessively owing to the use of a softer grade of cylinder iron and to high valve spring compression values. In such cases it is necessary to rebuild the seating with alloy iron by means of the welding process; the oxy-acetylene method with special alloy feeder rods and fluxes is generally used. The cylinder heads should be pre-heated for this purpose and annealed afterwards, in order to avoid any internal stress effects due to differential cooling.

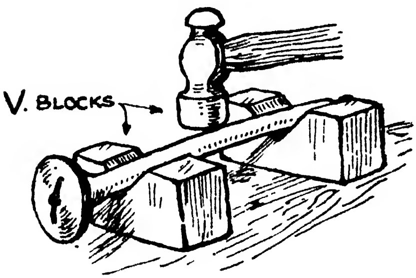


FIG. 103.
Straightening Bent Valve Stem.

Special valve seating cutters are available for facing, removing pockets and similar seating machining operations, as for petrol engine practice.

The most convenient type of tool is the multi-toothed milling cutter one; this can be operated by hand or by an electric motor provided with a suitable reduction gear.

For re-facing stellited valve seatings a special conical stone of suitable grade is employed.

Valve Tools

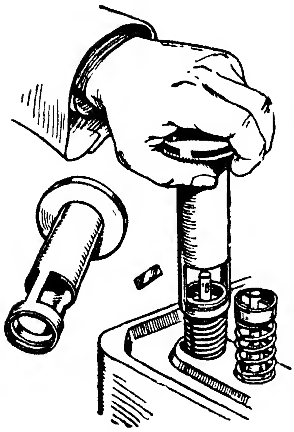


FIG. 104.—Overhead Valve Spring Compressing Tool.

The tools required for removing or re-grinding overhead valves are very simple and can readily be made in the workshop.

Fig. 104 shows a tubular type of tool for compressing the valve springs, in order to remove the cotter and valve collar.

Fig. 105 illustrates a simple Tee-head clamp for re-grinding overhead valves on to their seatings.

The Aldon pneumatic valve grinder shown in Fig. 106, operates off a compressed air supply at 50 to 100 lbs. per sq. in. It has a spindle, with suitable keys for the valve heads, which is given a rapid reciprocating movement, variable as required from 600 to 6,000 strokes per minute. As the spindle oscillates it automatically *moves forward* one-sixth of a revolution per stroke so that it never stops twice in the same place and, therefore, does not tend to form valleys or high spots on the valve seating.

The tool in question weighs 28 ozs., has a trigger control and also a knurled screw adjustment for the speed of operation. It is suitable for both ordinary cast iron and hard alloy seatings.

Correcting Wide Valve Seatings

The effect of long usage and numerous valve re-grindings is to widen the face of the valve seating so that a greater resistance is offered to the gas flow.

When this occurs the valve face (Fig. 107) should be reduced in effective width by means of special "narrowing cutters." The 15° and 75° angle milling cutters pattern shown in Fig. 108 are mostly used for this purpose. Referring to

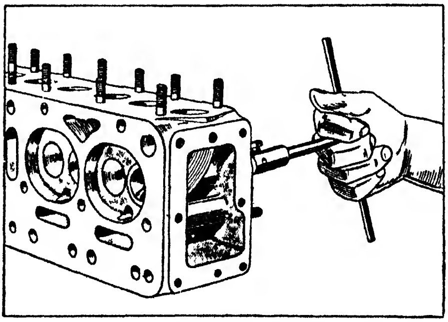


FIG. 105.—Tool for re-grinding Valves.

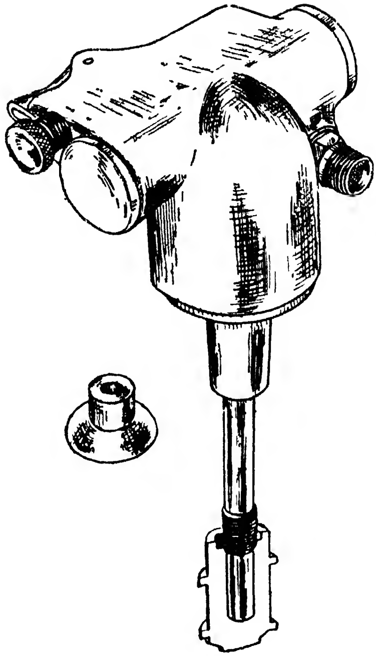


Fig. 106.—The Aldon Pneumatic Valve Grinder.

Fig. 107, the 15° cutter removes the surplus metal at *ACA*, whilst the 75° cutter machines away the lower part at *BDB*, thus leaving a seating for the valve of the reduced width shown at *CD*.

If the valve seating is of the "pocketed" type it will be necessary to use a conical or a flat-faced cutter to remove the surplus metal *ABC* at the top of the seating (Fig. 109).

In all cases when using cutters for re-conditioning valve seatings, they should be used with a proper pilot engaging in the valve guide hole, to ensure concentricity of the re-cut surfaces. Special expanding pilots are made for this purpose by Van Norman.[1]

Stellited Valve Seatings

In order to prolong considerably the life of the valve seatings of high speed C.I. engines, between overhauls, it is becoming the practice to employ inserted valverings, or seats, made of special centrifugally cast, heat-treated alloy cast-irons

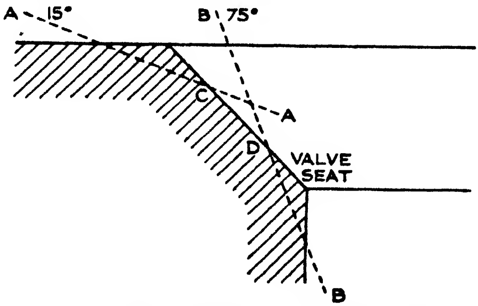


Fig. 107.—Illustrating Valve Seat Operations

[1] E. P. Barrus Ltd., London.

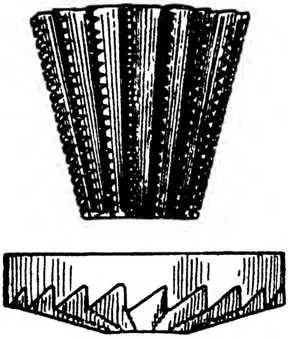


Fig. 108.
Valve Seating Cutters.
(Above) 75° Cutter.
(Below) 15° Cutter.

such as Bricromium, Chromidium, etc. An even harder material for this purpose is the machine-tool cutting alloy known as Stellite. This is a synthetic material consisting chiefly of cobalt, chromium and molybdenum, made by a high temperature electric fusion process. It has a much greater hardness than any tool steel and will retain its cutting edge even at a red heat.

Valve seatings made of Stellite have shown mileages of over 150,000 before re-grinding became necessary.

The usual form of valve seating for Stelliting is shown in Fig. 113, the seat being turned to shape in good quality medium carbon steel. The small square section groove shown receives a square section spring steel ring which is split for assembly in the groove.

The ring is a press fit in a corresponding recess machined over the old valve seat, the recess having a shallow square-edged groove to match or line up with the groove in the ring. Hence, on inserting the ring with the spring band in place there is an opening into which the band may expand and lock

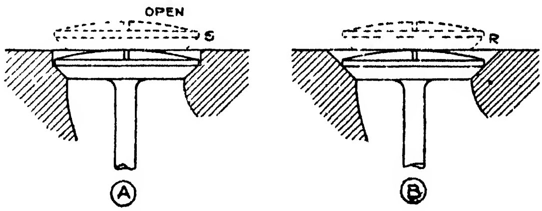


Fig. 109.—Showing (A) Pocketed Valve. (B) Surplus metal removed from Seating.

the ring in position, the band resting half in the ring and half in the block metal.

The rings are prepared by a series of turning operations, a circular groove being finally cut in the part that forms the valve seat. Following this the rings are placed on an adapter, and a layer of Stellite is deposited in the circular groove by the aid of an oxy-acetylene blowpipe. The Stellite is No.

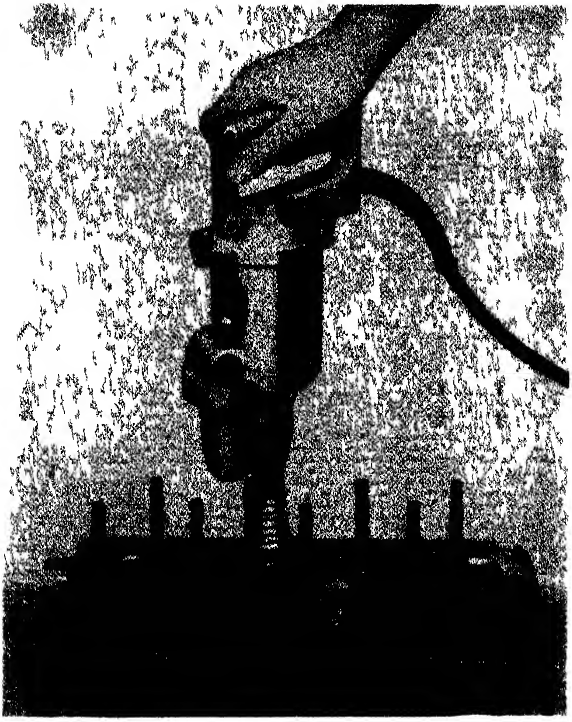


FIG. 111.—Special Valve Seat Abrasive Stone Cutter used with Portable Electric Drill, for Hard Valve Seatings.

[*To face page* 113.

10 grade, supplied by the Delora Smelting & Refining Co. Ltd., Birmingham, in the form of ground rods, and is easily worked.

The depositing is done by using an oxy-acetylene flame in which there is an excess of acetylene. The excess of acetylene

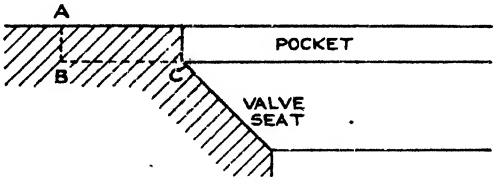


FIG. 110.—Showing Alternative Method of re-conditioning Valve Pocket.

also serves the purpose of protecting the Stellite from oxidation and change in composition during the deposition, and as Stellite has not the same susceptibility to carburization as steel no embrittlement is caused. Apart from its hard-wearing properties the application of Stellite is particularly appropriate in the case of valve seats, especially for exhaust valves which frequently work at a red heat, the latter being a condition which leaves the hardness of Stellite quite unaffected.

After forming the deposit the seat is allowed to cool, and is then finished by a series of grinding operations. The processes include shaping the Stellite deposit, for which a coarse grit and soft bond wheel such as Norton 60 K is used. The seat is finally trued by grinding in position by means of a portable electric grinder having a special grinding wheel located by means of an expanding mandrel placed in the valve guide. The tungsten carbide-tipped cutter is also used for truing stellited valve seats.

The makers of the A.E.C. oil engines now fit stellited exhaust valve seatings when these are specified; they are of the screwed-in pattern. The Leyland oil engines also have stellite valve seatings.

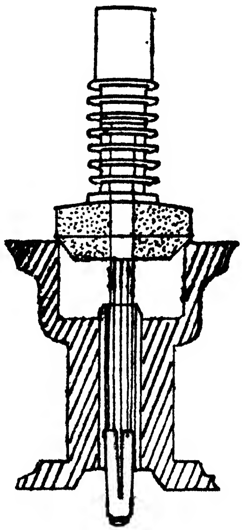


FIG. 112.—Valve Seating Tool with Conical Stone Grinder and Pilot in Valve Guide.

In the latter case, when re-facing of these seatings becomes necessary a special cone-shaped carborundum stone, ground to 30° and located by a stem in the valve guide is used. The stone is rotated at a high speed by means of an electric drill; afterwards the valve can be ground in, using carborundum paste, in the usual way.

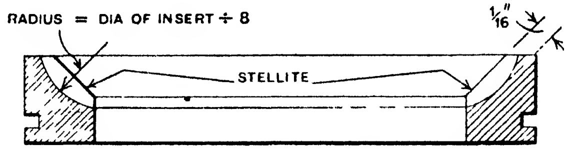


FIG. 113.—A Stellite Valve Seating Insert.

Stellited Centrilock Inserts

The Centrilock [1] valve seat insert belongs to the Stellited steel class. The principle of the design used is shown in Fig. 115.

The seat is finished externally in two diameters, the recess in the block being similarly stepped. When the seat is pressed into place its lower (larger) diameter is compressed as it passes through the upper part of the recess, and on reaching the lower and larger part the seat springs into position as a result of its elastic recovery. The relative sizes of the seat diameters, and those of the recess, are so arranged as to provide the necessary interference fit when the seat is in position.

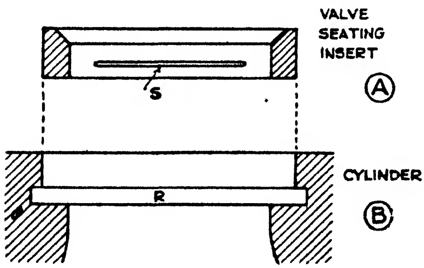


FIG. 114.
Wellworthy Valve Seating Insert.

The valve inserts are supplied ready for fitting with the mitre incorporated, and require, after insertion, only a final grinding operation, with an eccentric valve seat grinder.

The fitting of these inserts involves three considerations (Fig. 115), viz. (1) The port diameter *B*. (2) Width available for insert, *B* and (3) Depth available, *C*.

The manufacturers stock a large number of valve inserts of different sizes, the letters given in Fig. 115 (*A*) referring to

[1] Sheepbridge Stokes Co. Ltd., Chesterfield.

dimensions in the makers tables of insert sizes. The limits given for the two diameters *A* of the recess are identical for all sizes. The dimension *D* is $\frac{3}{32}$ in. and is the same for all seats.

Fig. 115 (*B*) shows the insert dimensions; the sizes of these being selected so as to give the necessary plus allowance of dimension *A* for the desired interference fit in the cylinder recess.

INSERT DIMENSIONS.

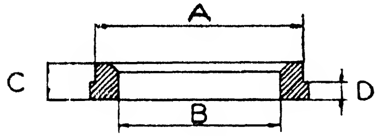


FIG. 115A.

RECESSING DIMENSIONS.

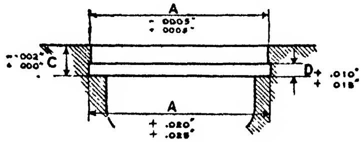


FIG. 115B.

Other Valve Inserts

Valve seatings are also made in aluminium-bronze (for aero. engine use), in copper-tungsten alloy, nickel and nickel-chrome cast-iron. High speed steel has been found to give good results also as it has a low expansion coefficient and good heat conductivity.

Various methods have been suggested or tried for holding these seatings in position. Of these, the keyed or sprung-ring method appears to be the most favoured.

Satisfactory results have also been obtained by a somewhat similar method of producing an interference shrinkage fit to that used for cylinder liners, viz., by immersing the valve seating in liquid oxygen before inserting into the cylinder block.

Liquid air is also used for shrinking valve inserts, a typical instance being that of Ford Vee-Eight valve inserts, which are first placed in a reservoir cooled by liquid air at minus 310° F. for 15 mins. They are then inserted, automatically, into the cylinder block recesses using hydraulic pressure followed by a final hammer blow of 40 lbs.

The rings which are about 1½ ins. diameter, are contracted by ·009 inch before insertion. The subsequent expansion to room temperature affords a very tight fit.

The method used in the case of the Wellworthy valve seatings is illustrated in Fig. 116. In this instance the valve seating to be inserted is provided with a pair of slots *S*, near its lower face; these slots are not horizontally along the periphery of

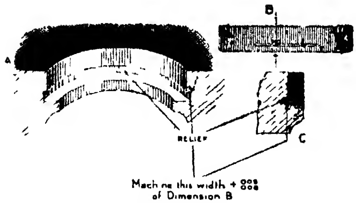


FIG. 116.
Illustrating method of fitting Wellworthy Valve Seat Insert.
" B " denotes side slit in ring.
" C " section of the ring in place.

the insert, and a recess *R*, corresponding in dimension to the area below the slots is machined in the valve pocket. A thin steel strip is inserted in each slot to obviate the possibility of damage during fitment of the insert into the recess. The interference fit of the insert is only sufficient to ensure the complete contact necessary for heat conduction, but the slotting, by giving a certain amount of flexibility, facilitates fitting, and when the portion of the insert below the slot reaches its corresponding recess, the release of pressure causes it to spring into an aperture and become firmly locked.

When considering the matter of fitting valve inserts, special attention should be given to the method of holding these in position, since cases have occurred of these inserts working loose.

The methods previously described—in particular those employing spring rings or slotted seatings—have proved satisfactory in practice.

Valve Insert Tools

The fitting of hard valve insert rings into cylinder blocks is now a recognised reconditioning process for engines having badly worn valve seatings. In such cases the old seatings are bored out with special cutters and the new insert seatings pressed into position.

There are several different makes of valve re-seating tools on the market, for fitting valve inserts in cylinder blocks *in situ* or after engine removal to the bench or stand ; of these the Boneham and Turner (Fig. 117) and Buma are, perhaps, the best known.

The former tool is a combination seating boring tool and ring press. It has a slotted bar for clamping to the cylinder block and a handle-operated multiple-tooth cutter with fine screw-thread feed (applied by another handle). The exact depth of cut is first set by using the new insert ring as a depth gauge. Afterwards, when the cutter has bored down to the required depth, the feed stops automatically.

The cutter is then removed and the tool reassembled with the press piece in place of the cutter. The valve insert is then placed in position and the same screw feed is employed to force it into the recess bored in the cylinder block.

The Buma tool operates on a similar principle but has a separate bracket and press for valve ring insertion.

In each case the valve guide is used for locating the cutter accurately, so that the new seating will be truly concentric with it.

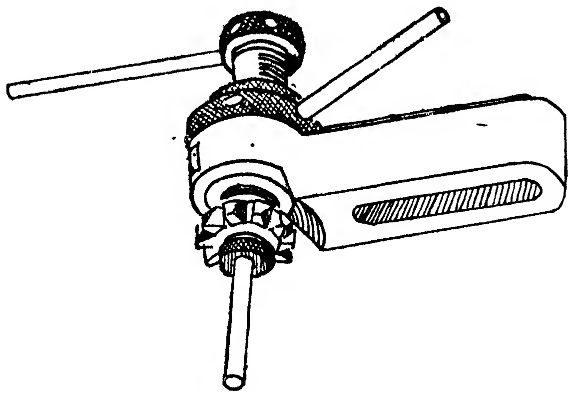


FIG. 117.—The B. and T. Valve Insert Tool.

Valve Clearances

Since practically all of the modern high speed C.I. engines employ overhead valves, the stem clearances of the latter are of the same order as those for petrol engines of the overhead valve type.

The following are some typical valve clearances for certain commercial vehicle oil engines :

Make.	Valve Stem Clearances (Inches). Engine Hot.	
	Inlet.	Exhaust.
A.E.C. four- and six-cylinder engines	·008 to ·010	·008 to ·010
Leyland cavity piston engines	·008	·010
Leyland spherical ante-chamber engines	·020	·020
Armstrong Saurer (Dual Turbulence)	·006	·008
Crossley four- and six-cylinder engines	·020	·020
Tangye VC2 to 6 (Comet Head)	·006	·006

It is necessary to check the valve clearances at regular intervals, in order to maintain the running efficiency of the engine. Whilst it is advisable to check these clearances every 1,500 miles or so, they should certainly be attended to every 2,000 to 3,000 miles as a regular routine procedure.

Valve Timing

The operator is seldom concerned with the matter of valve-timing except when the engine is completely dismantled for a thorough overhaul. Before the timing gears are removed it is advisable to examine the flywheel for timing marks on its periphery, or, where timing gear-wheels are used, the teeth of these wheels for meshing marks. It is the common practice of British manufacturers to mark the fly-wheel rim, to facilitate valve re-timing (Fig. 118).

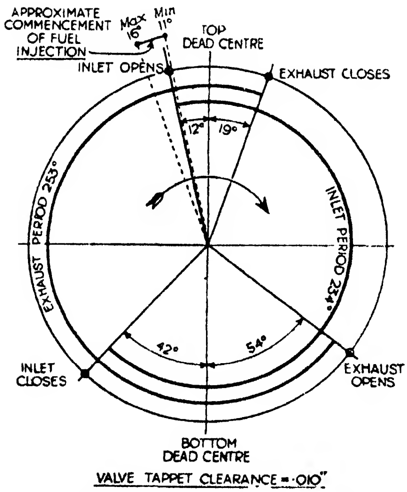


FIG. 120.—Valve Timing Diagram for Gardner LW type Engine.

In many engines the piston crown comes within a very small distance of the cylinder head on its top centre, so that there is very little clearance between it and the overhead valves.

It is therefore *most important to time the valve openings* correctly; otherwise, the valves may be struck by the piston. Where the manufacturers give the valve opening and closing positions in degrees and only mark the T.D.C. of No. 1 piston, the angles corresponding to the valve opening diagram may be estimated as follows:

Measure the flywheel periphery with a thin steel tape, or calculate it from the diameter, by multiplying the latter by $\pi = 3{\cdot}14159$. Call the circumference L inches. Then the peripheral distance x from T.D.C. to the valve opening or closing angle θ is given by

$$x = \frac{\theta \cdot L}{360} \text{ inches.}$$

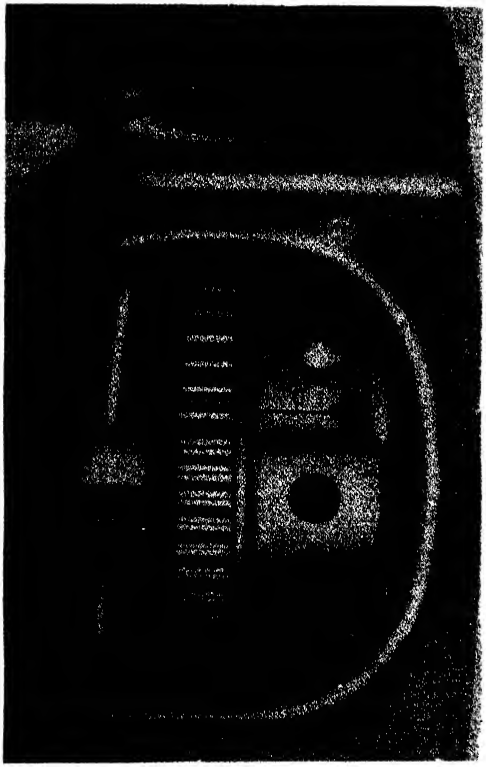


FIG. 118.—Flywheel Timing Marks.

[*To face page* 118.

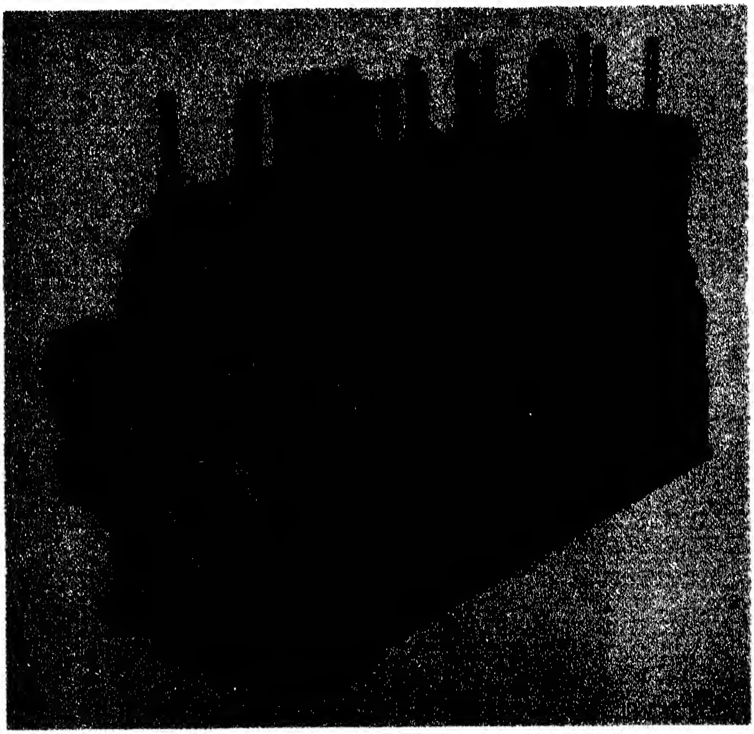


FIG. 119.—Showing arrangement of Timing Gears on Cummins' Diesel Engine.

[*To face page* 119.

The rim of the flywheel can then be engraved, if desired, for future reference purposes.

Fig. 118 illustrates the method adopted in the A.E.C. oil engines. In this case the crankcase has an aperture through which the rim of the flywheel can be seen. There is a fixed pointer on the right of this aperture and the timing lines on the flywheel are read against this pointer. As shown, the engine is on top dead centre for the front, or No. 1 cylinder.

The valve timing is as follows :

Exhaust closes 8° ($1\frac{1}{4}$ in.) after T.D.C.
Inlet opens 10° ($1\frac{1}{2}$ in.) before T.D.C.
Inlet closes 38° ($5\frac{11}{16}$ in.) after B.D.C.
Exhaust opens 40° (6 in.) before B.D.C.

The measurements given relate to distances measured on the flywheel rim from the dead centre positions.

The A.E.C. four-cylinder engine is provided with a convenient *camshaft timing indicator.* It consists of a line cut across the tops of the teeth of the timing wheel and arranged to come opposite to two arrows placed one each side of a little window in the timing wheel cover at the same time as the piston of No. 1 cylinder reaches its top dead centre. If the piston is set on its T.D.C. then the camshaft timing will be correct when these lines coincide.

The Leyland cavity piston oil engine valve timing is as follows :

Exhaust closes 8° after T.D.C.
Inlet opens 8° before T.D.C.
Inlet closes 44° after B.D.C.
Exhaust opens 44° before B.D.C.

The valve timing for the Leyland six cylinder, spherical ante-chamber engine is :

Exhaust closes 6° after T.D.C.
Inlet opens 5° before T.D.C.
Inlet closes 35° after B.D.C.
Exhaust opens 44° before B.D.C.

The valve timings of other makes of engine vary, but most agree in arranging for an overlap of the inlet and exhaust valves, i.e., the inlet opens before T.D.C. and the exhaust closes after T.D.C.

With overhead camshaft engines, the valve timing is set correctly by first placing No. 1 cylinder on its top centre, and turning the camshaft gear wheel until the line marked on its rear face is in line with one on the cylinder head. The latter should then be lowered until the camshaft meshes with the pinion of the timing gear. Another method is to set the piston as before on its T.D.C. and to lower the head until the camshaft wheel meshes with the pinion. The setscrew locking the hub are then unscrewed and the camshaft is turned until its timing mark registers with the fixed cylinder head mark. These two methods are applicable to the Leyland engine.

In the Armstrong Saurer engine the timing gears are of the helical teeth type, there being a train of such wheels to drive the camshaft; it is claimed that this arrangement is more satisfactory than chain drive, which on account of stretch and backlash (except where chain tensioner sprockets are used) is to effect the timing of the fuel injection pump.

The timing gears are marked as follows: The crankshaft pinion is marked " O." The idler gear wheel has three pairs of markings, " 00," " 11 " and " 22." For the correct timing each of these three markings should correspond respectively with " 0 " on the crankshaft pinion, " 1 " on the camshaft gear and " 2 " on the fuel injection pump gear.

It is advisable to check the piston being on its compression T.D.C. when re-timing engines, by noting whether the fuel pump delivers fuel through the priming orifice or nozzle on the upward stroke of the piston; the nozzle should be removed from the cylinder head for this purpose.

Timing Chain Maintenance

The majority of modern oil engines employ double or triple roller chains and sprockets to drive the camshaft, fan, water pump, fuel injection pump, vacuum pump—or exhauster and the dynamo.

The arrangement of the drive differs in the various designs of engine, but the principle of operation is the same in each case, namely, that of a continuous roller chain passing under or over the chain sprockets, and the provision of a chain tensioner sprocket—usually of the automatic adjusting pattern. The chain passes around part of the periphery of this sprocket and a flat spiral or a compression spring holds the sprocket against the chain with a predetermined tension. As the chain stretches the sprocket is moved forward to take up most of the stretch, a ratchet device preventing backward movement of the pulley.

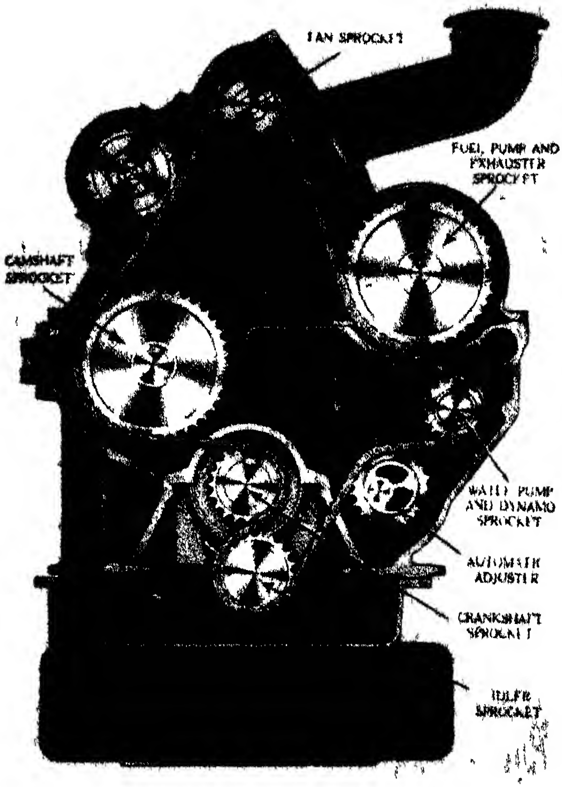


FIG 122 —A E C Engine Timing Chain with Tensioning Sprocket

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Fig. 121 shows the timing chain arrangement of the 115 h.p., 6-cylinder O.H.V. type of A.E.C. oil engine, the various drives being indicated. Timing chains of the triple roller pattern described require little maintenance attention, owing to the automatic tensioner device and the provision of regular lubrication from the engine oiling system.

After about 40,000 to 50,000 miles of road service, however, it generally becomes necessary—owing to chain stretch and wear—to replace the chains, and sometimes the chain sprockets also. As a rule, however, it is the chain that receives the greater part of the wear. Whenever an engine is given a complete overhaul, the chain—if it is still in good condition—should be removed and washed thoroughly in a paraffin bath; afterwards it should be hung up in a clean place to dry, before re-oiling and re-assembling.

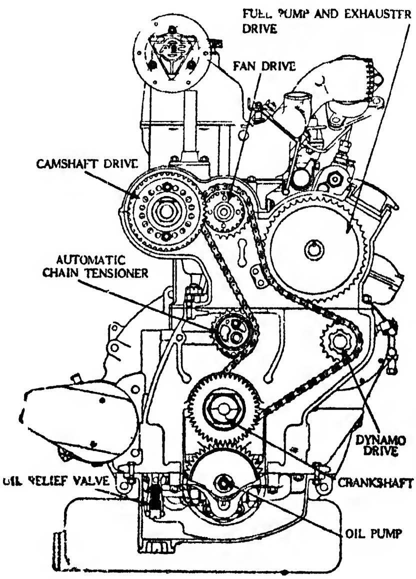

Fig 121 —Example of Timing Chain Drive, showing the various components

For the latter purpose it will be necessary to fit a new outer link to replace that taken out by the chain rivet extractor.

The method of removal of a timing chain can best be described by considering a typical case, namely, that of the A.E.C. oil engine.

The first operation is to remove the timing case, for which purpose the radiator must be removed, as well as the sump, exhauster and fuel pump.

Then, break the timing chain at the bottom using a rivet extracting tool for this purpose. Next, remove the nuts securing the timing case to the engine and lift up the timing case complete with the chain.

To remove the chain tensioner.—The chain tensioner is situated in the crankcase, and it is necessary for the water pump to be removed before access can be made to this unit.

Release the spring by freeing the outer end out from the slot in which it is located. The eccentric complete may then be pulled off. When removing the tensioner while the timing case and the chain are in position, the sprocket will be stripped off the eccentric as the latter is removed.

To replace the chain.—Remove the oil filler from the timing case but leave the chain tensioner sprocket hanging loosely on its spindle. Feed the chain into the timing case so that it wraps over the fan sprocket at the top and down on the underside of the exhauster and fuel pump sprocket. Leave about an equal length of chain hanging down below the timing case on either side and lower the timing case on to the crankcase so that the chain drops between the camshaft sprocket and the crankcase wall on the offside, and over the dynamo sprocket and over the chain tensioner sprocket on the nearside. Lower the timing case on to the crankcase and fix down with nuts. Then from the underside of the engine feed the offside end of the chain from the tensioner sprocket under the crankshaft sprocket and join up to the other end with the slack end of the chain. Now fit the eccentric into the chain tensioner sprocket and turn the eccentric in a clockwise direction as far as it will go and replace the ratchet.

It is, of course, necessary to re-time the engine when the chain has been removed.

To tension the chain correctly, turn the chain tensioner eccentric as far as it will go in a clockwise direction, replace the ratchet with its slotted cover plate outwards and engage the pin in the eccentric with the slot in the ratchet. Engage the tongue in the centre of the spring with the slot in the chain tensioner spindle and wind up three and a quarter times in an anti-clockwise direction ; then lock the end into one of the four slots provided for it in the outer edge of the eccentric.

Replacing a worn chain.—When it become necessary to replace a worn chain with a new part the timing case need not be removed. The sump should be removed and the chain tensioner slackened back by releasing the spring. The chain should then be broken and the new chain attached to one end of it by means of a link. The engine should now be rotated so that the new chain is fed on to the sprockets as the old one is removed. When it is completely fed on, the chain should be riveted up and the chain tensioner adjusted as previously described.

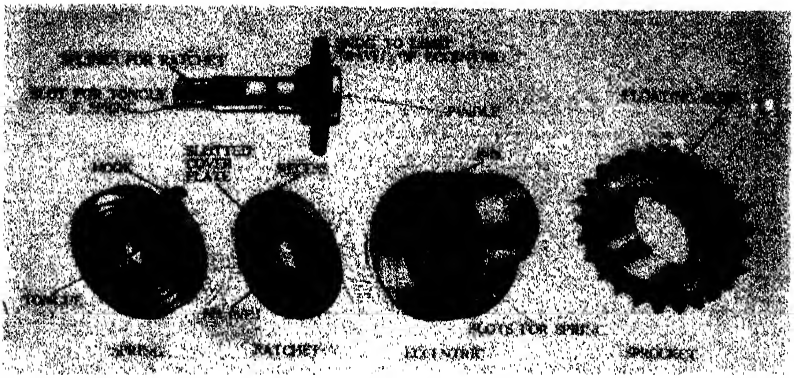

FIG. 123.—Components of the A.E.C. Engine Automatic Chain Tensioner.

FIG. 124.—Illustrating Method of Tensioning the Automatic Chain Sprocket Tensioner Spring, after re-assembly. (A.E.C.)

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CHAPTER VII

THE CONNECTING ROD AND CRANKSHAFT

The Connecting Rod

WHEN reconditioning an engine, each connecting-rod should be examined carefully for any bend or twist effects; if these defects exist excessive wear may occur on the bearings or piston and cylinder walls.

To test for a bent rod in the crankshaft gudgeon pin plane, Fig. 125, Diagram A, a pair of parallel bars is employed. These should be truly straight and cylindrical, each being a good push-fit in the corresponding bearing. If there is any difference between the measurements X and Y, taken on opposite sides of the rod near the ends of the trial bars, this indicates a bent rod. The test for bending in the plane of the rod itself is most conveniently done by reference to a comparison, new rod, placed beneath the one to be examined; any want of symmetry will be apparent upon close inspection or by testing the sides *S*, *S* (Diagram *B*, Fig. 125) with a straight-edge. Bending effects in the plane of the rod are seldom serious, and unless the amount of bending is appreciable, hardly need correction, for no additional friction or stress is caused to the other working parts.

Another effect occasionally met with is that of a twisted rod, due, usually, to misuse or the exertion of undue force when removing the gudgeon pin. Such effects can readily be detected by using the same trial bars as in Diagram A. If the two bars *AB* and *CD* are sighted from the small-end side any twist will at once be apparent (Fig. 125, Diagram C).

A slightly bent or twisted rod can readily be corrected by cold bending in a screw press, or in the vice, provided special precautions are taken to avoid damaging the surface of the metal when applying the correcting pressure.

Special twisting and bending tools are usually provided with connecting-rod aligning jigs now on the market, such as the G.E. and Ammco patterns.

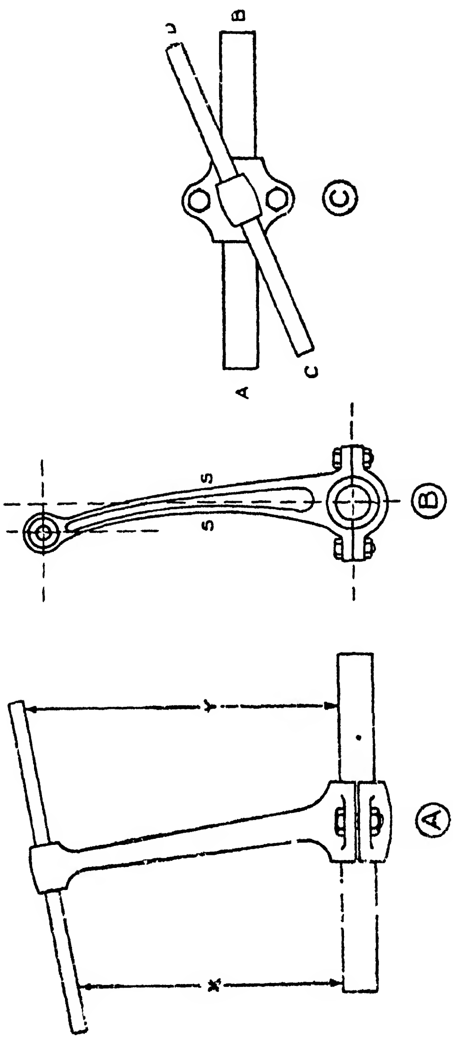

Fig. 125.—Methods of Testing for Connecting Rod Defects.

Where a number of connecting-rods of the same type have to be checked, as when several engines of identical design have to be serviced, it is best to employ a connecting-rod aligning device of the type previously referred to.

The principle of these devices is illustrated in Fig. 128. The relatively stiff bracket *C* is usually an iron casting of channel

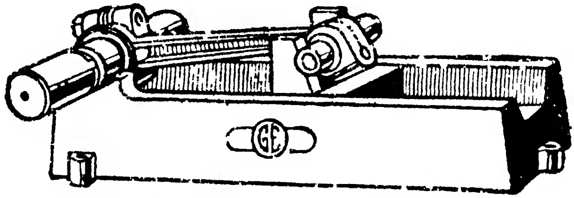

FIG. 126.—A Connecting Rod Testing Jig.

or "T"-section, provided with a fairly heavy base, upon which to stand.

It is provided with a machined and ground pin *D*, of the same diameter as the crankpin journal. An angle-plate, *B*, capable of being fixed in any desired position on the vertical column, *F*, is provided for checking the alignment of the piston and rod assembly. In some cases a dummy gudgeon pin fixture is provided to check for connecting-rod length, twist and bending. If there is any bending in the crankshaft gudgeon pin (H) plane this is disclosed by measurements with a feeler gauge between the piston *A* and angle-plate *J*.

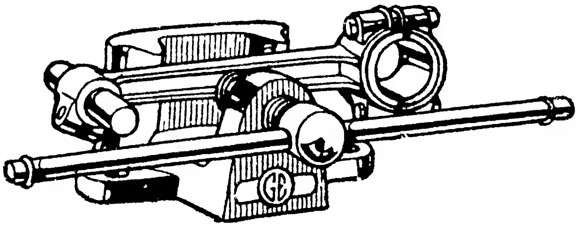

FIG. 127.—Connecting Rod Straightening Device.

The Harvey Frost connecting-rod aligner is illustrated in Figs. 129, 130 and 131. Fig. 130 shows a piston assembly being aligned by tilting and sighting against the face-plate of the appliance. It will be noticed that there is a small adjustable plate which tests the face of the big-end bearing. Fig. 131 shows the auxiliary gauge *A* in use for testing the rod for bending and twists. It has a pair of points which rest on the machined face shown, and two Vee-blocks are embodied for use in connection with the gudgeon pin when checking alignment. The connecting-rod need not be removed when correcting bends and twists, special tools being used for this purpose.

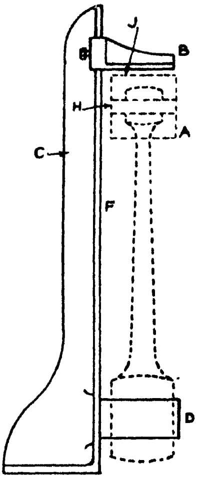

Fig. 128.
Connecting Rod Aligner.

The Crankshaft

This should be given a careful inspection when the engine is dismantled for a general overhaul. In particular it should be *tested for straightness* by mounting between centres in the lathe, using a dial gauge held on a scribing block base for checking the straightness. If not appreciably bent the shaft can readily be re-set in a suitable press. The crankpin and main journals should be measured, each in several places as a check against taper and ovality. The crankpin journal will often be found to have worn oval after a long period of service, owing to the fact that the big-end pressures vary at different parts of the journal, thus giving differential wear effects.

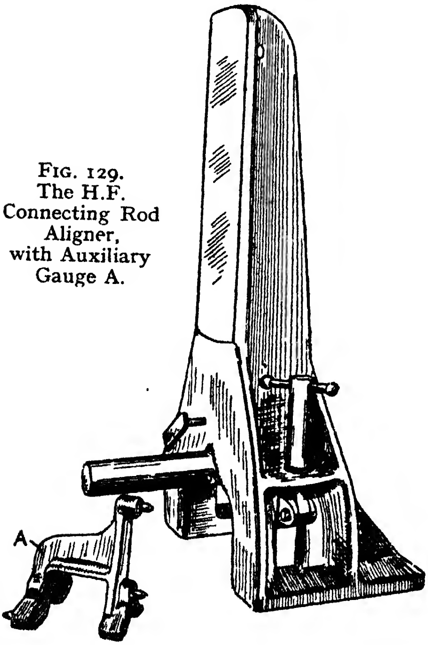

Fig. 129.
The H.F.
Connecting Rod Aligner,
with Auxiliary Gauge A.

In most cases the crankpin journal can be trued by using one of the hand-operated cutter-bar machines designed for this purpose. The principle of these machines is that of two or more guide surfaces parallel to the crankpin axis, but at an angle with each other. The cutter-bar also has its edge parallel with the crankpin axis, so that it cuts truly cylindrical. Typical crankpin truing tools include the G.E., Ammco (Fig. 133) and K.B. models.

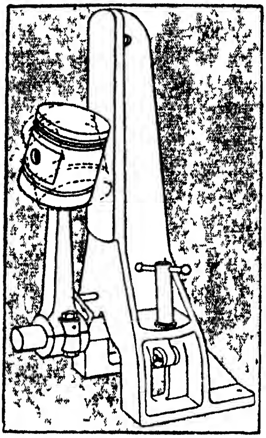

FIG 130—The H F Aligner with Connecting Rod and Piston in Place

It is possible to obtain a cylindrical surface within ·00025 to ·0005 in. both in regard to roundness and taper. The time taken with the K.B. tool is 15 minutes per pin.

If a number of crankshafts has to be trued, in regard to the crankpins it is usually expedient to employ the grinding process, where a crankshaft grinding machine is available ; a better bearing surface finish is obtained in this manner.

Repairing Crankshafts

The repair of fractured C.I. engine crankshafts by the electric arc welding method is now an established practice, but in order to ensure satisfactory results the services of a welding specialist are required. Firms such as Messrs. Barimar undertake this type of welding repair and guarantee the results. In this connection, although there have been cases of further crankshaft breakage, indicating that the fault is one of design rather than of material, it is very seldom indeed that a subsequent failure occurs at the point of welding.

This class of work calls for skilful treatment and it is not only used for the crankshafts of small high speed C.I. engines, but also for those of much larger size. The accuracy of the finished repair is such that if the main bearings of the engine are in good condition the crankshaft can generally be replaced without the need for re-bedding, which is a good testimony to the skill of modern repairing engineers.

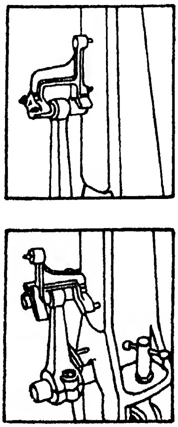

FIG 131. Illustrating use of the Auxiliary Gauge A (Fig. 129) on the Gudgeon Pin, as a check for Connecting-Rod Bending.

Main and Big End Bearings

In the early stages of the development of the commercial C.I. engine a certain amount of trouble was experienced owing to cracking and breakdown of the whitemetal used in the main and big-end bearings. The higher

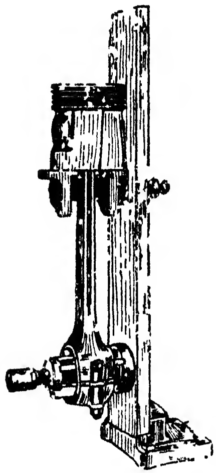

Fig 132 —Another type of Connecting Rod Aligner.

loadings and more rapid increase in the bearing loading during the initial combustion process stage are the principal causes; moreover, the impact effect caused by "Diesel knock" caused severe stresses in the bearing metal.

Hitherto, a tin-base whitemetal in a steel or bronze shell has been used for these bearings. This metal is relatively soft and its tensile strength very low, viz., about 4 tons per sq. in. at normal temperatures. With increase in temperature the strength and hardness properties fall off progressively.

Bearing failures after only about 15,000 miles of road service were not uncommon in some of the engines of the 1929 to 1931 period. An improvement was obtained by using thicker bronze sheels, but still the trouble persisted.

To overcome this, lead-bronze bearings have been adopted in many modern automobile and aircraft engines, and it is significant that this type of bearing now gives useful mileages of 80,000 to over 100,000 before reconditioning is necessary; to obtain such mileages the oil used must be kept well filtered.

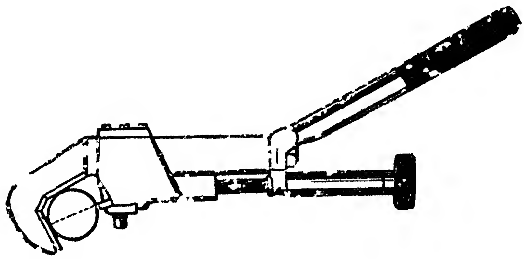

Fig. 133 —The Ammco Crank Pin Truing Tool. This has two guide planes at right angles and an adjustable cutter, operated by the lower screw.

As lead-bronze is more expensive it is now usual to make only the top half of the big-end bearing and the bottom half of the main bearing of these metals, using whitemetal for the other halves. This is the A.E.C. practice.

Lead-bronze is composed of copper, tin and lead; a typical composition is Copper, 65 per cent.; Lead, 30 per cent. and Tin, 5 per cent.

Duralumin connecting-rods running direct on hardened crankpins are giving satisfaction, showing no wear after 30,000 miles of running.

In the case of lead-bronze bearings, one manufacturer has found that there is no need to employ case-hardened pins or journals; ordinary nickel-chrome crankshaft-steel was found to give entirely satisfactory results.

Another satisfactory alloy recently introduced in the U.S.A., for high duty bearing purposes is a cadmium-silver-copper one. This has a higher safety factor at elevated temperatures, is readily-bonded to bearing back materials and has better strength and physical properties than tin-base bearing metals. Cromet aluminium alloy bearings have also been used for C.I. engines with improved results over whitemetal ones.

It has also been found that cadmium-base alloys containing nickel (1·3 to 3·0 per cent.) give better wearing results than tin-base alloys. The former type show superior compression strength at higher temperatures and have appreciably higher melting points. Tensile tests show that the tin-base and cadmium-base alloys possess about the same degree of ductility, while creep tests show that the latter alloy is definitely superior; the cadmium alloy is also harder, at the same temperature, than the tin-base one. Cadmium bearing alloys readily bond with steel and brass, and actual tests on motor vehicles show superior results with this alloy.

The Leyland engines have big-end bearings of the shell type, the upper half being of aluminium alloy and the lower half a bronze shell, whitemetal lined. On some of the earlier engines aluminium alloy connecting rods running direct on to the crankpins were employed.

Clearances

For main and big-end bearings having one-shell whitemetal lined and the other lead-bronze lined, the latter bearing taking the gas pressures, the latter bearing requires *more clearance* than when whitemetal is used for both halves. The recommended clearances in the case of A.E.C. oil engines are as follows:

Connecting Rods

	Minimum.	Maximum.
Clearance on diameter ..	·0045 in.	·0055 in.
Side clearance	·006 in.	·008 in.

Main Bearings

	Minimum.	Maximum.
Clearance on diameter ..	·005 in.	·007 in.
Side clearance	·008 in.	·010 in.

In reference to the Leyland C.I. engines it is recommended that crankpins and journals should be re-ground when they are more than ·003 in. oval.

The amount of play in the big-end bearings of all Leyland engines should not exceed ·006 in.; if more, the excess should be taken up by filing the rods and caps. Extreme care must be exercised when filing connecting-rods and caps to ensure that the faces are filed true and perfectly flat so that they bed all over when bolted up.

A clearance of ·0015 in. to ·0030 in. should be allowed on the crankpin and the connecting-rods should be checked for alignment after bolting up.

The *endplay* on the crankshaft should be ·0035 to ·0070 in. and should not be allowed to exceed ·012 in.

In regard to the Leyland aluminium alloy connecting rods previously fitted, these are not supplied with undersize bearings but new ones may be obtained if the crankpins are not worn. Steel rods with undersize bearings are supplied to replace aluminium rods when the crankshaft has been re-ground.

The big-end bearings of the Armstrong Saurer engine, when new, are given ·0015 in. clearance on the crankpin, and ·005 in. (maximum) side clearance.

CHAPTER VIII

THE FUEL INJECTION SYSTEM

THE high speed C.I. engine, as previously mentioned, has many common features with the petrol engine, the essential differences being those connected with the combustion chamber design and the fuel injection system.

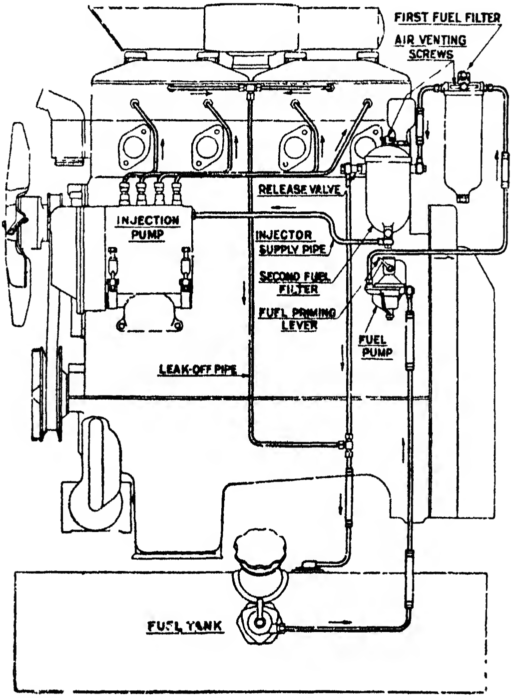

FIG. 134.—The Complete Fuel System used on the Dennis Four-Cylinder Oil Engine.

The maintenance and tuning of the latter system is, perhaps, the most important of all operations to those whose previous experience has been limited to petrol engines only, so that it is proposed to deal with this subject rather more fully than would otherwise be the case.

As an outline of the fuel injection system has already been given it will be assumed that the reader is familiar with the underlying principles of the fuel pump and injector.

The Complete Fuel System

The Diesel oil is stored in a fuel tank in a similar manner to that used for petrol, in the case of petrol engines. The fuel should be well-filtered before it passes into the fuel tank. From the latter it is drawn by a suction pump through another fuel filter and delivered to the suction side of the fuel injection pump. In some cases, however, the second fuel filter is placed on the delivery side of the fuel feed pump, a pressure release valve being incorporated in the filter to enable any excess of fuel to be returned to the fuel tank (Fig. 134).

The fuel arrangement recommended for the Bosch fuel pump system is that shown diagrammatically in Fig. 135. In this case the fuel feed pump is mounted on the fuel injection pump and it draws fuel direct from the fuel tank, delivering the fuel, through a filter device to the suction side of the fuel pump. There is a relief valve fitted on the fuel filter and an air venting screw.

In the case of the Leyland C.I. engine the fuel tank and first filter are identical with those of the Leyland petrol engine. An Autovac vacuum fuel-feed system is employed to keep the fuel pump supplied with Diesel oil. A second fine filter is, however, provided between the Autovac and the fuel pump; this is fitted under the engine bonnet to minimise the possibility of choking due to waxing. The A.E.C. oil engines also employ the Autovac fuel feed system, whilst in other cases the mechanical fuel pump, such as the A.C. or Amal types are used to draw the fuel from the main supply tank and deliver it to the fuel injection pump.

Electrical Fuel Pump

Where *the electrical type of pump* is employed, for example, the S.U. electric pressure pump, this should be wired up so that it is always in a "live" circuit, i.e. the current is always flowing or ready to flow when the contacts of the pump are closed.

It is advisable to fit a fuse in this circuit so that should excess current tend to flow the pump windings will be protected; further, the fuse can be removed to break the circuit when the pump has to be examined.

By arranging to have the pump always in circuit, there is no risk of the fuel injection pump "starving" or of air getting into the fuel line.

The Fuel Feeding Pump

It will be assumed that the reader is familiar with the vacuum feed, mechanical and electrical fuel feeding pump systems used on petrol engines, so that it will here only be necessary to

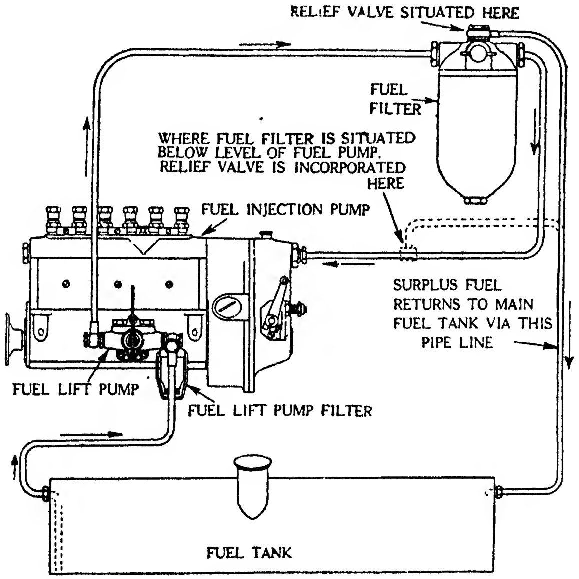

FIG. 135.—The C.A.V.-Bosch Fuel Feed System.

describe a special pump developed by Messrs. C.A.V.-Bosch especially for high speed C.I. engine fuel systems. This pump keeps the fuel injection pump supplied with fuel under all conditions of load and speed without any risk of air locks, fuel starvation or excess supply.

It is desirable, with oil engine fuel feed pumps that the output of fuel should vary in proportion to the engines' requirements in relation to the varying loads. Accordingly, the amount of fuel delivered by the feed pump should vary correspondingly, to avoid starving or, conversely, excessive supply.

The C.A.V.-Bosch fuel feed pump which has been designed to fulfil these conditions is shown, diagrammatically, in Fig. 136, *A*, *B* and *C*, and sectionally in Fig. 136A.

Referring to Fig. 136A the unit consists of a main flanged body *W* into which are screwed the inlet and outlet connections. Under the two heads are spring-loaded release valves *F* and *H* for fuel pressure control. A plunger *L* is actuated *via* the guide and spindle *N* by the injection pump camshaft through the tappet roller *B* (Fig. 137).

The hand-operated priming lever *Z* (Fig. 137) is fitted for independent operation of the main plunger through a con-

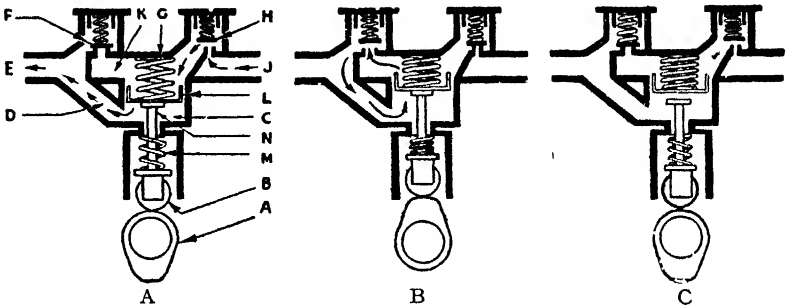

FIG. 136.
The C.A.V.-Bosch Fuel Feed Pump, Illustrating Method of Operation.

necting link and rod. Leakage of fuel along spindle *N* is avoided by making the latter a piston fit in the housing and providing an oil connecting groove, having a hole communicating with the inlet plug chamber.

In some instances the fuel feed pump is fitted with a preliminary fuel filter.

The operation of the feed pump (Fig. 136) is as follows :

When the cam *A* is in the position of minimum lift as shown in Diagram *A*, the spring *G* forces plunger *L* down so that the fuel is sucked up from the fuel tank through inlet *J* and into inner chamber *K*. During the same movement the opposite side of the plunger forces the fuel from the outer chamber *C* through connecting channel *D* into fuel outlet *E*.

As the cam turns and lifts the plunger, the inlet valve *H* is closed and the fuel forced past outlet valve *F* through connecting channel *D* into the outer chamber *C* as shown in Diagram *B*.

At the next upward stroke of plunger *L* fuel is delivered into outlet *F* via valve *F* provided the injection pump requires a further fuel supply. If, on the other hand, sufficient fuel has for the moment been delivered to meet the demand of the injection pump, the plunger *L* will only move upward a sufficient amount in order to balance the pressure between that in the outlet *E* and the spring *G* (Diagram *C*). The tappet spindle *N* will then leave the plunger suspended and will not re-engage until the next upward stroke. Consequently, the subsequent plunger stroke will depend upon the pressure in outlet *E* which, in turn, is dependent upon the amount of fuel the engine is consuming.

Another point worthy of note is that the outer pressure chamber *C* which surrounds the tappet plunger *N* is under continual pressure, thus eliminating the possibility of air locks due to air entering with the fuel from the tank.

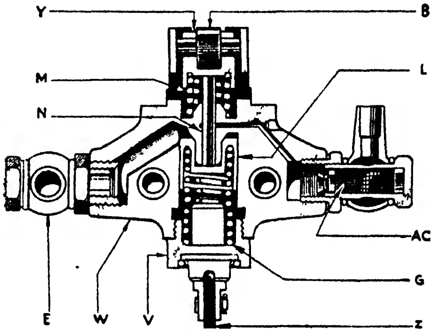

FIG 137 —The C A.V -Bosch Fuel Feed Pump in Section

The feed pump will readily cope with the demands of the larger sizes of 6-cylinder motor vehicle engine and will lift the fuel from a maximum distance of 6 feet below the centre of pump.

The maintenance of this fuel feed pump, together with possible faults and their remedies is described in Chapter XII.

Fuel Injection System Troubles

The various troubles traceable to the injection system are usually manifest by the following symptoms :

(1) Loss of power.
(2) Irregular running or knocking.
(3) Poor acceleration.
(4) Smoky exhaust.
(5) Failure to run at all.

As with the petrol engine, these troubles are in some ways analogous to ignition and carburation ones, for if a given cylinder fails to fire or fires irregularly the result will be the same as for a choked injection nozzle or a partially choked one.

Similarly, if the injector nozzle fails to close properly owing to the presence of dirt on the valve seating, or it "dribbles," the effect will be the same as for a petrol engine operating upon an over-rich mixture. In both cases there will be a smoky exhaust, but that of the C.I. engine will be more pronounced and, incidentally, more pungent.

Finding the Faulty Cylinder

Assuming that the engine is firing irregularly owing to the faulty running of one cylinder unit, the method of locating the offending cylinder is similar to that used in petrol engines for finding a faulty sparking plug. In the latter case each plug is short-circuited to the metal of the cylinder, or "earthed," by connecting the terminal of the central electrode to the cylinder metal, using a screw-driver or similar insulated tool.

With the C.I. engine each cylinder is "cut out" in turn by stopping the fuel supply to its injector. If the cylinder thus tested is *not* the faulty one then the result of cutting off its fuel supply will be to slow up the engine, appreciably. If, on the other hand, the faulty cylinder is "cut out," this *will not reduce the speed* of the engine.

If one of the cylinders is knocking, owing to some form of injection trouble, the nozzle unions, or release plugs of each injector in turn should be released until the knocking ceases; the union, or release, that causes this cessation will, of course, indicate the offending cylinder.

Most fuel injector systems are provided with a hand-control for cutting off the fuel to each injector. Otherwise, one of the nuts on the fuel supply pipe-line between the fuel injection pump and the injector should be unscrewed so as to release the pressure in this pipe-line and allow the fuel to ooze out of the joint instead of being forced through the injector nozzle; the Bosch fuel injection nozzles are tested in this manner.

Compression Taps.—Some oil engines, e.g. the Saurer, are fitted with compression taps, which can be used to find the faulty injector. This is done by opening the taps one after the other whilst the engine is running; by slightly accelerating the engine a difference in the firing noise can at once be detected and the faulty injector traced.

Feeling the Fuel Pipes.—In some instances it is possible to find the faulty injector by feeling the fuel pipes. If snappy slight reaction shocks are felt on the pipes, the injectors are working satisfactorily, but if these shocks are not experienced from one or other of the pipes, it is a sign that the corresponding injector is at fault.

The Feeler Pin.—When injection nozzles of the Bosch pattern are working properly this fact can at once be verified by touching the end of the feeler pin; if the latter does not move at all this indicates a faulty injector unit.

Having located the cylinder that is "mis-firing," the cause of the trouble will, obviously, be in one of the following:

(1) The Injection Nozzle.
(2) The Pipe Line.
(3) The Injection Pump.

The various possible faults in items (1) and (3) and their cure are dealt with in detail in the following pages, but it will here, perhaps, be advisable to consider item (2) first.

PIPE LINE TROUBLES.—The most likely troubles that can occur in the fine bore pipe-line between the fuel pump delivery side and the injection nozzle are as follows:

(*a*) Damaged fuel pipe, due to accidental "kinking" or sharp bend.
(*b*) Leakage of fuel at pump or injector union joints, owing to faulty pipe end seatings or slackened unions.
(*c*) Air bubbles in fuel.

The latter is the most common pipe-line trouble and is due to the small bore fuel pipe having been improperly primed with fuel. *To obviate this trouble,* the closing plug on the injector, or its equivalent priming device, should be opened whilst the engine is running and the fuel allowed to flow out until no air bubbles are observed. The priming device should then be closed, whilst the engine is still running.

Notes on Fuel Pipes

The steel pipes used for connecting the fuel pump to the injectors are usually of about 6 mm. diameter with a bore of 2 mm. or 3 mm.

When fitting a new pipe it should be cleaned thoroughly, after it has been bent to shape and tightened in position, by flushing through with fuel oil. In this way, any dirt or scale dislodged during the bending can be eliminated. Compressed air can also be used for cleaning the pipes. Whenever fuel pipes have been loosened, or disconnected, they should afterwards be primed with fuel by cranking the engine with the accelerator depressed or by priming with a hand pump—if one is fitted to the fuel injection pump—until the fuel flows out of the unions freely and without any traces of air bubbles.

The fuel pipe from the fuel feeding pump or vacuum feed (or the filter between this and fuel injection pump) and the fuel injection pump is of copper, and for Bosch fuel pumps measures 8 mm. bore by 10 mm. outside diameter.

In connection with the steel delivery pipes these—so far as is possible—should be equal in length for each injector and free from sharp bends ; otherwise, the injection characteristics will be different for the various cylinders.

The nipples for fuel pipes can be silver-soldered or " swelled " or swaged at the end ; suitable dies can now be obtained for the latter purpose. Soft soldered joints should never be used.

Eliminating Air from the Fuel System

If the fuel flowing from the nozzle priming device continues to contain air bubbles it will be necessary to make a careful inspection of the fuel system, for even a small bubble of air will often interfere with the regular running of the engine.

In the case of the Bosch fuel system on the A.E.C. engines, with Autovac fuel feed supply, and in all similar cases, air will be introduced into the system under the following circumstances :

If the fuel tank has been allowed to run dry.

If any part of the fuel system between the Autovac and the fuel pump has been removed or disconnected.

If the engine has been run with the fuel cock closed.

If the filter has been allowed to become so clogged as to interfere with the flow of fuel to the Autovac.

If the Autovac should fail to work.

In cases where the tank has been allowed to run dry, and where the Autovac tank has run dry, fill the Autovac tank with fuel. Open the air vent cock on the Bosch pump to allow fuel from the Autovac to displace the air from the pump chamber. Close the cock as soon as fuel issues in a steady stream from the overflow pipe.

Slack off all the pressure pipe unions on the injectors.

Fully depress the accelerator and crank the engine until

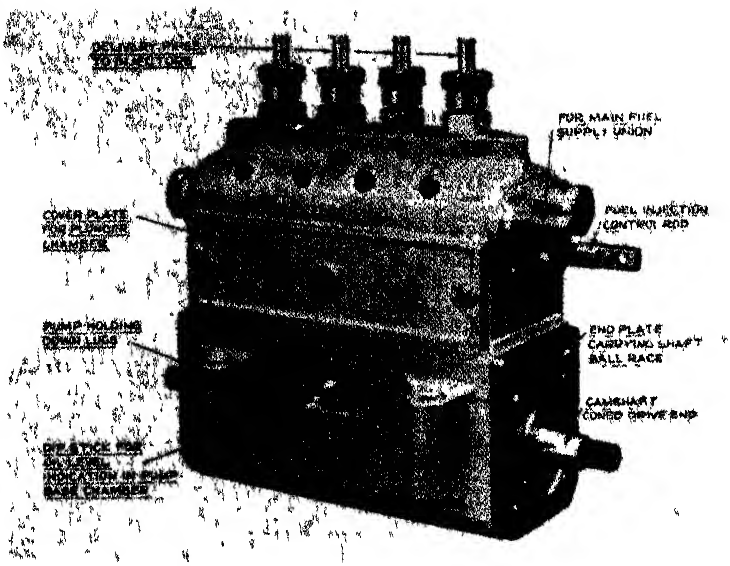

FIG 138.—Showing the Principal External Parts of the Fuel Pump

[To face page 138.

fuel flows from all four fuel connections. Tighten up the fuel connections and start the engine in the usual manner.

It will sometimes happen that one or more of the pump elements, usually those at the forward end of the pump, will refuse to deliver fuel. This is on account of air not having been properly cleared out of the pump chamber. If this cannot be cured by use of the vent cock on the Bosch pump, disconnect the fuel pipe concerned from the pump and remove the delivery valve holder, lift the valve from its seat, to enable the air to escape, and allow the fuel to flow until free from bubbles. Should the fuel not flow, turn the engine slightly by means of the cranking handle. To avoid the risk of losing either the valve or spring, it is advisable to keep the delivery valve holder over its place, lifting it just far enough above the body of the pump to allow the valve to lift sufficiently for the air to escape.

Do not handle the valve with dirty fingers.

Replace the delivery valve holder and reconnect the pipe. Crank the engine, and as soon as fuel issues from the injector end of the pipe, tighten up this union also.

Repeat the process for all pump elements which are not delivering fuel and start up the engine in the usual manner.

When the engine has warmed up, accelerate the engine to a good speed several times.

The engine should accelerate rapidly and without any hesitation, or fluffiness, if the system is properly clear.

If this does not happen, slack off each injector union in turn, just sufficiently to allow the fuel to seep out and watch for air bubbles between the pipe and the union nut. Should bubbles be detected, *leave the nut slack until all bubbles disappear.*

Treat each union in turn in this manner. It is a wise precaution to do this, even though the acceleration test indicates that all air has been removed.

If the union nuts are slacked off more than just enough to allow the oil to seep out, *the force with which the oil issues from the pipe will produce a froth* even if no air is present in the pipe.

After running for a few minutes, open the vent cock on the fuel pump for a few moments to make sure that the pump chamber is full.

The procedure has been described in detail, as it is of highest importance that all air should be removed from the system, otherwise the engine will not operate properly. *Knocking, sluggishness and boiling will result from air in the fuel system.*

If either the fuel pump or the fuel pipe connecting the Autovac to the pump have been removed, the procedure detailed above should be employed, as air will certainly have entered the pump chamber.

If the engine is run with the fuel cock closed, any air which has been dissolved in the fuel will be released and will either collect in the pump chamber, where its presence may prevent one or more of the plungers from delivering fuel, or it may be passed into the fuel pipes and interfere with the uniformity of the injection. It may sometimes happen that no trouble will follow, but in all cases, after having opened the cock, restart the engine and open the pump vent cock until the fuel flows freely. When the engine is hot apply the acceleration test already described above. The acceleration should be clean and with no signs of woolliness. *Woolliness, lack of pull, or a sharp knock* in one or more cylinders will indicate either that there is air in the fuel pump or in the fuel pipes, and this must be removed as already described.

As a rule, opening the pump vent cock for a few seconds is all that is required.

It is a good plan to prime the fuel pump periodically, while the engine is running, and thus make sure that the system is kept free of air at all times.

If an injector has been removed, the fuel pipe should be vented as described above, before finally coupling up again.

The priming of the fuel system just described is a very important operation with all C.I. engines ; the maintenance engineer should therefore make himself familiar with the method of priming engines under his charge.

Fuel Pump Troubles

The modern high speed C.I. fuel injection pump is so well designed and made that it is very seldom indeed that any trouble is experienced with it in the mechanical sense.

Practically all of the troubles associated with the fuel pump are traceable to dirt in the fuel supply, to air bubbles in the fuel or to faulty pump or governor timing.

Provided that the fuel can be kept quite clean, the life of the working parts of a modern fuel pump is generally longer than that of the engine itself, even allowing for periodical complete overhauls.

Thus, in the case of a Bosch fuel pump manufactured some years ago and fitted to a commercial vehicle engine it was found that after about 80,000 miles of running the delivery of the pump had diminished by about 25 per cent. at idling speeds, but only by about 3 per cent. at normal running speeds. At the maximum speed the diminution was about 1.5 per cent. Later type fuel pumps show appreciably better performances than this.

If, however, the fuel filter system is inefficient, or the filters become damaged, the effect of solid matter in the fuel is to cause relatively rapid wear of the plungers and barrels of the fuel pump, so that eventually leakages of a serious order may occur.

It is important *when re-assembling fuel pumps* to take special precautions against the ingress of dirt, either from the hands or the air around, into the pump.

Another important maintenance matter is *the regular lubrication of the pump*, camshaft and bearings and also the advance device. The sump at the base of the pump should be replenished to the " dip-stick " level at regular intervals.

If the fuel pump is suspected of causing trouble, check the discharge from each plunger by disconnecting each of the injector unions in turn, while the engine is running, or motored by the starting electric motor, momentarily depressing the accelerator pedal. The fuel should be delivered in uniform and equal discharges from all of the fuel pipes.

If it is found that one or more plungers are either not delivering fuel or are sending it along irregularly, then the probable cause is either (1) *An air lock in the pump chamber*, (2) *Delivery valve sticking, or* (3) *Broken plunger spring.*

The method of clearing air out of the fuel system, previously described, should be employed in the former case.

If the delivery valve is suspected of sticking there will usually be a persistent dribble at the injector nozzle. It is very probable that, in this case, there is dirt on the delivery valve or its seating. The valve should be removed, cleaned and replaced with care.

In the case of the Bosch pump, the delivery valves are made a plunger-fit in their respective guides and should on no account be changed around. Each valve and its seating should therefore be kept as a pair.

If the trouble is definitely shown not to be due to Items

(1) and (2) it can then be assumed that the most likely cause is a broken plunger spring; the fuel pump should therefore be examined for this defect. The method of dismantling the Bosch fuel pump is given in the next Chapter.

Testing a Multiple Plunger Fuel Pump

The fuel pump should be removed from the engine, mounted on a wooden base on the bench and driven by means of an electric motor at different speeds, corresponding to the engine speed range. The outputs from the different plungers, taken over a fixed number of pump-shaft revolutions should then be measured by collecting the fuel discharged from each outlet pipe in a graduated glass vessel. The outlet pipes should be of the same length and kept parallel, being finally bent over at their ends so as to discharge downwards.

The method employed at the London Traffic Pool Board Experimental Department, Chiswick, is to collect the discharges corresponding to 100 revolutions of the pump shaft.

Underneath each outlet a vertical graduated glass tube should be arranged, but between the top of the tube and the outlet a swinging tray or deflector should be fixed in such a way that normally the oil from the outlet pipes does not flow into the glass measuring tube, but is diverted away from it. Upon swinging the deflector aside, however, the outlet streams should then flow into their respective tubes.

It should be arranged to collect the discharges corresponding to 100 revolutions of the pump and then, once again to divert the streams. If these discharges are not equal, this is an indication that one or other of the pump plungers requires adjustment to increase or diminish its discharge. On the Bosch fuel pump a special clamp is provided for the plunger toothed segment; by releasing its screw the plunger can be rotated to give the desired variation of discharge.

It is not a difficult matter to arrange for the automatic tipping of the deflector device at the beginning and end of the 100 revolution period, as is done in the Bosch test equipment.

Hand Tests of Fuel Pumps

An outfit for testing fuel pumps[1] illustrated in Fig. 139, enables the operation of each plunger unit to be checked and the outputs of the separate units compared.

It consists of a suitably calibrated pressure gauge which has

[1] Deutsche Motor-Zeitsclinft.

a connection for fitting to the outlet unions of the fuel pump and another for attaching an atomiser. A small reservoir, attached by two chains to the nozzle holder enables the fuel ejected by the nozzle to be collected and measured.

Each plunger is operated in turn by means of a plunger lifting tool, resembling a motor engine valve spring lifter, which is inserted under the plunger spring collar and its tappet so as to lift the plunger. By giving the latter a definite number of complete lifting movements, in each case, the

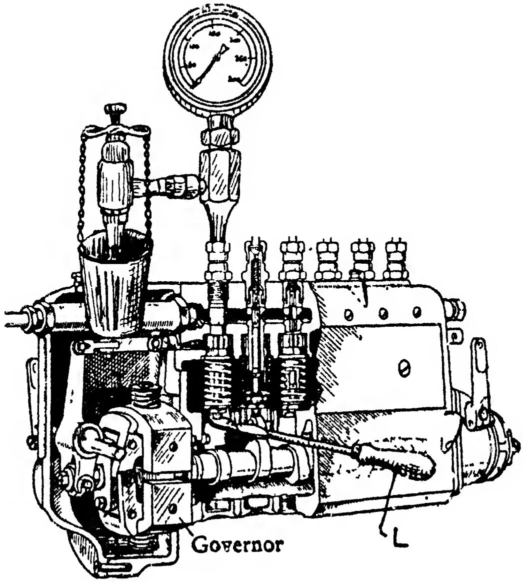

FIG. 139.—Equipment for Testing Fuel Pump Operation and Nozzle Discharge.

outputs of all of the plungers can be compared and, if necessary, suitable adjustments made to equalise these.

The outfit in question is suitable for the Bosch fuel injection pumps, and can be employed for testing fuel injection nozzles, for opening pressure and spraying characteristics.

Testing the Pump Plungers

The plungers of the fuel pump should be tested at long intervals for wear, or leakage effects, by subjecting the plungers in their own barrels to hydraulic pressure.

The usual test is to utilize the fuel pipe line, connecting one end to an hydraulic pump capable of applying high pressures; an injection nozzle testing pump can be used for this purpose. The other end of the pipe line should be connected to the delivery nozzle of the plunger that is to be tested. With the plunger on its delivery stroke it should be capable of withstanding a pressure of 250 atmospheres without any appreciable leakage. It is usual to apply a pressure of about 250 atmospheres and to note the rate at which the pressure in the pipe line falls. A well fitting plunger should allow about eight minutes before the pressure falls to 150 atmospheres.

Another method is to use the fuel pump plunger as a pump, and to check whether it will build up a pressure of 250 atmospheres and maintain this.

Lubrication of Fuel Pumps

Regular attention should be given to the matter of the lubrication of the pump camshaft, bearings, rollers, tappets, and, when fitted, the governor mechanism. The plungers are lubricated by the fuel itself.

Practically all fuel pumps have oil sumps in the lower parts of their pump housings—similar to the oil sumps of the engines, themselves.

Ordinary engine lubricating oil should be maintained up to a given level in the sump, a dipstick type of oil gauge rod being used to show the level.

At regular intervals the oil level should be checked. In the Bosch pump the oil is filled into the camshaft chamber through the oil gauge rod hole.

The idling and maximum speed inbuilt governor must be lubricated separately. In the case of the Bosch centrifugal type of governor about one quarter pint of engine oil is poured into the governor housing through the lubricator cup 110*c* (Fig. 188); an oil level gauge plug is provided in the governor housing to which level the oil should always be maintained.

The fuel pump advance (timing) device should be lubricated with engine oil every 500 miles or so.

Faulty Injector Nozzles

As the fuel injector is the most likely source of any trouble liable to occur in the fuel injection system, the injector should be unscrewed from the combustion head of the cylinder that is not "firing" regularly.

The injector should then be replaced on its fuel supply piping, but with the nozzle in the open air in order to test the fuel spraying effect.

The spray emitted when the fuel pump (or its hand-pump priming device) is operated should be symmetrical, and finely atomized, whilst the *valve should give a distinctive grunt* if the nozzle is in proper condition.

If the nozzle emits an irregular and one-sided stream (in the case of single hole nozzles), this is a sign of dirt being present on the seating. Similarly if the individual sprays from multiple-hole nozzles are irregular there may be dirt on the seating or partially choked emission holes.

The principal fuel injector troubles likely to occur are as follows :—

(1) *Dirt between the nozzle valve and its seating.*
(2) *Sticking nozzle valve in its guide.*
(3) *Cracked nozzle body.*
(4) *Broken nozzle valve control spring.*
(5) *Incorrect spring compression.* This is usually caused by a slackening of the adjusting screw controlling the spring compression.

It should first be ascertained whether there is any air (or water) in the fuel system as this will cause injection trouble.

The presence of dirt on the seating is indicated by blue smoke in the exhaust gases, when the engine is working and the fuel injection timing lever fully advanced.

If the nozzle valve is sticking in its guide the cylinder in question will often exhibit a knock. This will sometimes disappear if the injection lever is retarded much below its normal position.

A cracked nozzle is indicated by misfiring in the cylinder to which it is fitted. This misfiring may be intermittent or continuous. It should be pointed out, however, that *misfiring can also be caused* by air in the fuel line, or a poor compression.

Most fuel injectors have a stem, known as a *Feeler Pin*, often with a small knob at the end, extending for a short distance out of the upper, or outside end ; in some cases a readily detachable cap or cover is fitted over this stem. If an end cap is fitted, remove this and *press the finger on the end of the stem whilst the engine is running.* If the valve is working properly a sharp kicking or pulsating movement will be felt.

A feeble motion or the absence of any motion at all indicates that *the injector valve is sticking in its guide* or *the valve spring is broken*; alternatively, the spring adjustment screw may have slackened back.

If the spring is broken the pulsation may feel normal if the pin is pressed hard; a light pressure, however, will indicate that the valve is not working normally.

The Open Air Spray Test

Reverting to this method of testing an injector, as previously stated, when working properly the injector should give a fine mist of regular appearance and symmetrical shape. There should, however, be no semblance of a jet of fuel; the end face of the nozzle should remain dry, and no drip should come from it.

Any signs of a jet of fuel in the centre of the spray will indicate either 1, 2, 4 or 5 in the list of injector troubles, previously given. The presence of a jet may also be accompanied by a certain amount of dribble.

A good spray accompanied by dribble may be due to either No. 1 or 3 and occasionally 2. Wipe the nozzle dry and repeat the test, watching carefully to see the point from which the dribble originates. If from the nozzle orifice, 1 or 2 is the cause, if from between the nozzle and the nozzle cap cut, or elsewhere, a cracked nozzle is the cause.

A jet of fuel, with little or no spray, will be caused by either 2, 4 or 5. The latter only if the adjusting screw has slacked off so far as to remove all spring tension.

Nozzle Testing Devices

In connection with the routine testing of injection nozzles, it is advisable to employ a nozzle testing apparatus of the bench type, such as the Armstrong (Fig. 140) or Bosch (Figs. (141 and 142).

Another useful nozzle tester is the Bryce one, consisting of a standard Bryce fuel injection pump unit (without its control rod), fitted with hand-operating lever, fuel oil container, delivery connection to the nozzle holder and a pressure gauge. The latter is controlled by a cock which is only opened when a reading of the nozzle release pressure is required.

The principle of these nozzle testers is to apply a similar fuel pressure to the nozzle to that employed in the working injection system, the value of this pressure being read off a suitably calibrated pressure gauge. On the application of this

Nozzle Testing and Correction Procedure

The following table sets out in a convenient manner the procedure recommended by Messrs. C. A. V.—Bosch, Ltd., for the detection of nozzle faults and their corrections :

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. (See below.) Clean the nozzle. (See below.)
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. (See below.) Replace the spring.
Nozzle drips.	Nozzle leaky due to carbon deposit.	Clean the nozzle. (See below.) 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. (See below.) Replace nozzle and needle.
Nozzle does not buzz while injecting.	Needle too tight, binding, or needle seating leaky.	Clean the nozzle. (See below.) If this does not clear the fault, replace nozzle and needle.
Too much oil escaping at the leak-off oil pipe.	1. Nozzle needle 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.

pressure (usually by means of a hand pump), the nature of the spray can be studied and any defects at once detected.

The various defects enumerated on page 147 can readily be checked for with the nozzle tester. Thus, if the nozzle does not "buzz" in its characteristic fashion while injecting, this indicates that the needle is too tight, is binding or the seating is untrue.

Too high a nozzle pressure shows that the nozzle is partly

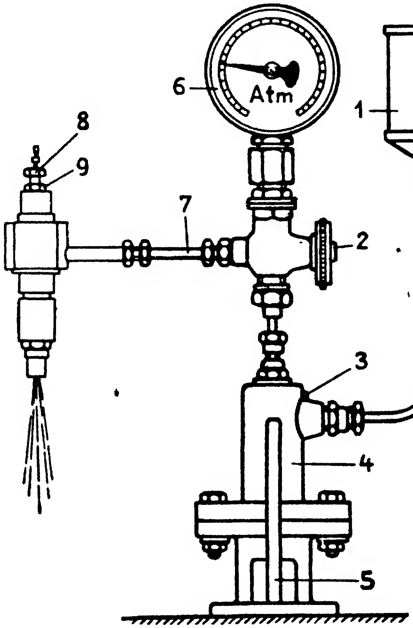

FIG. 141.
Illustrating the Principle of the Bosch Nozzle Tester.

seized up, the valve is sticking or dirty, or the openings partly blocked with carbon or dirt.

If, on the other hand the pressure on the gauge is lower than the given or known injection pressure, there may be dirt on the valve seating, the valve may be stuck "open" or the nozzle spring broken. Referring to Fig. 141 showing the Bosch nozzle tester, the fuel is fed to the nozzle holder from the tank 1, through a stopcock and through the pressure pump 4, which is operated by the handle 5. The pressure gauge (manometer) 6 which is connected to the pressure pipe 7 reads up to 300

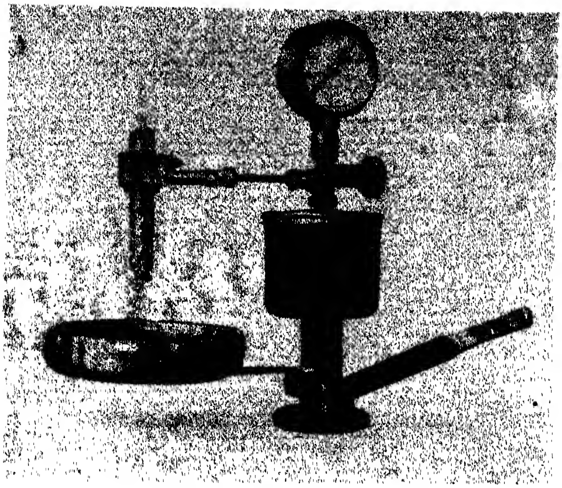

FIG. 140.—The Armstrong Nozzle Tester.

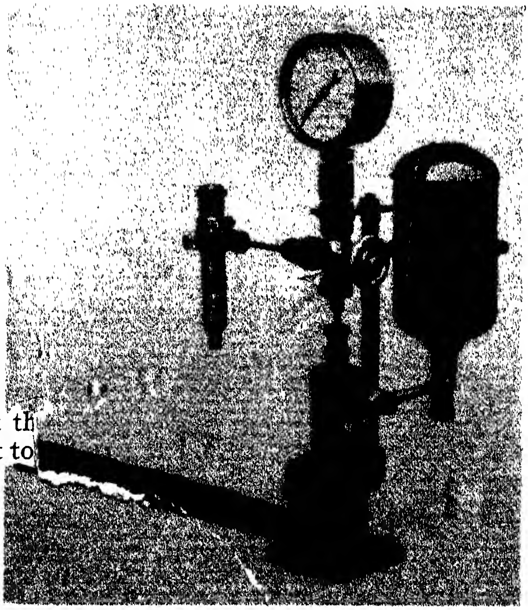

FIG. 142.—The Bosch Nozzle Tester.

[*To face page* 148.

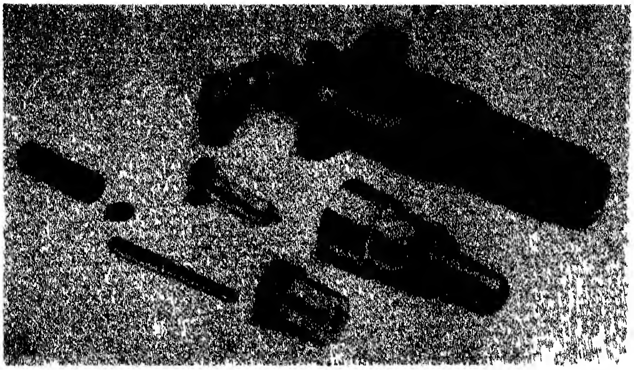

FIG. 143.—The Armstrong Saurer Fuel Injector and its Component Parts. The injector sprays off in four directions, the bores being 0·25 mm. and injection pressure 300 atmospheres.

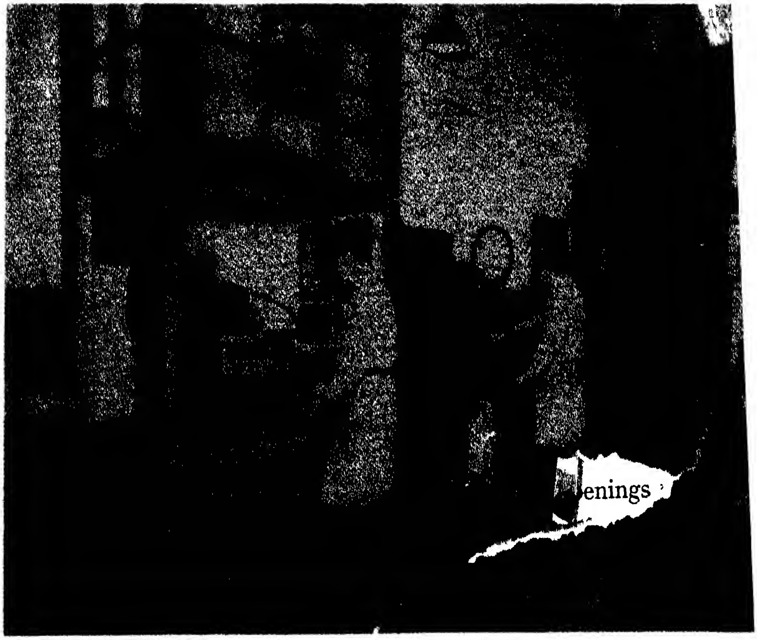

FIG. 144.—The Fuel Injection Testing Equipment at the London Traffic Pool Laborat
On the left a Fuel Pump is being tested for individual plunger deliveries; on the ri
the injection period and timing are being checked

[To face page

atmospheres. The shut-off cock 2 is provided so that the gauge may be shut off during the nozzle tests. When the nozzle tester is to be used it must first be cleared of air. To do this remove the air release screw 3 ; when the fuel oil has flowed out for about three seconds replace the screw and tighten up. Now pump until the fuel flows from the pressure pipe 7. The apparatus is now ready for use and the nozzle holder with the nozzle to be tested may be connected. The nozzle pressure is adjusted by means of the adjusting screw 8 after releasing the locking nut 9. It is then read on the pressure gauge.

Cleaning Injection Nozzles

Periodically, namely about once every 2,000 to 3,000 miles, all injection nozzles should be removed from the engine and cleaned. The end of each nozzle should first be scraped clean (of carbon) and the nozzle then dismantled.

It may here be mentioned that in the case of a large fleet of commercial oil engine vehicles it has long been the practice to remove the injection nozzles every eight days (corresponding to about 1,000 miles of road service) and to replace them with nozzles which have been cleaned and tested. The nozzles removed are then reconditioned ready for the next replacement. In this way no trouble has ever been experienced on the road owing to faulty nozzles.

Assuming the nozzle is of the usual spring-loaded pintle type, after dismantling wash thoroughly all the parts in paraffin or petrol. Wipe the valve face and the pintle of the valve with a cloth, using an appreciable amount of hand pressure. Do not use waste or a fluffy cloth for this purpose.

To remove all trace of carbon, scrape the pintle (which has two diameters) either with the finger nail or, very carefully, with a knife. Emery paper or any similar material must on no account be used.

To clean out the nozzle orifice, sharpen a match stick to a point and use it to ream out the hole. On no account must any metal object be used.

Immerse the nozzle body in a cup of paraffin and, placing the valve in position, pump the valve up and down vigorously.

The valve seat in the body may be wiped by wrapping a thin rag round a match stick and inserting it into the nozzle body.

If a compressed air supply is available, the body may with advantage be blown out.

With a clean valve seat, the valve, when snapped smartly on to its seat, should produce a metallic click. Any stickiness or softness will indicate that there is dirt on the seat.

It is important to observe that *on no account must any abrasive substance be used* on the valve or nozzle.

Before assembling *the nozzle valve it should be dipped in clean Diesel fuel oil* so that the valve slides freely in its guide. Immediately after cleaning the nozzle it should be tested on a nozzle testing apparatus, in order to check it for correct working.

Absolute cleanliness must be observed when handling nozzles, or the defect to be remedied may be retained.

Precaution with New Fuel Piping

When a new fuel pump and its piping have been installed there is always the possibility of fine particles of scale or dirt from inside the piping becoming detached. Owing to the great difficulty of ensuring that all such particles have been removed from the interiors of the delivery pipes some manufacturers recommend that the first run-in with new fuel injection equipment should be made with a set of test nozzles in the atomizers, in order that the permanent nozzles belonging to the engine shall not be damaged by any particles of dirt from the delivery pipes.

Notes on Injector Nozzle Maintenance

The following notes give, in greater detail, the methods recommended[1] for determining nozzle faults and remedying them ; these notes are intended to supplement the information previously given.

To free sticking injector valve.—A badly stuck valve may be found to be firmly fixed in the nozzle body. To remove, grasp the projecting stem of the valve carefully with a small hand vice, or in a bench vice with soft jaws, and work the nozzle body carefully with the fingers to free the valve. Soaking in paraffin or the application of a drop of Graphol may be found helpful. No undue force must be used, and if the valve cannot be freed by adopting the above method, the trouble is probably due to distortion, and a new nozzle must be fitted.

After removing the valve, proceed as described for cleaning the nozzle, scraping the barrel of the valve with the finger-nail if it shows any signs of carbon.

[1] These methods are principally employed on the A.E.C. oil engines.

If this does not free the valve, it should be lapped into the body, using *Oil*, or, in extreme cases, a little *liquid* metal polish may be applied. *On no account must any abrasive substance be used.*

When fitting a new nozzle, both the nozzle and valve must be renewed. Owing to the high degree of accuracy required, the valves are not interchangeable and *must always be kept in the nozzle in which they are supplied.* For this reason it is as well never to remove more than one nozzle at a time ; otherwise the parts may get mixed up.

The valve should be perfectly free in the nozzle, but without any perceptible shake.

To determine a cracked nozzle.—A cracked nozzle is a very rare occurrence and is difficult to see even with the aid of a magnifying glass. The crack will nearly always be around the circumference in the corner between the two diameters.

The fact that the nozzle is cracked should have been ascertained by the test made immediately after removing the injector from the engine. Should this not have been done, repeat the test as already described.

Provided the nozzle cap nut has been screwed up tight, and the jointing face of both the nozzle body and the nozzle holder are clean and undamaged, dribble from any point other than the orifice will indicate a cracked nozzle. Dribble from the orifice will indicate one of the other causes mentioned.

To detect a broken spring.—When placing the nozzle and valve in position, on the face of the injector, the spring will, if intact and in correct adjustment, prevent the nozzle body from being brought into contact with the injector body face if pressed with the hands. If the two faces come together, it will indicate either a broken spring, or that the adjusting screw has slacked right off. Both of these are most unlikely to occur.

To replace a broken spring.—Remove the end cap and, *without touching the adjusting screw or lock nut,* unscrew the spring cap nut. The broken spring can then be lifted out and a new one substituted. On replacing the spring cap nut, the proper adjustment will be obtained if the adjusting screw has not been interfered with.

Improper spring adjustment.—An alteration in spring adjustment is almost an impossibility unless the lock nut has been interfered with. The proper adjustment of the spring tension requires special equipment and enquiry should therefore be made at the fuel injector manufacturer's Service Station.

The correct pressure is 95 atmospheres (1,400 lbs. per sq. inch).

With the type of injector fitted to the A.E.C. engine, it is unnecessary to have the injector pressures checked periodically.

Replacing the injector.—To make sure that the injector is working properly, it is as well to check it before replacing. To do this, repeat the test given for use when the injector was first removed.

In order to eliminate air from the pipe, after replacing the injector, leave the fuel-pipe union nut slack until the engine is running or, in the case of a cold engine, the engine has been turned over sufficiently to make the fuel flow from the union.

Persistent dribble from the nozzle orifice, despite careful cleaning, or after fitting a new nozzle, will indicate that the fault lies in the fuel injection pump. If this is suspected, test the injector on the fuel line of a cylinder which is operating satisfactorily and, if found in order, examine the pump.

The Gardner Fuel Injection Sprayer

The fuel injector or sprayer is of the non-adjustable multi-hole type that has been used on Gardner engines for over 30 years.

These sprayers should be withdrawn from the engine every 3,000 to 4,000 miles and any carbon deposit wiped from around the holes. The needle valves should be examined to ensure that there are no leakages and the jet holes in the nozzles should be clear, each delivery the same amount and shape of spray.

It should be noted that with certain grades of fuel there is a greater tendency to carbonisation of the jets than with other fuels.

Fig. 145 illustrates the construction of the Gardner spraying nozzle, the tool for holding the valve for grinding purposes being shown on the right.

The principal items of attention are (1) The jet holes; (2) The seating between the piston valve and its valve seat; and (3) The injection pressure valve.

The sprayer should be tested for stoppage of the jet holes by removing it from the cylinder and connecting it again in the open-air where the spray may be observed whilst the hand lever of the pump is worked. If the sprays from each jet are not of the same shape and of equal size the sprayer should be dismantled and the jet holes pricked with the correct size of pricker supplied by the makers. At the same time the central bore of the nozzle should be cleared out, as any particles dislodged naturally fall into this central bore. The method of clearing the latter is by forcing liquid through the jet holes *from the outside of the nozzle to the inside.* For this purpose a special syringe is supplied for use in conjunction with a special nozzle which replaces the sprayer nozzle during the operation. The extra equipment is necessary by reason of the futility of any attempts to clear the central bore by forcing liquid in the same direction as the flow of the fuel when the sprayer is at work.

If subsequent tests, after the sprayer has been reassembled, reveal serious leakage between the valve and its seating, the whole sprayer should be replaced by a spare (one of which is supplied with each engine) ; for while it is sometimes possible to restore the defective seals by the aid of the special grinding tool, shewn in Fig. 145, this should be attempted only as a final resource, a far better plan being to send the defective sprayer to the Gardner engine works for rectification. The cleaning charge is a very low one.

With regard to the one other condition of sprayer action mentioned above, a pressure of 60 lbs. per sq. in. should compress the spring to a length of exactly $1\frac{5}{16}$ in.

One very important point to be observed whilst sprayers are in course of being dismantled is that of keeping every one of the component parts together, for, since the vital parts are lapped together before assembly at the works, the

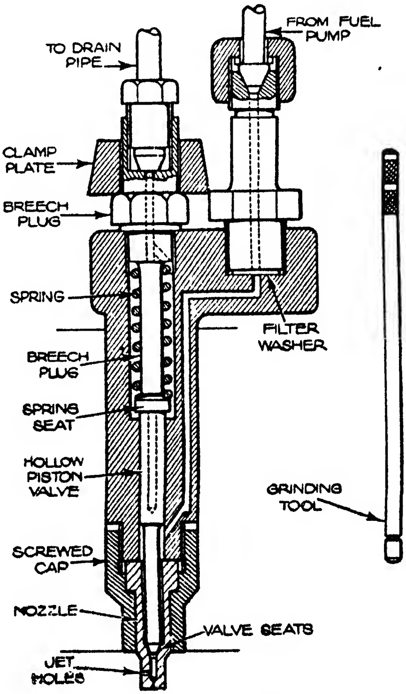

FIG. 145.—The Gardner Multiple Jet Sprayer and (on right) Tool used for grinding purposes.

sprayers may not operate properly should their components become mixed inadvertently. This happens to be one of the rare instances where interchangeability is not practicable.

The sprayer valve *should be tested for leakage* by the outside testing method, giving the fuel pump handle a few strokes in order to expel all air from the fuel. The pump handle should then be pressed with a force just short of that required to lift the sprayer valve from its seating. If *the valve is unsound,* fuel will emerge from the jet holes and run down the nozzle. If more than two drops per minute leak out the valve seating should be examined for dirt or wear effects. In any case the valve and its seating should be washed with clean paraffin. If, on further trial the valve still leaks, the seating may require grinding in.

The method of grinding in a sprayer valve seat is as follows :

Take the sprayer to pieces in the following order : (1) The screwed cap and the nozzle ; (2) The breech plug and spring ; (3) The hollow piston valve with the small spring seat.

Remove the spring seat from the hollow end of the piston valve and screw into the hollow the knurled grinding tool supplied with the engine and replace the piston valve in the sprayer. Then smear the valve seat *with the most minute possible dab of flour emery and oil, taking the utmost care that no emery gets anywhere but on the valve seat, as otherwise it might tend to destroy the close fit which is so essential for the piston.* Placing the sprayer nozzle in its screwed cap, screw the latter about two turns on the sprayer body, then, while pressing the piston valve hard down on to its seat in the nozzle, by the aid of the grinding tool, screw home the cap, first with the fingers and then tighten up lightly with a spanner. The object of this step is to ensure that the valve seat in the nozzle is in perfect alignment with that on the piston valve. During grinding apply only very *light hand pressure.*

After grinding take the sprayer to pieces and wash every part scrupulously clean with clean paraffin, and, *without wiping,* reassemble in the following order :

(1) The piston valve with the small spring seat at the upper (hollow) end ; (2) The spring ; (3) The breech plug ; (4) The screwed cap with the nozzle in place.

It is essential to follow the above reassembling instructions in order that the spring pressure on the piston valve shall bear on the valve seat of the nozzle all the time during the screwing home of the cap.

FIG. 146.—Illustrating method of Cleaning or Testing the Gardner Injector.

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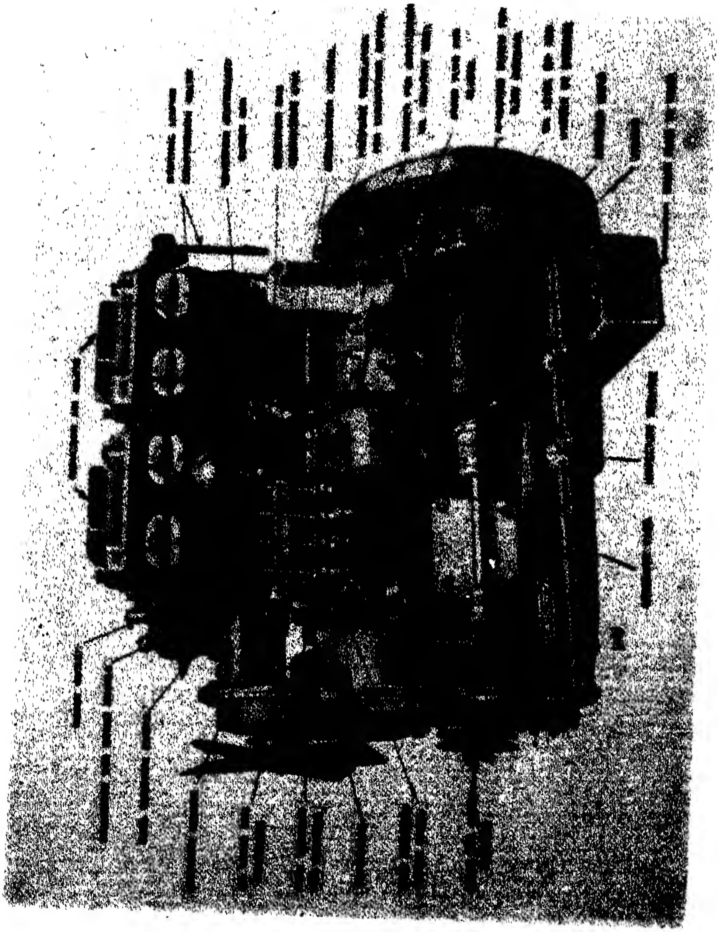

FIG. 147.—The Gardner Four-Cylinder High Speed Oil Engine

[To face page 155.

The correct lift of the piston valve is 0·008 in. For this reason the parts of each sprayer should be kept together and not interchanged with those of another sprayer.

The Armstrong Saurer Injection Nozzle

The injection nozzle used in the " dual turbulence " engines is of the multi-hole pattern, having four holes each of 0·25 mm.

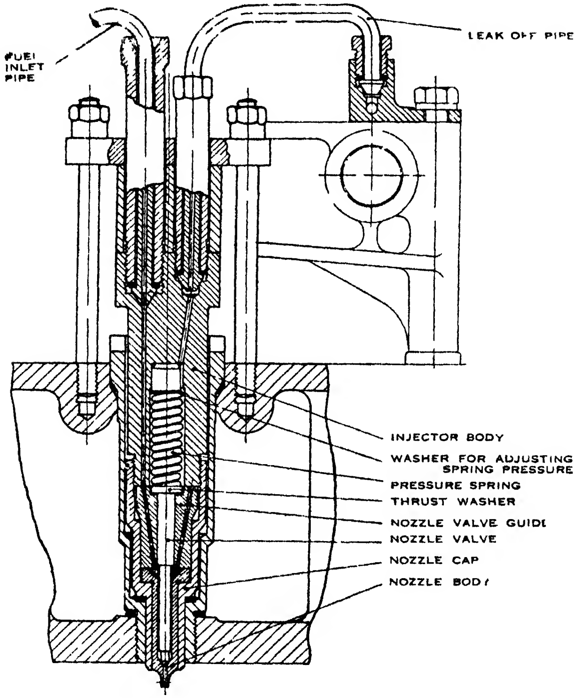

FIG. 148—Armstrong Saurer Fuel Injection Nozzle in Cylinder Head

diameter, giving a horizontal spray when in position. This nozzle is shown in outline in Fig. 8, and in detail in Fig. 148.

In connection with this type of nozzle, special care of the fuel filtering arrangement is essential to prevent blockages. The injector is situated in a special steel housing, the latter being screwed directly into the cylinder head; the water jacket surrounds this housing. The water seals comprise a copper joint at the bottom and a rubber ring at the top; it is recommended that a new ring be used each time the joint has to be remade. Further, a liberal amount of soft soap should be smeared over the ring before screwing the housing down.

The copper washer should come out with the injector when the latter is removed. To facilitate refitting of the injectors it is advisable to stick the washer on to the nozzle body with a little grease; this will prevent the washer falling into the interior housing.

The copper washers for injector joints should occasionally be annealed by heating to a black heat and quenching in water.

The injector nozzles are set to an opening pressure of 190 to 200 atmospheres (2,800 to 3,000 lb. per sq. in.).

The Cummins Injection System

The injection system employed on the well-known American Cummins engines which are used for motor vehicles, marine, railroad and stationary purposes, employs a single plunger fuel pump for measuring and delivering the fuel at relatively low pressures, viz., 90 to 120 lbs. per sq. in. to all of the cylinders, irrespective of the number of the latter and regardless of the setting or adjustment of the fuel pump. The fuel is distributed by means of a rotary type distributor disc to each of the cylinders in turn.

The single plunger pump is given a variable stroke, the latter being controlled by hand throttle or governor; the maximum stroke is such that no more fuel is delivered than can be burned in the cylinder with the available air charge. Valves are eliminated in this type of pump by the distributor disc, previously mentioned, with proper posts which index as they revolve in correct time with the suction and discharge of the plunger. In order to operate satisfactorily at high speed, it is necessary to deliver the fuel to this pumping and distributing mechanism under a certain pressure. A small gear-wheel pump with pressure regulator takes the fuel from the main tanks and delivers it at 90 to 120 lbs. per sq. in. pressure to the plunger chamber. In this way the use of the ordinary high fuel pressures has been avoided. Fig. 149 shows the general layout of the Cummins fuel metering and delivery to the positively operated injector valve, all of the important components being suitably annotated; the arrangement of the distributor shown on the extreme right hand side is for a six-cylinder engine.

The advantages of this method of fuel delivery and injection are, firstly, that it is a " valveless " system; secondly, exactly

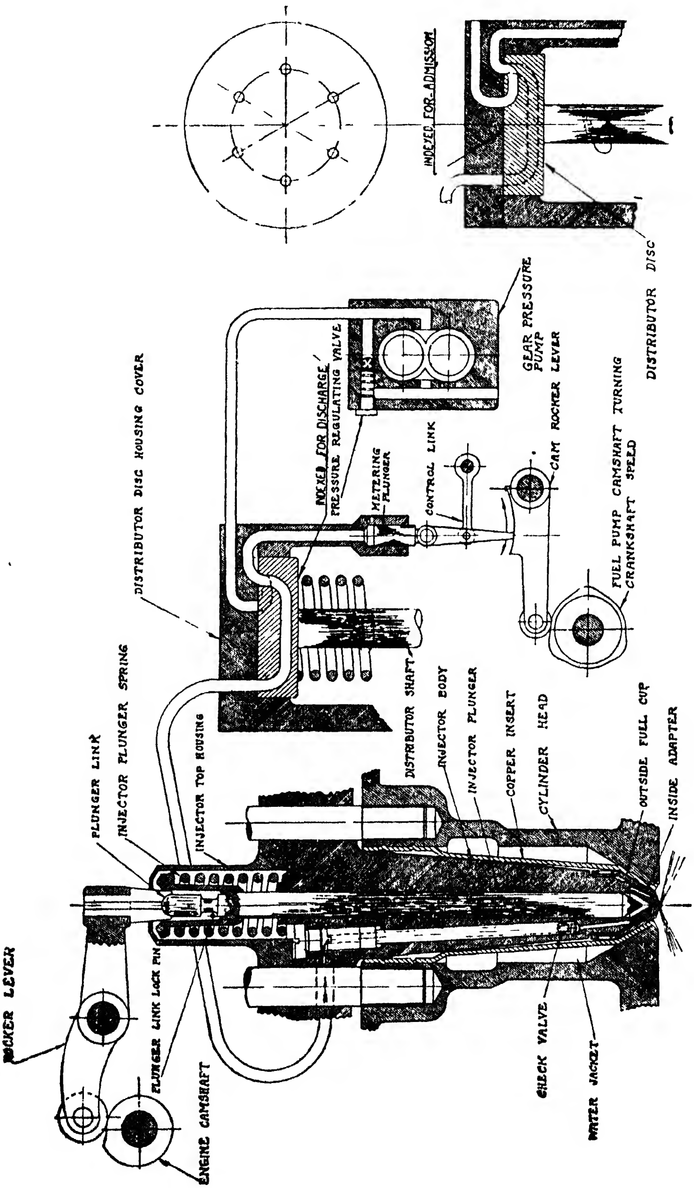

FIG. 149.—The Complete Fuel Injection System of the Cummins Engine.

the same quantity of fuel is delivered to each and every cylinder; and, thirdly, the use of low fuel pressures in the delivery side of the system.

In regard to the injector (Fig. 149), the cup assembly consists of the outer cup and a cone adapter, one fitting inside the other. The inner adapter is a ground fit to the outer cup and must hold both the fuel pressure and the combustion pressure.

The cone adapter seats on the end of the injector body. This seat is ground at the factory and if taken care of properly should last the life of the injector. Any small nick, dent or piece of dirt on this seat will cause it to leak and permit the fuel oil to flow up around the injector body and dilute the lubricating oil.

If the outer cup shows discoloration from heat above the tip, which extends into the combustion chamber, or the injector assembly sticks when being removed from the head, this indicates that the seat between the outside cup and the head is leaking. If this seat leaks and blow-by is permitted, the injector cup will become so hot the fuel will carbonize and the spray holes will stop up.

Make sure both the cup seat and the seat in the head are clean.

If the fine fuel spray nozzles of the injector cup should become clogged or the spray holes obstructed, it is usually caused by improper setting of injector plungers, dirt in the fuel or operation of the engine at overload or an overheated engine. A cup cleaning kit is furnished, consisting of a file card brush with two openings in the end of the handle in which will be found a small drill, several very small wire drills and a drill vice for these small drills.

(1) Hold injector in left hand, as it is taken from engine. Clean cup by brushing lightly with brush. Do not use file or emery cloth—only the brush furnished by Cummins Engine Company.

(2) Hold the outer cup as shown, upside down, when using large drill in order that any foreign matter may fall out of the cup. *Never use a drill other than the one supplied by the makers for this purpose.*

(3) When cleaning small spray holes have the small wire drill project not more than $\frac{1}{32}$ in. from its holder. Apply the drill at the angle shown in Fig. 151 and be sure that no burrs occur on the end of the drill; otherwise it will not enter the small holes in the cup.

The small holes *A* and *C* (Fig. 150) in the small adapter or inside cup should be cleaned with the small drill furnished in the cleaning kit. These holes are fuel passages and if allowed

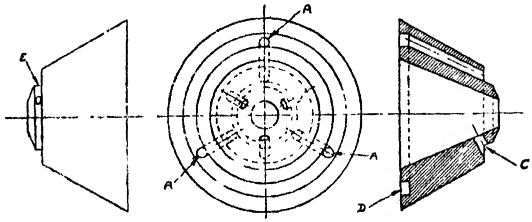

Fig. 150.—The Cummins Injector Cone.

to carbon up will cause a falling off in power. The small groove *D* (Fig. 150) in the seat of the cup should be kept clean, but the seat against the body must not be scratched or fuel will leak past the cups, causing dilution. Annular space *E* should be brushed clean if any carbon collects.

After cleaning an injector cup, fill it with clean fuel and blow the fuel through the spray holes.

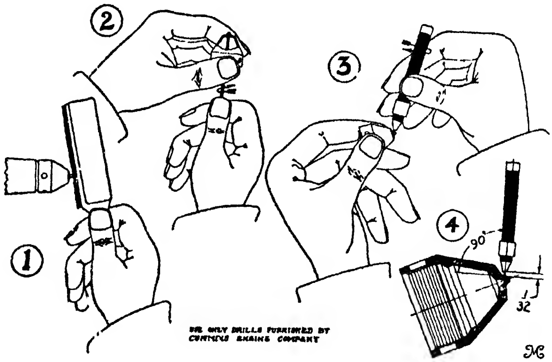

Fig. 151.
Illustrating Method of Cleaning Cummins Injector Cup.

Each spray should spurt out in the proper direction, and at the proper angle, making a balanced pattern.

If one of the sprays should be deflected, the hole should be re-cleaned. Deflection of a spray causes it to strike against the cylinder wall or cylinder head, where it condenses and will not readily burn, because it will not be in fine particles with each particle completely surrounded with air.

The Simms Uniflow Pump

This make of pump, by a well-known magneto manufacturing concern, operates on the jerk-pump principle in which an accurately metered quantity of fuel is introduced into the pump chamber before the beginning of each working stroke. By cam action the plunger is moved upwards, thus discharging the fuel through a delivery valve to the fuel piping. The pump works on the system of constant directional flow — or "uniflow"—and its principal elements are (1) A suitably recessed and ported plunger; (2) A similarly machined working barrel; (3) Delivery valve; and (4) Mechanism for rotating the plunger to give variable cut-off or spill.

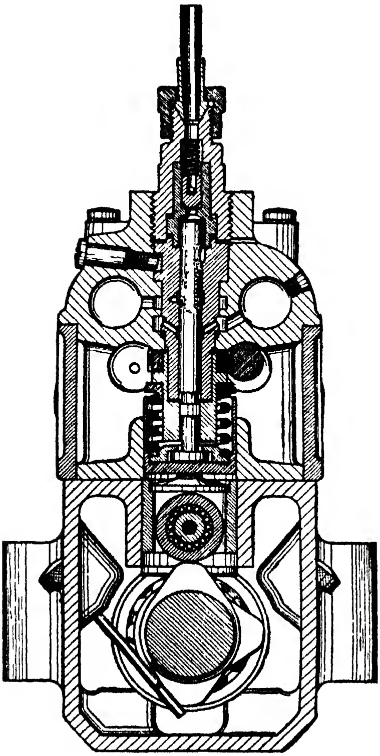

FIG 152 —End Sectional View of Simms Fuel Pump.

Referring to Fig. 126 and assuming the plunger to be at the outer end of its stroke, the pump working chamber has been filled with fuel-oil drawn into it during the previous suction stroke. The upward stroke of the plunger raises the pressure of the contained oil and forces it past a valve into an atomiser pipe and atomiser, where the oil is sprayed in the well-known manner. In this way a full metered charge of oil is delivered to the atomiser. When, however, in response to governor action or hand control, an earlier cut-off is necessary, the working plunger is rotated a few degrees by a rack and pinion mechanism. This action, at a certain point in the stroke, brings the plunger helix into coincidence with the helical edge of port cut in the upper end of the barrel. Thus fuel trapped in the working chamber "spills" into the helical channel of the plunger, whence it is ejected at high velocity into the spill annulus.

Next, during the downward—or suction stroke, oil enters the suction annulus (under some pressure) by way of the ports shown, and when the plunger is near its lowest position this oil passes into the axial suction duct in the plunger, through the radial ports shown and thence is delivered to the working chamber The direction of flow of the oil is always the same, there being no reversal of flow. Another advantage of the arrangement described is the scavenging action given by the supply fuel. The Simms pumps are made in plunger diameter sizes, from 7 mm. to 11 mm. for automobile engines ; they are compact in form and easy to instal. A series of models for industrial and marine engines, both single and multi-cylinder, with plunger diameters from 6 to 16 mm. and strokes from 7·5 to 16 mm.

Notes on Simm's Fuel Pump Maintenance

After a pump has been dismantled for inspection it is necessary to see that every part is quite clean ; each item should be washed in petrol or fuel oil and wiped with clean "fluff-less" cloth. It is preferable to use compressed air for cleaning, however.

In order to ensure the correct operation of the re-assembled pump, it is vitally important that each part should be re-assembled in the reverse order to that taken down. To facilitate re-assembly it is advisable to use a partitioned box during the process of dis-assembling so that the various parts can be kept separately.

It is not here proposed to give a detailed account of the method of assembly since the maker's issue a fully illustrated handbook on the subject of "Service and Assembly Instructions."

After assembly, the method of balancing the fuel pump necessitates checking the phase angle, correcting any errors by the method of changing the spacing pieces ; the calibration should also be checked.

Check Phase Angle.—The elements should commence to inject fuel in a definite sequence, and at precisely equal intervals (limits of 1°)—thus, for one type the sequence is 1 4 2 6 3 5, and phase angle is 60° plus and minus ·5°.

Correct Errors by Changing Spacing Pieces.—Standard

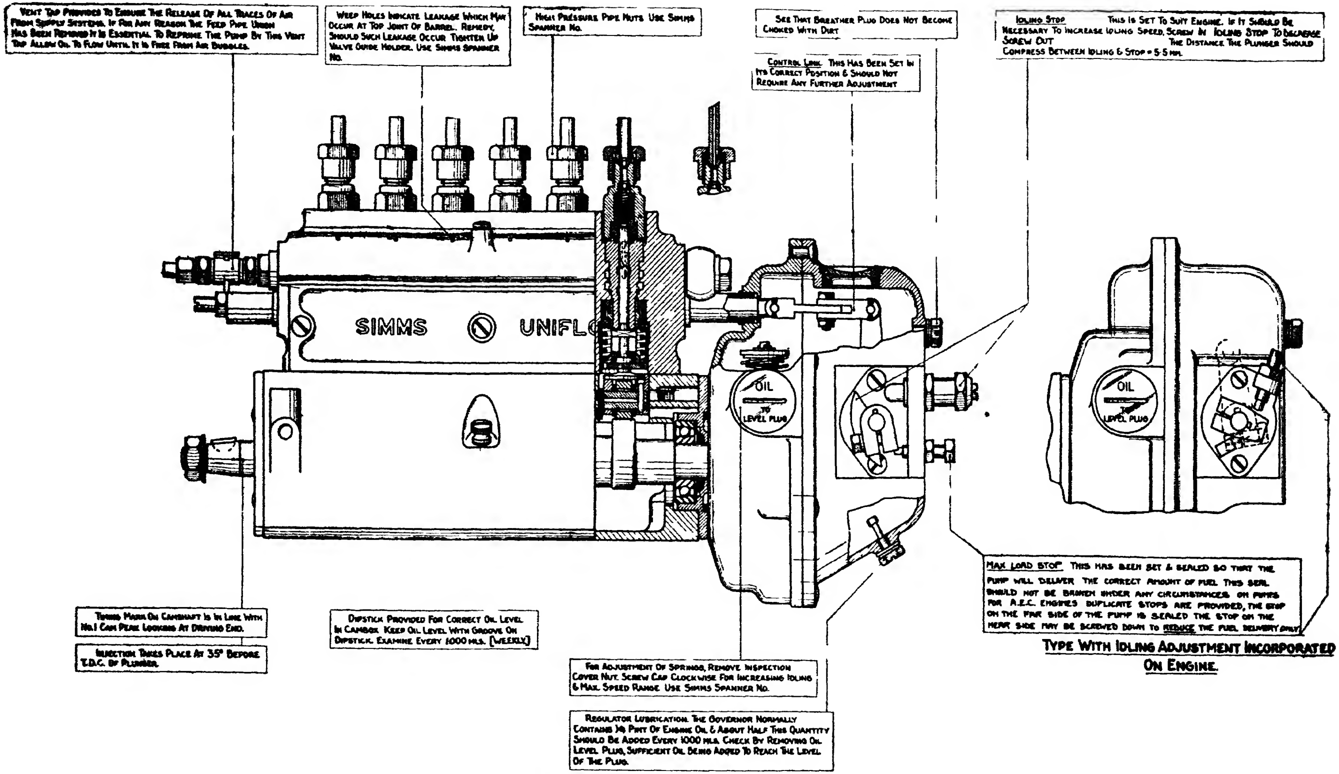

Fig. 153.—Maintenance of Simms Fuel Injection Pumps

spacing piece is 5·5 mm. thick. To *advance* timing 2° fit 5·7 mm. spacing piece. To *retard* timing 2° fit 5·3 mm. spacing piece. (These are standard stock sizes. Intermediate sizes are available.)

e.g.—When phase angle is, say, 0 to 58° a 5·3 mm. spacing piece is needed. If 0 to 62° a 5·7 mm. piece is required.

Calibration.—Each element should deliver an equal quantity of fuel per stroke.

A coarse adjustment can be made by moving pinion and sleeve together—after disengaging rack—any number of teeth necessary. Or, when the rack is out of mesh, by moving pinions in relation to sleeve giving vernier adjustment. Vernier adjustment is obtained by moving the pinion sleeve one hole and the pinion two teeth in the opposite direction in relation to the rack.

To increase amount of fuel, move pinion to left in both cases, except when barrels and plungers have right-hand helices.

. The following precautions are necessary, namely :

(*a*) See that top spring plate is seating, *after* using clamp.

(*b*) Also, that the spring container is at bottom of its stroke *during adjustment.*

Approximate Differences made by Adjustment. Pintle nozzle (set at 1,500 lbs. sq. in.) : One *tooth* on control pinion makes 30 ccs. per 1,000 strokes. One *hole* in control sleeve makes 4 ccs. per 1,000 strokes.

Hole type nozzle (set at 2,350 lbs. sq. in.) : One *tooth* on control pinion makes 20 ccs. per 1,000 strokes. One *hole* in control sleeve makes 3 ccs. per 1,000 strokes.

Theory of Adjustments. Pinions have 34 teeth, therefore one tooth moves plunger through 10°. 35 mins.

Sleeves have 18 holes, therefore one hole movement equals $\frac{34}{18}$ teeth, and, upon re-engagement with rack, moves plunger through 1° 6 mins, equals 1/9th tooth.

Maximum Setting. The Control stop or stops on regulator should be set so that delivery is :

Leyland Pumps—80 ccs./1,000 strokes at 500 r.p.m.

A.E.C. Pumps—93 ccs./1,000 strokes at 600 r.p.m.

Variations in Fuel Delivery may be Caused by : (a) Condition of Valves, due to:

1. Dirt.
2. Lift not being standard 1 mm.
3. Strength of springs not standard.

Effect No. 2—If the lift is too great the delivery is low. The reverse happens with too little lift.

Effect No. 3—Spring too strong, means high delivery, because lift is restricted.

(*b*) *Condition of Atomisers*, due to :

1. Dirt.
2. Wrong pressure setting. *Standard settings are* :—
   Pintle—1,500 lb. sq. in. or 100 atmospheres.
   Open or hole—2,350 lb. sq. in. or 160 atmospheres.
3. Sticky needle.
4. Leaky joint face between nozzle and body.

The Bryce Fuel Pump

This belongs to the constant stroke plunger class, and control is effected by the co-operation of drilled passages in the pump barrel and helical groove on the plunger.

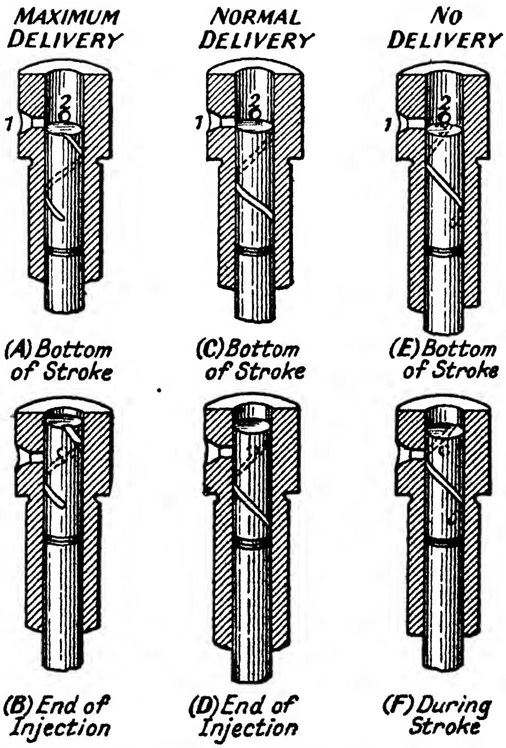

FIG. 154.—The Bryce Fuel Pump Plunger Positions.

For control the plunger is rotated by means of a control rod having teeth forming a rack which engages with the plunger through the medium of a pinion and slotted sleeve. Fig. 154 shows the pump plunger and barrel in different relative positions.

Fuel is supplied under gravity from the service tank, through suitable filters, and then to an annular space in the pump housing around the ports 1 and 2 (Fig. 154) in the barrel. When the plunger is at the lowest position, it does not cover the ports and fuel can flow freely into the barrel.

Views (*A*) and (*B*) show the plunger in the angular position giving maximum output: as the plunger rises it first expels oil through the ports towards the fuel tank, but when the ports are covered delivery begins and continues until the helical groove reaches port 2, after which the further movement of the rising plunger forces the fuel down the helical groove and out of the pump barrel through the port 2.

For normal delivery the plunger is as shown in views (*C*) and (*D*), the sequence being the same as for maximum delivery except that owing to a different angular position of the plunger, the groove reaches the port 2 earlier and the delivery is reduced.

When no delivery is required, the plunger is rotated to the angular position shown at (*E*) and (*F*). In this case, before the plunger has completely covered the ports 1 and 2, and before the groove has passed port 2, it reaches port 1 and so communication is always maintained between the pump pressure chamber and the suction annulus —via the helical groove and ports.

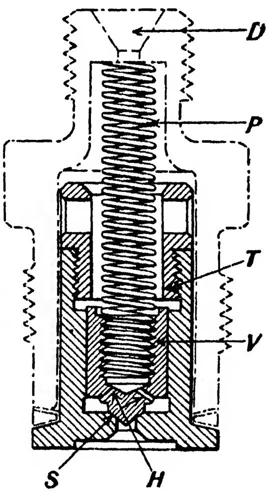

FIG. 155.—The Bryce Fuel Pump Delivery Valve.

With reference to (2) the Bryce delivery valve is of the plain thimble type, with a conical seat *S* (Fig. 155), the valve itself being shown at *V*, which is lifted by the pressure of the fuel in the element on delivery stroke. When the fuel has passed the valve seat it has to pass through two holes *H* in the lower end of the thimble, and thence from the interior of the valve to the discharge union *D*.

The size of the holes *H* is so graded that the flow of fuel through them is sufficient to overcome the pressure of the spring *P* on the valve and raise this latter till it comes against its stop *T*. It remains in this position throughout the period of delivery.

When spill occurs the pressure in the element falls suddenly, and the pressure in the delivery pipes acting in conjunction with the spring, forces the valve down on to its seat. A certain amount of fuel flows back through the holes in the valve into the element, and the combined result of these two actions is an effective and sudden pressure drop in the delivery pipe, so that the needle valve in the atomizer can seat promptly and cut off the injection without dribble.

Maintenance of Bryce Fuel Pump

All equipment is sent out from the factory in correct adjustment. The only maintenance required for a very long period, if the equipment receives proper usage, is occasional cleaning. It should not be necessary to dismantle the pump, except at very long intervals, providing it is supplied with really clean fuel and lubricating oil.

On no account must repairs be attempted to the pump element (barrel and plunger), delivery valve, or nozzle and needle. In case of any failure of these parts they should be returned to the makers.

Dismantling.—As with other fuel pumps absolute cleanliness is essential when handling the component parts.

The spring circlip retaining the pump tappet must first be removed, and to facilitate this the pump tappet should be pressed in until a pin can be inserted in the hole provided in the spigot. After removing the circlip and pin, the pump tappet, lower spring plate, plunger spring and pump plunger should be carefully withdrawn. The next operation is to unscrew the delivery union at the top of the pump, when the delivery valve can be withdrawn by means of the special tool which is supplied by the makers.

After unscrewing the barrel-locating screw, the barrel may be removed from the top of the pump by pushing it from underneath with a piece of soft wood or brass.

The parts from each pump unit must be kept together and separate from other units, and it is most important to keep the plungers with the barrels into which they were originally fitted. The plunger and barrel constitute a "mated" unit and the parts are not interchangeable with portions of other units although they may be of the same size.

Re-assembling.—Before assembling, each part must be washed in clean fuel oil, paraffin or petrol, but not wiped dry, as particles of foreign matter may adhere. It is advisable to use a small quantity of lubricating oil to assist in assembly.

Replace the pump barrel and its retaining screw, taking great care that the joint washer is under the screw head, and that the end of the screw enters the slot provided in the barrel. The screw is *not* intended to lock the barrel, but only to retain it; there must therefore be a small axial movement of the barrel after tightening the screw. Replace the delivery valve assembly and the joint washer, and screw the delivery union in place and tighten.

Note.—It is useless to replace the delivery union with a damaged delivery union joint washer, as this will cause pump leakage.

If the control rod and pinion have been removed they must be assembled according to the adjusting marks; the pinion may then be retained in position by the upper spring plate and retaining circlip. Replace the plunger spring, plunger (taking care that it is in its correct angular position), lower spring plate and pump tappet. The marked plunger lug or dog must fit in the marked slot, when the tappet can be depressed allowing a pin to be inserted while the spring circlip is being replaced.

Fuel Pump Timing.—In order to establish the position of the plunger when fuel delivery commences, a small inspection window is provided in the pump housing on the side of which is a mark. On the pump tappet there is also placed a line which should still be visible when the plunger is at either the top or bottom of its stroke. When the line on the pump tappet corresponds to the line on the inspection window, injection of fuel commences.

Fuel Line Pressure Indicator

It is often convenient to be able to measure the maximum oil pressure in the fuel line piping between the pump and injector. Apart from checking the maximum pressure this enables the nozzle opening pressure to be measured and any undue resistances to flow detected in the fuel line piping.

A convenient maximum pressure indicator for this purpose is that shown in Fig. 156. It depends upon the measurement of the oil pressure that will operate a spring-loaded plunger.

The spring in question can be adjusted and its regulating screw has a micrometer type of scale which reads the plunger opening pressure in kilograms per sq. cm. (0 to 1,000). It is, therefore, only necessary to insert this device in the pipe line, apply the fuel pump pressure by running the pump at its normal speeds, and then to adjust the spring regulating screw until oil just commences to flow from the holes above the plunger.

The pressure indicator can be used with a hand-pump on the bench to check the opening pressure of the fuel injector valve. A further use is that of a safety valve in the fuel piping in order to obviate the occurrence of any excessive pressures; in this case the indicator plunger is set to move when the pressure in the line is at the predetermined or given maximum value.

The indicator in question can be fitted near the fuel pump (Fig. 156A) or at the injector nozzle end of the pipe line. *When used for measuring the maximum pressure* the regulating nut 3 (Fig. 156) is adjusted above the pressure value anticipated. The engine is started and when running normally, the regulating nut turned slowly backwards until there is just a perceptible flow of fuel from the indicator; the maximum pressure can then be read off the scale.

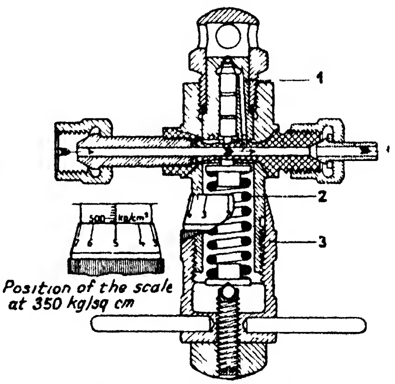

FIG 156—The Bosch Fuel Line Pressure Indicator
1—Nozzle 2—Spring 3—Regulating nut

To adjust the injection nozzle opening pressure the indicator is fitted near to the former in the pipe line and the regulating nut 3 is adjusted to the desired nozzle opening pressure. The regulating screw of the spring on the nozzle is then adjusted so that the nozzle sprays satisfactorily in the open air when the fuel pump or priming pump is operated.

To use as a safety-valve it is only necessary to set the indicator scale to the maximum permissible pressure reading. If the latter pressure is exceeded fuel will escape from the indicator.

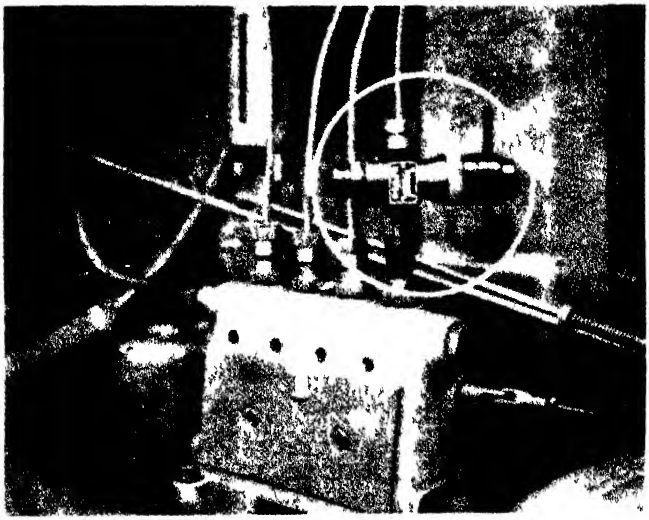

Fig. 156a.—The Bosch Fuel Line Pressure Indicator.

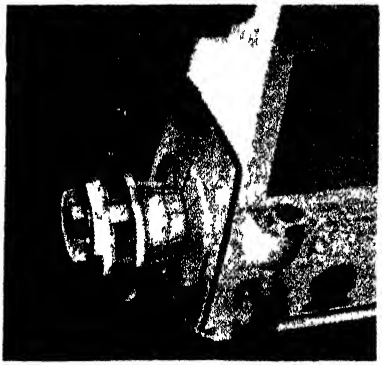

Fig. 157.—A.E.C. Fuel Pump Timing Device.

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CHAPTER IX

TIMING THE FUEL PUMP: THE GOVERNOR

Timing the Fuel Pump

THE injection process, as previously mentioned, must be accurately timed, or arranged so that it commences at a definite moment in relation to the piston's position when approaching the end of its compression stroke.

The actual point of commencement of injection depends upon several factors concerned with the engine design, such as the mode of injection, combustion chamber design, compression ratio and engine speed, so that each particular engine has its own injection setting.

For commercial vehicle engines, it is usual to arrange for the injection to commence from 10° to 30° before the piston reaches its top dead centre; this is known as the *Injection Advance*, and its value should be ascertained from the engine manufacturers. The general procedure, where fixed injection advance is employed, is as follows:

Set No. 1 piston on its top dead centre on compression stroke. The inlet and exhaust valves should both be closed, so that the compression can be distinguished from the exhaust stroke. The flywheel should then *be rotated backwards*, i.e., in the opposite direction to its normal rotation, *by an amount equal to the injection advance angle.*

Usually the manufacturers engrave marks on the flywheel rim representing the T.D.C. position of No. 1 piston and also the Fuel Injection Advance. The latter mark will be found some 10° to 30° before the T.D.C. one and should be set opposite the fixed mark, or pointer on the crankcase or clutch housing.

The next operation is to set the fuel pump so that its No. 1 cylinder feeding plunger is just about to deliver fuel. It will be assumed that the engine drive to the fuel pump is disconnected, so that the fuel pump shaft can be turned by hand.

In order to ascertain when No. 1 plunger is just delivering fuel the pump should first be examined for indicating marks, for certain *types of fuel pump are provided with windows* through which marks on the plungers can be observed. When these marks, in turn, coincide with fixed marks on the sides of the windows the plungers are just commencing their injection. In this case it is only necessary to bring the fixed and moving marks of No. 1 plunger into coincidence when the engine drive to the fuel pump can be coupled up and the injection timing will be correct.

If no such marks are found on the fuel pump the fuel should be turned on to supply the pump and the control lever set so as to deliver fuel. The delivery pipe union should be disconnected at the pump end and the surplus fuel wiped off with the clean finger (do not use a cloth) so as to leave a concave surface on the fuel remaining in the pump delivery passage of No. 1 plunger. Now, turn the fuel pump's shaft in its correct direction of rotation—which is usually opposite to the engine rotation—until *the concave surface suddenly flattens*; this indicates that the plunger is just commencing to deliver fuel.

The engine drive should be connected to the pump shaft at the latter's coupling, without altering the positions of the engine crankshaft or pump shaft, when the fuel injection timing will be correct.

Typical Engine Timings

In order to illustrate the injection timing procedure more fully, the methods employed on two well-known C.I. engines, viz., the Leyland and A.E.C., will be described in detail.

In the Leyland engine, when correctly timed, injection begins at the pump 27° before T.D.C.; no other timing should be employed. The timing may be checked as follows:

Turn on the fuel and set the control lever forward to deliver fuel. Disconnect the delivery pipe union of No. 1 plunger at the pump end and turn the pump shaft until fuel delivery is just commencing as tested by the concave surface method previously described.

Now check that the mark "INJ." on the flywheel coincides with the fixed mark on the clutch housing and that both valves of No. 1 cylinder are closed. If the marks do not coincide set the engine correctly and re-set the pump by slackening the drive coupling setscrews and turning the pump driven coupling by hand until injection commences. One notch (3°) on the pump shaft corresponds to ¾in. on the flywheel rim and the pump shaft rotates in the opposite direction to the flywheel.

The Bosch fuel pump used on the A.E.C. engines is timed as follows:

(1) *If the Bosch Pump only has been removed from the engine :* The coupling must be re-engaged so that the letter O marked on each of the parts of the coupling come opposite each other. The correct timing will then be picked up automatically (*see Fig.* 158).

(2) *If the Timing Chain has been disconnected :* Timing marks are provided on the flywheel to facilitate retiming the fuel pump in cases where the chain has been disconnected.

On the six cylinder engine flywheel, two markings are provided and marked OP and NP. This is necessitated by a change in the fuel pump cam ; the mark OP being that for the original pump and NP for the newer type. Before attempting to time the pump, it will be necessary to determine which pump is fitted to the engine. The necessary information is given by the Bosch type number, which will be found on a plate affixed to the side of the fuel pump. The original pump was designated PE6BA121S20, but the final S20 is the part which provides the required information. Pumps having this termination should be set to the OP mark on the flywheel.

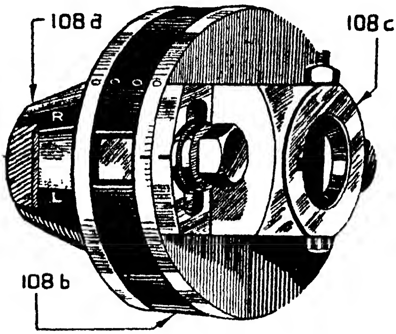

FIG. 158.—The C.A.V.-Bosch Fuel Pump Coupling.
108*a* = Pump side half coupling.
108*b* = Special fibre disc.
108*c* = Engine side half coupling.

Pumps fitted with the modified cam are designated PE6B70A121V46 or PE6B70A121S144. Only a few pumps, however, are marked with the final V46, and any so marked or which have the termination S144 must be set to the NP mark.

If the pump has no advance and retard device it is designated BPE6B70A120S144. In this case there is a mark on the flywheel ⅜in. before T.D.C. mark.

The fuel pump rotates in the same direction as the crankshaft and the pump itself is provided with two timing marks, one for each direction of rotation and marked R and L. *That marked* R *is the one which must be used.*

To time the pump, turn the crankshaft so that the pointer is opposite to the required mark on the flywheel when No. 1 cylinder (the forward one) is on compression stroke and then couple up the fuel pump so that the *line marked R on the coupling* is opposite the line cut on the end of the advance device casing (Fig. 157).

General Notes on Fuel Pump Timing

In connection with the Bosch fuel pump timing, it is essential to use the correct R or L lines (for right and left-hand rotation, respectively) on the half-coupling boss (Fig. 158), and to align these with the marks on the pump body, relative to the direction in which the pumps are to be driven.

The engine should then be turned until No. 1 cylinder is in the position (usually about 10° before T.D.C.) at which injection should commence. The engine drive and pump can then be coupled, after which final adjustments may be made by means of the adjusting slots and setscrews provided on the coupling flanges. The amount of this adjustment can be measured by means of the graduations provided on the coupling flange, each division of which represents 3° measured on the pump camshaft.

Armstrong Saurer Fuel Pump Timing

The " dual turbulence " engine with the 6 mm. plunger Bosch fuel pump, is timed so that when fully retarded injection occurs at 42°/48° before T.D.C. The advance range is 12°.

With the 8 mm. plunger and quick lift cam, the injection fully retarded is 20°/22° before T.D.C., and range 8°.

With the 8 mm. plunger and normal cam, the injection fully retarded is 30°/32° (fixed setting).

The Gardner L.W. Type Engine Timing

In regard to the timing of the valves, when re-assembling the engine after an overhaul, it is essential that this timing is correctly carried out ; *otherwise the valves will foul the pistons.*

Fig. 120 shows the valve timing diagram. It will be observed that there is an overlap of the inlet and exhaust valves. The top dead centre is ascertained as follows : Drawn across the periphery of the flywheel will be found a number of timing lines, these being a group of three for each cylinder. A short line will also be observed on top of the crankcase at the base of the cylinder ; this is the zero line.

In the case of No. 1 cylinder, when the longer line, marked "No. 1 T.D.C." registers with the zero line, Crank No. 1 is exactly on the T.D.C. and when the two shorter lines marked, respectively, "No. 1 cylinder injection 11 and 16" register with the zero line, fuel injection begins in No. 1 cylinder. The numbers 11 and 16 denote the number of degrees before T.D.C. corresponding, respectively, with minimum and maximum advance.

It is important, when timing the fuel injection, to set the pointer of the advance and retard device to the corresponding positions being timed.

Each pump is provided with a sight hole or window through which the plunger can be seen working. There is a horizontal line on the sides of the window and also one on the plunger. When these two lines coincide the pump is at the beginning of its injection period, and this occurs at the same time that the corresponding injection lines on the flywheel register with the zero line, as previously described.

The flywheel must be rotated in its correct working direction when setting or checking the fuel injection timing.

The latest method of setting the injection timing utilizes a lower line on the side of the fuel pump window. This line is marked with a dot, at a lower position in the fuel pump tappet stroke. The figures 11° and 16° become 25° and 30°, respectively, and the flywheel is marked similarly.

Should the tappet adjusting screw become deranged, it should be adjusted so that when the tappet has lifted 0.140 in. from the base of the cam, the line on the plunger coincides with the lower or dotted line on the window.

Electrical Method of Checking Timing

A simple but accurate method of checking the timing of the injection, that can be used either in the laboratory or on actual engines, is as follows: The injection nozzle plunger which lifts every time injection commences is arranged to complete an electrical circuit every time the plunger lifts. A spark gap is included in this circuit so that each time the circuit is made a spark occurs across this gap.

On the fuel pump shaft, or crankshaft, a disc, calibrated around its edge in degrees, is clamped, the scale being adjusted so that its zero corresponds to the top dead centre position of No. 1 piston. The spark gap is arranged to illuminate a slot, or small window placed close to the calibrated edge of the disc.

When the fuel pump and its injector are working the spark that occurs at the window illuminates the graduated disc, so that the reading observed by this flash gives the angle, in degrees, at which fuel injection actually occurs. It is not necessary to employ a high voltage; a comparatively low one will be found to give sufficient illumination.

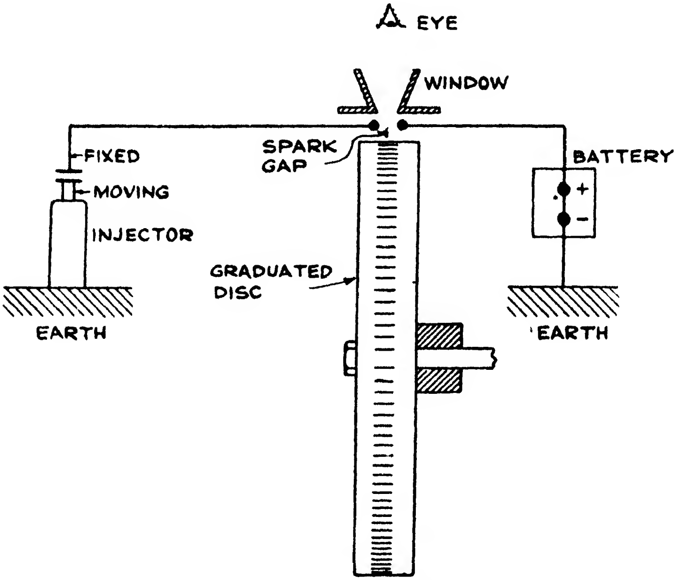

FIG. 159.—Electrical Device for Indicating Injector Timing.

The Engine Governor

Practically every type of fuel pump is now fitted with some form of governing device to limit the upper speed, for, unless this is done, excess fuel may be delivered and the engine will tend to "knock" and give a smoky exhaust. With the petrol engine this governing of the maximum speed is comparatively unimportant, since the mixture strength will not be affected to any appreciable extent.

For stationary engine purposes it is usual to provide a governor to control the engine speed to some pre-arranged value, so that the governing device regulates the period of the fuel injection (or quantity of fuel injected), in such a manner that should the load on the engine increase, tending to reduce its speed, more fuel is admitted, and less fuel if the load is reduced and the engine tends to " race."

In most cases there is a variable stop, or control, to enable the governed speed value to be altered over a certain range; this stop may be hand-controlled or only adjustable for setting purposes.

For automobile engines the governor is arranged to limit the " idling," or " no load," speed and also the maximum speed;

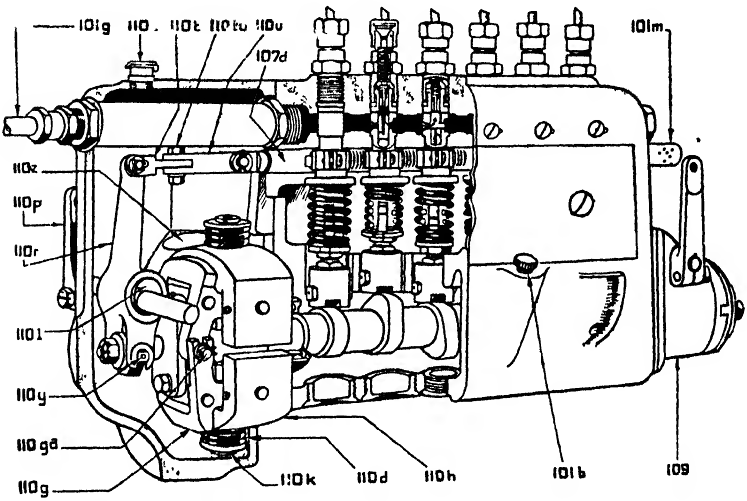

FIG. 160.—The C.A.V.-Bosch 6-cylinder Fuel Pump with Governor.

101*g* = Fuel inlet connection.	110*d, e, f* = Governor springs.
101*m* = Control rod stop.	110*g* = Bell crank levers.
107*d* = Control rod.	110*ga* = Bell crank lever pin.
109 = Advance device.	110*h* = Fly weights.
110*c* = Oil cup.	110*k* = Adjusting nut.
110*l* = Eccentric.	110*tu* = Screw for link forks.
110*p* = Control lever.	110*u* = Inner link fork.
110*r* = Floating lever.	110*y* = Coupling Crosshead pin.
110*t* = Outer link fork.	110*z* = Closing plug.

in the latter case this speed is fixed by the makers and should on no account be exceeded. The speeds between the " idling " and " maximum " values are variable at will by means of the driver's over-riding accelerator pedal control. In one example, viz., that of the Bosch fuel pump governor, it is so arranged that the fuel pump delivers rather more fuel for starting purposes than the " idling " adjustment gives.

In the case of the A.E.C. oil engines (1935), the "idling" speed standardised is 340/400 r.p.m. and the maximum speed 2,000 r.p.m., or according to special requirements. It is possible, however, to set the maximum speed to any desired value by means of an adjustable stop on the fuel pump.

In order to understand, clearly, the general method of adjusting fuel pump governors it is necessary to describe a typical governor mechanism in detail; the widely used C.A.V.-Bosch type, as fitted to the Leyland engine, will therefore be described.

In principle, the governor comprises centrifugally actuated weights complete with suitable linkage which transmits the motion of the weights to the fuel pump control rod.

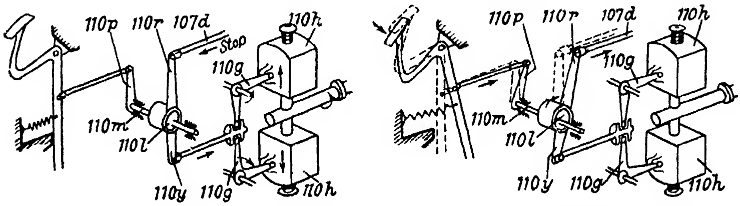

FIG. 161.—Illustrating Principle of Bosch Governor

The governor is assembled in the rear end of the fuel pump unit, i.e., on the opposite side to the driving shaft coupling.

The operation of the governor is shown diagrammatically in Figs. 160 and 161, where it will be seen that the two weights 110 h are mounted on an extension of the fuel pump cam-shaft, and to these weights are attached bell crank levers 110 g, which, in turn, are connected to the floating lever 110 r.

When the engine rotates rapidly, the governor weights tend to fly outward and thus to pull the control rod of the pump towards the "Stop" position, when the engine is slowed down. These weights are, however, retained by springs so that if the engine speed falls, the springs move the weights inwards, when the delivery of the fuel (and consequently the speed of the engine) is increased.

Referring now to the part-sectional view of the governor as fitted to the Leyland engine, shown in Fig. 162. A driving centre *A*, Fig. 162, keyed on the taper end of the camshaft *B* and secured by a nut *C*, has two cranked levers *D* pivoted at its extremities. The cranked levers are coupled to two weights *E* and to the operating shaft *F* which is carried on a bracket *G* secured to the driving centre *A*. To the rear end of the operating shaft is attached a collar *H* in which is located a guide pivoted in the forked end of the operating lever *J*. The lever *J* is pivoted on an eccentric *K* formed on the control shaft *L* supported in two bushes in the casing; the control lever *U* is secured on the end of the shaft outside the casing. The top end of lever *J* is coupled to the control rod *M* of the fuel pump.

Housed in the two weights *E* are three concentric springs *N*, the outer spring being held between the collars *O* screwed on the end of studs *P* in the driving centre, and the base of the weight. The two inner springs are held between the same collars *O* and collars *Q* which normally rest on stops *R* on the sleeves *S*.

A stop-screw is provided to limit the travel of the lever *U* and thus the delivery of fuel. This screw is set so that the maximum permissible delivery of fuel cannot be exceeded and is then sealed. *This setting must on no account be altered.* No improvement in power will result from running over-rich, while if the engine is run with black smoke in the exhaust, a piston seizure and serious damage may result. If this adjustment should slip, re-set until the engine will run with no trace of black smoke at wide open throttle at full speed.

The slow running stop-screw is provided with a spring-loaded plunger. The spring is strong enough to hold the pump control-rod at idling delivery but will permit of delivery being completely cut off to stop the engine when the accelerator pedal is lifted by the driver's toe.

The control lever is coupled to the foot throttle in the usual manner. When the foot throttle is depressed, the lever *U* moves forward and rotates the shaft *L*. The lever *J*, being pivoted on an eccentric on this shaft, moves forward using *H* as fulcrum point, and increases the delivery of fuel to the engine. As the engine speed increases, the weights tend to move outwards against the pressure of the springs *N*. When the maximum speed is exceeded, the centrifugal force of the weights overcomes the pressure of the springs and the weights move outwards. The cranked levers *D*, coupled to the weights, move in the same direction, thus causing a pull on the operating shaft *F*, which pulls the lower end of lever *J* forward. The lever *J* being pivoted on *K* and using this as fulcrum point, pulls the control rod back, thus decreasing the fuel delivery from the pump.

When pressure is released from the foot control, the control rod moves back to the " stop " position until the engine speed falls to 350 r.p.m. The fulcrum shaft is then in such a position that only the outer springs are in operation and the weights float at a radius determined by their centrifugal force and the pressure of the springs. If the engine speed increases the weights move outwards and pull back the control rod. Conversely if the engine speed decreases the control rod is moved forward to inject more fuel.

The method of adjusting the A.E.C. governor is illustrated in Fig. 163. It will be observed that there are two stops provided, viz., a fixed and an adjustable one. When the lever is brought against the fixed stop no fuel is delivered to the cylinders, and the engine therefore stops, while the adjustable stop limits the maximum quantity of fuel which can be delivered to the engine.

To adjust the idling speed so that the engine will run steadily at a low speed, the control lever must be held a short distance away from the fixed stop referred to above. Provision for this is made on the levers which are mounted on the off-side of the engine, as shown in Fig. 164, which shows the arrangement adopted for the six-cylinder engine; that for the four-cylinder engine is similar. The lever which is coupled to the accelerator pedal carries an adjusting screw, any manipulation of which changes the position to which the governor control levers return when the accelerator pedal is released. Screwing the screw inwards increases the speed of idling.

The engine, it should be observed, must be at its correct working temperature when making idling speed adjustments, and the correct idling speed should, as previously stated, be about 340 to 400 r.p.m.; this is rather higher than for petrol engines. If the speed is brought lower, then " hunting " will occur.

To adjust the maximum quantity of fuel, the adjustable stop on the governor control lever (Fig. 163) should be used. The position of this stop is fixed by the engine manufacturers on the test bed, to give the maximum amount of fuel which can be used in the engine *without any trace of smoke in the exhaust*; this adjustment is sealed at the A.E.C. works.

It is important to observe that in some instances *an improved fuel consumption can be obtained by reducing the maximum quantity of fuel*; this affects only the maximum power and not that at the intermediate accelerator positions.

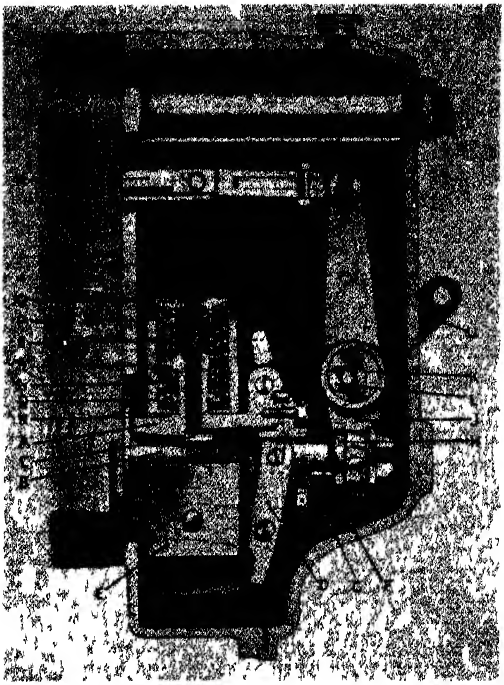

FIG 162 — The arrangement of the Governor on Leyland Oil Engine

FIG. 163.—Showing A E C. Engine Accelerator Stop.

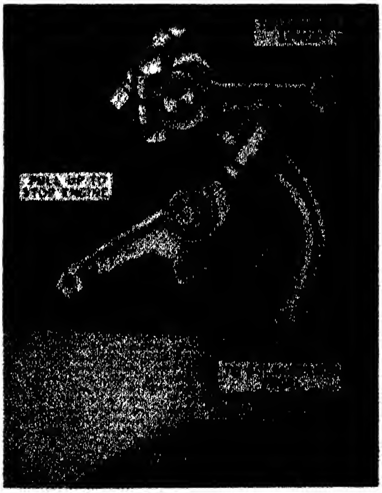

FIG 164 —The A E C -Bosch Fuel Pump Control Lever Stops.

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The Pneumatic Type Governor

The pneumatic type governor was introduced primarily for oil engines of small capacity. It has greater flexibility in the control of low and also high speeds and occupies less space than the centrifugal governor.

The governor in question utilizes the venturi principle and employs a choke, or venturi, located in the main air supply pipe of the engine. The difference in pressure between the throat of the venturi and the outside atmosphere is employed to actuate a diaphragm type of fuel control in the fuel injection pump.

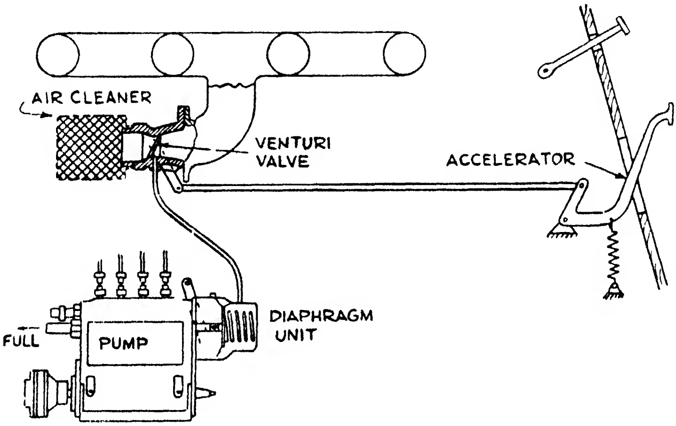

FIG. 165.—Illustrating Principle of Pneumatic Governor for Fuel Pump.

The two main units are: (1) the venturi air flow control mounted between the suction pipe of the engine and the air filter and, (2) the diaphragm unit mounted on the fuel pump. A flexible tube connects the two units.

With this arrangement the output of the fuel pump is controlled between the idling and maximum speeds limit; the latter are pre-determined by stop-screw adjustments.

The operation of the pneumatic governor is illustrated in Figs. 165 and 166. The throat of the venturi is given suitable dimensions according to the type of engine on which it is used. At the smallest section a butterfly valve C is fitted for controlling the air flow; this throttle is actuated from the driver's accelerator pedal through the lever *A*.

The amount of *movement between the maximum and idling* *speeds* is regulated by means of the two adjustable stops *AJ* and *AK*. A screwed connection *D* is provided through which the air is exhausted from the diaphragm unit actuating the fuel pump control rod. The diaphragm unit consists of a housing *G* mounted on a separate casting *H*, with a special leather diaphragm clamped between the two, providing an

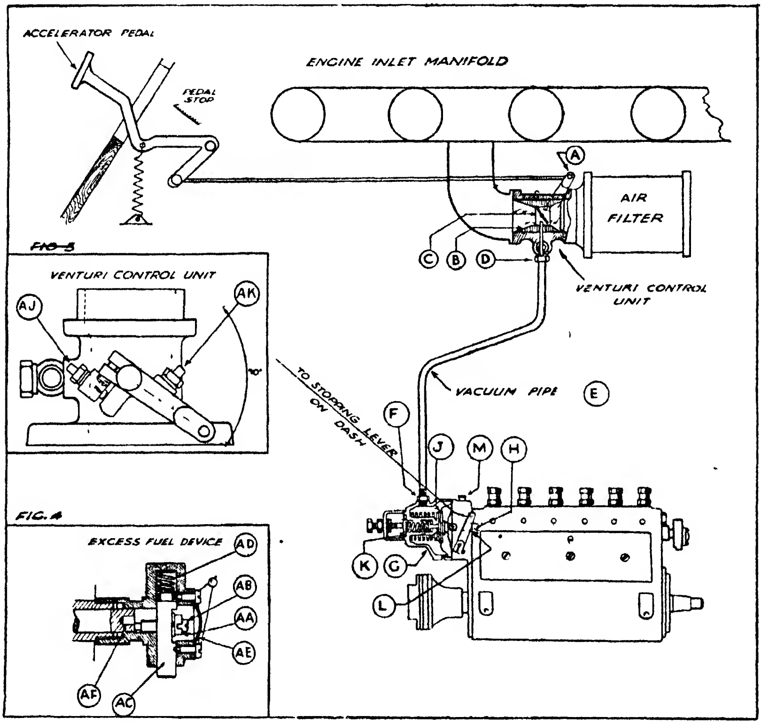

FIG. 166.—The C A.V.-Bosch Pneumatic Governor.

air-tight chamber unside the housing *G*. A light spring *K* acting on the diaphragm damps out any oscillations that may occur, and keeps the control rod in full open position, an additional lever *L* being provided to stop the engine; this is worked from the driver's compartment by a steel wire or similar control.

The device shown in Fig. 166 is suitable for multi-cylinder engines idling at 350 to 400 r.p.m.; two other forms of diaphragm control are available for engines with four or fewer cylinders.

Referring to Fig. 166, with the engine stationary and the lever *L* released, the spring *K* forces the control rod into the full load position. Then by pressing the plunger *AC* (Fig. 166, lower left diagram) on the excess fuel device the control rod is allowed to open automatically to the extent of its travel and so provide an excess of fuel to be available for starting. When the engine has started it may be idled by releasing the accelerator pedal and thus closing partially the butterfly valve *C* when high vacuum is created in the connecting tube *E* and air-tight compartment *G*. As the air in the compartment *H* is at atmospheric pressure and therefore now in excess of that in compartment *G*, the diaphragm together with the control rod is moved towards the "Stop" position until the engine is running at the pre-determined idling speed required. The movement of the control rod towards the idling position releases the plunger *AC* of the excess fuel device which returns to its original position and forms a positive stop to the control rod preventing it returning to the starting position.

To increase engine speed, the accelerator pedal is depressed, opening the valve *C* and so decreasing the air velocity past the mouth of the connecting tube. This results in an increased pressure in *G*, and the movement of the control rod towards the maximum speed position. A maximum speed stop is therefore provided in order to prevent the valve moving beyond this position as further movement will tend partially to close the opening, thereby reducing rather than increasing the speed.

It is claimed that the use of this venturi form of control does not affect the volumetric efficiency of the engine.

Adjustment and Maintenance

There are three principal adjustments namely: (1) For *the fuel supply*: (2) For *maximum speed*: and, (3) For *idling speed*.

(1) *Adjustment for Fuel Supply*.—Normally, the adjustments of the fuel pump and governor are made—and in some cases sealed—by the manufacturers before the engine leaves the works. Should any adjustment be necessary after overhaul or under special circumstances the procedure is as follows: To alter the fuel supply

(*a*) Remove sealing cover *AE* (Fig. 166).

(*b*) Release lock nut *AA* by means of a key spanner.

(*c*) To increase fuel supply the set-screw *AB* should be screwed inwards, whilst the reverse is necessary to decrease the supply.

A compromise between power, exhaust colour and fuel consumption should be aimed at, and if, for example with the original setting, the power is ample but the exhaust colour and fuel consumption are not satisfactory, then by further slight alteration to the set-screw *AB*, it may be found possible to diminish the smokiness of the exhaust and perhaps in consequence reduce the fuel consumption to some extent.

(*d*) Re-lock nut *AA* and replace cover *AE*.

(2) *Maximum Speed.*—The absolute maximum speed is governed entirely by the diameter of the venturi in the valve unit and cannot, therefore, be altered. The speed may be decreased, however, by the adjustment of the control valve movement by means of the screw *AJ* (Fig. 166).

(3) *Idling Speed.*—To reduce the idling speed, unscrew set-screw *AK* (Fig. 166) to the required amount in order to allow the venturi valve more movement towards the closing point. Screw in slightly to increase the idling speed. Re-adjustment of auxiliary set-screw *Q* (Fig. 166) should only be made if the idling performance becomes unstable.

Maintenance of Pneumatic Governor

The diaphragm being made from a specially prepared leather should give lasting service, but in the event of a leak being suspected, the following procedure should be adopted :

(*a*) Remove vacuum pipe *E*.

(*b*) Move the stop lever *L* into " stop " position.

(*c*) Place a finger over the diaphragm housing union *F* in order to seal it.

(*d*) Release the stop lever.

(*e*) The control rod should then slowly return back to the maximum speed position after a quick initial movement for a fraction of the distance.

If it returns quickly for the whole movement and the housings *G* and *H* are clamped firmly together, then the diaphragm is leaking and should be replaced, preferably by the makers.

The diaphragm should be kept pliant by the addition of one table-spoonful of lubricating oil through the oil cap *M* every 1,000 miles.

Vacuum pipe *E* can be tested for leaks in exactly the same way as the diaphragm except that the diaphragm housing end is connected to union *F* and a finger applied to the venturi end of the pipe.

See that slackness does not occur between the accelerator pedal and all the levers and pins connected with the venturi or diaphragm unit.

It is advisable to provide an accelerator stop to take the load of continual pedal depression rather than the maximum speed set-screw *AJ*

Clean the air filter fitted to the valve unit at regular intervals according to the conditions under which the engine is operating. If the supply is restricted through a partially choked filter the maximum speed will be diminished.

Never run the engine without the air filter in position.

Oil the excess fuel device plunger *AC* occasionally.

Stop lever *L* should be perfectly free throughout the whole of its permitted movements.

CHAPTER X

STARTING PROCEDURE AND RUNNING TROUBLES

Starting C.I. Engines

THE high speed C.I. engine, on account of its high compression pressure, requires a rather different method of starting from the cold than that used for petrol engines.

The difficulty of swinging the engine over this high compression is overcome in the majority of engines by means of compression releasing devices, or decompressors which release the compressed air charge so that the engine can be cranked around, either by hand or electric motor in order to obtain sufficient momentum. The compression release device is then cut out so as to obtain normal compression conditions, when the momentum previously attained should carry the engine over this compression, thus allowing the cylinder to " fire."

If the combustion chamber is fitted with glow plugs these must be switched on for about half a minute beforehand. Usually a spring-controlled knob is fitted on the instrument board for this purpose so that on releasing this knob the current from the battery to the heater plugs is switched off ; this is an important point to observe.

Engines Fitted with Decompressors

Although, as will be seen later, the procedure for starting is different for certain designs of engines, the method more widely employed is as follows :

(1) Switch on heater plugs for about half-a-minute.

(2) Release compression by means of decompressors.

(3) Crank engine over until maximum cranking speed is attained.

(4) Release decompressors and depress accelerator pedal controlling fuel supply.

(5) As soon as engine starts release accelerator gradually so as not to slow engine down too much.

This procedure refers to starting from the cold. If the engine is warm the heater plugs need not, as a rule, be used and the accelerator pedal is only partly depressed on releasing decompressors.

The Fuel Control

The methods of starting from the cold advocated by the makers of various C.I. engines differ in regard to the position of the fuel control and injection advance.

In some instances the makers recommend that the fuel pump control lever should be in the *fully opened* position, whilst in others, it should be in the idling, or "partly open" position. Similarly, whilst some makers stipulate that the injection should be *fully advanced* for starting, others recommend an intermediate position; where fixed injection timing is used, there is, of course, no necessity to consider this item.

As the method of starting the engine, to some extent is dependent upon its particular design, it may be instructive to describe, briefly, the methods advocated by the makers of a few well-known engines.

(1) THE LEYLAND.—Assuming that the fuel system has been properly primed beforehand to eliminate any air bubbles, press the foot throttle or accelerator (controlling the quantity of fuel supplied by the pump) right down once, to ensure that the governor is not sticking in its "stop" position; then let it come back to the normal position and press the starter switch. If necessary, open the throttle wider. Control the engine speed with the accelerator and set it to the best idling position by means of the adjustable screw stop on the pump.

(2) THE ARMSTRONG-SAURER ENGINE (*Bosch-Acro Pre-Combustion Head*).—Before starting see that the gear lever is in neutral, the hand brake on, the fuel supply tank has plenty of fuel and that there is sufficient oil in the engine sump.

Switch on the Autopulse fuel supply pump by means of switch on instrument board. Open test cock on top of Bosch main fuel filter and leave open until there is a continuous flow of fuel free from air bubbles; then close the cock.

The injection system should also be checked for freedom from air bubbles in the fuel.

Next, place pump control lever in fully open position and injection advance lever (above steering wheel) to fully advanced position. Switch on the glow plugs for 30 seconds, and whilst keeping the heater plug handle down, depress the starter foot switch when the engine should at once "fire." As soon as it has gathered sufficient speed release glow plug switch and starter switch and push back the pump control lever to the "idling" position. Also slightly retard the injection advance control lever.

In very cold weather it is advisable to ease the engine by turning it by hand after injection of a few drops of paraffin into the compression tap.

(3) THE DORMAN RICARDO ENGINE.—The six-cylinder type engine is fitted with heater plugs as in the case of similar "Comet" head engines. Decompressors are fitted for starting purposes, on each of the three-cylinder block heads (Fig. 167). To start these engines, switch on the heater plugs for 30 to 40 seconds. Then move the decompressor lever as far over as possible in the downward direction. Next, move the fuel injection pump control lever towards the rear of the engine as far as it will go; this allows the maximum amount of fuel for starting purposes. As soon as the engine is cranked or motored to a sufficient speed the decompressors lever should be moved over to the "normal" position. When the engine "fires," move the control lever slowly back to the idling position.

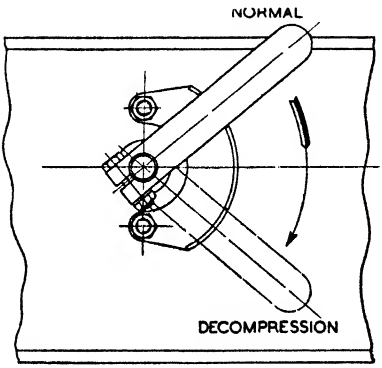

FIG. 167.—Decompressor on Dorman-Ricardo Engine.

(4) THE CROSSLEY ENGINES (*Comet Combustion Head*).—Assuming that the engine sump has been filled with oil, and that the fuel tank has also been filled, the following procedure is necessary to start from cold: It should be noted that the only controls in the driver's cab appertaining to the engine, other than the accelerator pedal, are the decompressor device, the electric starter button and the heater switch.

A tell-tale plug is also fitted to indicate the glow of the wire element at the heater plugs in the combustion chamber.

Assuming now that the operator is seated in the driver's cab:

Operation 1.—Pull the decompressor lever to its fullest extent towards the rear. This opens the exhaust valves and releases the compression.

Operation 2.—Connect the two-volt battery plug to its socket and leave this connected until the wire element on the tell-tale plug is a cherry red.

Operation 3.—Press down the accelerator pedal to its fullest extent.

Operation 4.—Press electric starter button until engine is revolving at a reasonable rate.

Operation 5.—Now smartly push forward decompression lever to close the compression, leaving the foot on the accelerator, when the engine should at once start. Immediately the engine has started, release electric starter button. It will be found necessary to leave the foot on the accelerator pedal (not of necessity in the maximum opening position) for a minute or so until the engine runs evenly at the slow running position, that is, when the foot is removed entirely from the accelerator pedal. The above method should also be adopted if the engine stops after it has been warmed up.

Care should be taken to ensure that all the atomisers are functioning correctly, this can be detected by the evenness of the exhaust note.

(5) THE TANGYE ENGINES (*Comet Combustion Head*).—Set the injection timing control in the " S " position as marked on the quadrant, lift the decompression lever to the position marked " O," when compression will be relieved on all cylinders. On allowing this lever to fall through the positions shown by the index marks, compression takes place in cylinder No. 1, then No. 2, etc. Turn the starting handle vigorously, four or five revolutions should be sufficient, and then allow the decompression lever to fall slowly whilst maintaining the turning speed. The cylinders will " fire " in the order indicated above.

In the case of the four, five and six-cylinder engines, two decompression levers are fitted; that nearest the starting handle should be dropped first.

The above remarks only apply to hand start engines, special instructions being given for electric, automatic and compressed air start engines.

Handle Starting

The smaller sizes of high speed oil engine can conveniently be started by hand, if the correct procedure is followed.

Taking the four-cylinder Perkins engine as a typical example, the starting handle of this is keyed to the crankshaft extension in such a way that when Nos. 1 and 4 pistons are on T.D.C. the handle is also at the top of its turning circle.

The handle should be turned until it is about 30 over T.D.C., when the following procedure is employed :

Disengage handle and re-engage in opposite dog, i.e. handle about 30° beyond bottom centre. Depress accelerator fully and then release (this ensures full fuel for starting). Also ensure that the Bosch fuel pump " stop " control is not preventing throttle from opening. If the accelerator control is not arranged for adjustable stop it may be found desirable to wedge the accelerator open in order to give a good supply of fuel for starting. In this case the wedge should be removed as soon as the engine fires. Now pull the engine smartly right over compression when the engine should fire and continue to run on the governor. The whole secret of starting lies in getting a very smart pull right over compression. Continuous slow turning will never start a Diesel engine. If the engine does not start at the second or third pull it may be that assistance will be required to pull it over compression smartly enough. A second man standing at the right side of the handle looking on the radiator, and gripping it with his left hand can materially increase the speed of the engine over compression by pulling horizontally on the starting handle whilst the first man pulls upwards. Make sure the atomisers " squeak " when turning the engine. Absence of squeak indicates air still in the fuel system. If a cold engine fires and tends to stop immediately after starting, it may be that the governor is sluggish due to the sticking of the lubricating oil, in this case the accelerator should be held partly open and the engine controlled by the accelerator pedal for a minute or so to take the stickiness off the lubricating oil and warm the engine up slightly before leaving it to run on the governor.

The Victor Opposed Cylinder Engines

See that oil level is correct, and that water is turned on, or radiator, or cooling tank, full. Especially when installation is new, bleed the fuel pipe free of air at filter and at engine. Move throttle to full open position, or when constant speed governor is fitted move control lever to position marked " Run." Turn decompressor knob clockwise, lifting it at the same time until it " clicks " into raised position. Engage starting handle and if, on turning it, the engine is still found to be with full compression, bounce the engine against compression until it swings back far enough to allow decompressor cam to engage, or force engine over first compression, when decompressor cam will be heard to spring into position between exhaust valve tappets. Spin engine as rapidly as possible in decompressed condition, and when adequate speed has been attained, tap the top of decompressor knob, whereupon full compression will be restored, the fly wheel will carry engine over one or more firing strokes, and the engine will start. If an electric starter is fitted, it is not essential to decompress, but decompressing will greatly reduce the load on the battery.

As soon as engine starts, except when constant speed governor is fitted, take control of engine with throttle. With constant speed governor, control is taken up automatically, and no action on part of operator is required.

Starting the Engine When Warm

The preceding descriptions of starting methods refer to the cold engine conditions, which are, of course, more difficult for starting than when the engine is warm.

The resistance to cranking or motoring the engine is appreciably less when the cylinders are warm and the engine oil has attained its normal working temperature, so that the starting effort is much less than when the engine is cold.

Under these circumstances the engine will usually start readily on the electric starter, the use of the glow plugs being unnecessary. When a decompressor device is fitted, however, this should be used as it not only reduces the amount of energy taken from the battery but gives a quicker start. The decompressor lever should first be engaged, the accelerator pedal slightly depressed, the electric starting motor switched on and, when in operation, the decompressor quickly moved out of action.

Starting After an Overhaul

When an engine has to be started after an overhaul, or in cases where it has been standing for some time, unused, the important item of procedure is to *thoroughly prime the fuel system* from the main filter to the injection nozzle, to ensure that all air bubbles have been got rid of.

Thereafter, the procedure is the same as for starting from the cold.

Stopping C.I. Engines

When the engine has to be stopped it is important to note that on no account must it be brought to rest by turning off the *fuel supply* to the fuel injection pump ; this will result in air locks in the fuel system. Neither, in most cases, should the decompressor gear, when fitted, be used for a similar purpose.

The correct procedure is to reduce the quantity of fuel supplied by the fuel pump to *below that which is necessary to keep the engine idling.* Some makers, however, recommend the use of the decompressor for stopping the engine, after allowing it to idle for a short period. When the fuel pump has a governing device for the minimum, or idling speed, an over-riding control is fitted for this purpose.

Referring to Fig. 164, showing the A.E.C. fuel pump controls, the adjusting screw for limiting the idling speed is provided with a movable stop against which it rests when the accelerator pedal is released. This stop consists of a cam-shaped projection on the boss of a lever. Rotating the lever allows the adjusting screw to drop off the nose of the cam and this brings the governor control lever below the position necessary for idling and the engine stops. On depressing the accelerator pedal, the idling position is restored.

Running In Procedure

If the engine has had a complete overhaul, the bearings will be a little tighter than when properly bedded in. Similarly the pistons, rings and cylinder walls will require a certain period of running-in before the engine can be operated at full loads. Unless this running-in is done under light load and low engine speed conditions, more cylinder, big end and main bearing wear can take place than in many hundreds of miles normal running.

The engine should first be motored round by means of an electric motor, through a flexible coupling drive, for a period of one to two hours, using plenty of lubricant in the engine sump. All of the bearing surfaces, such as the cylinder walls, small and big-end bearings and main bearings should, previously, have been well smeared with engine oil on assembly.

Colloidal Graphite for Running In

The use of engine lubricating oil mixed with colloidal graphite in the proportion of 40 parts of the former to 1 part of the latter is well recommended by Messrs. A.E.C. Ltd., for engine running-in purposes, after overhaul.

The advantages of this solution are that the suspended graphite thoroughly coats all wearing parts with which it comes into contact with a most efficient lubricant—and the smallest pores in the metal are filled with it so that not only is the process of " running in " greatly assisted, but thorough and even lubrication is ensured during that period.

The procedure for running in is as follows: Before fitting the crankshaft load each journal pin with the solution, and coat all journals similarly. Next coat all pistons, big end bearing, the camshaft, rockers and shafts, and similar parts—prime the oil pump and the main filter with the solution.

The graphited solution should be warmed before use to make it penetrate thoroughly.

The engine should be lubricated during bench test with the solution, kept to the correct sump level. After bench test the sump should be cleaned and refilled with the solution before the engine is fitted to the chassis.

Subsequent replenishments to the sump should be made with the correct type of engine oil, but the original solution should not be drained off or the sump cleaned out at this period.

Colloidal graphite can readily be obtained from firms such as Messrs. E. G. Acheson, Ltd.

Running In Under Own Power

After the motoring period the engine can be started up, using the same motor for turning its crankshaft prior to starting. The electrical controls of the motor should be capable of converting it into a dynamo once the engine has started, so as to be capable of taking up the loads at various speeds.

The engine should run light for a few hours, and, if everything appears to be in order, in regard to engine temperature, regularity of running, absence of knock and vibration, it may then gradually be opened up for short periods.

In the case of new engines, after the part and full-load tests it is the custom of manufacturers, such as Messrs. A.E.C. Ltd., to strip the engines down for a careful inspection of the working surfaces.

When the engine, after the preliminary running-in process on the bench, is taken on the road in its chassis, it should be treated considerately and the running-speed kept down to a minimum; frequently works' testers do the preliminary road running-in of the engines.

In the case of new or reconditioned engines, however, it is advisable for the driver, on taking delivery from the makers, to keep the running speed well within its maximum limits for the first 200 or 300 miles, and to run the engine slowly for the first few minutes after starting from the cold. This gives the bearing surfaces the best conditions for bedding themselves together, so that the maximum period of service will be obtained.

When running new engines a check of the radiator water temperature should be taken to ensure the engine is not running too hot. The correct water temperature at the top of the radiator should be about 180° F.

Difficulty in Starting

If, in the case of engines fitted with heater plugs, there is any difficulty in starting, attention should be given to the heater plugs themselves to make certain, by examination, that none has been burnt out.

If the heater plugs are in good condition the battery may be run down or in a state of low charge. This can be checked by switching on the headlamps and examining the intensity of the light from each. The indicator in the heater circuit is another test, for if this only glows feebly it is a sign of a low battery. If, however, the heater indicator glows appreciably brighter than is normally the case, this is an indication that *one of the heater plugs has burnt out.*

If the starting motor will only crank the engine over at a low speed it is a good plan to *assist it with the starting handle,* for then a higher cranking-speed will be possible.

The use of unsuitable lubricating oil in the engine may be another possible cause of starting difficulty. The proper grades of oil only should be used and, further, the winter or summer grades of these should be employed to suit climatic conditions.

A Cause of Difficult Starting

When an A.E.C. oil engine is found to be difficult to start it will sometimes be found that this is due to a faulty earth connection to the heater plug circuit.

Where any doubt arises as to the efficiency of the earthing, the heater plugs should first be examined to see that they are in good order, and replaced. After this a voltmeter should be placed across the heater bar and any earth contact on the engine, and when the heater plugs are switched on a reading of 0·9 volts should show if the earthing is properly carried out.

Operators are advised to make this simple test with a view to seeing if the heater plug circuit is properly earthed, when the condition of difficult starting arises. If the resultant voltmeter reading is under 0·9 the earthing of the control board to the chassis should be checked, and if necessary the surface of the lower hinged mounting of the board should be cleaned up where it makes contact with the chassis.

If, after the usual starting measures previously described, the engine fails to start, the probable cause of the trouble will be one of the following :

(1) *Shortage of Fuel.*—Examine fuel tank or tank gauge.

(2) *Air Bubbles in Fuel.*—Check the fuel flow at injection nozzles by unscrewing unions and watching the fuel when engine is cranked around. The remedy is to prime the fuel system.

(3) *Incorrect Fuel Pump Timing.*—If the injection is not timed correctly the engine will not start. It may happen that the pump camshaft has been wrongly connected to the engine drive so that it is 180° out of phase ; in this case the pump will inject its fuel at the end of the exhaust stroke instead of the compression stroke. If the injection is *too far advanced* or *too retarded* the engine will, usually, not start.

(4) *Bad Compression.*—If the compression is not sufficiently high, as with a worn engine or one in which there is *not enough valve tappet clearance,* the engine will not "fire." Check the compression by cranking the engine by hand.

(5) *Defective Fuel Pump.*—If the nozzles are checked for correct working and the fuel system for air bubbles it is probable that the fuel pump may not be operating satisfactorily. The fuel flows from the delivery unions (with pipe lines removed) should then be checked in order to trace the cause to the pump itself.

(6) *Unsuitable Grade of Fuel.*—A poor quality of fuel, with a higher ignition temperature than that of the standard fuels for which the engine was designed will cause starting difficulties.

The quickest method of checking the injection system is to remove the injection nozzles from their cylinders, connect them up outside to their respective pipe lines and crank the engine around. The fuel should issue from each nozzle in turn in a fine symmetrical spray, with the characteristic " grunt " of the nozzle when it is working satisfactorily.

Irregular Running After Starting

It is sometimes the case that after a C.I. engine has started from the cold it will not run smoothly, but mis-fires, usually with a smoky exhaust.

The two principal causes of such irregular running are (1) The compression is insufficient ; (2) The fuel is not being delivered to the combustion chamber regularly.

(1) *Insufficient Compression.*—This may be due to one or other of the following causes, viz. :

(*a*) Scored or worn cylinder, or cylinders.
(*b*) Worn piston rings or damaged piston.
(*c*) Inlet or exhaust valve stuck in guide. Broken valve spring.
(*d*) Insufficient valve stem clearance.

A poor compression is indicated by reduced cranking effort as tested at the starting handle, and by smoke issuing through the crankcase " breather."

A faulty gasket between the cylinder head and cylinder block will also cause a loss of compression. Similarly, if the injection nozzle has a faulty gasket or copper-asbestos washer or is not screwed down tightly, the compression will suffer.

(2) *Unsatisfactory Fuel Delivery.*—This may be due to several causes, as follows :

(*a*) Fuel injector nozzle choked, needle valve stuck or spring incorrectly adjusted. (See Table on page 147.)
(*b*) Leakage of fuel from pipe line union.
(*c*) Fuel pump not working properly. (See Table on page 228.)
(*d*) Air in fuel pipe line.

(*e*) Fuel filter partly choked.
(*f*) Fuel pipe line broken.
(*g*) Injection timing incorrect, i.e., too retarded, giving smoky exhaust.

It will often happen that only one of the engine's cylinders is not working correctly. This cylinder can readily be located by the method described on page 136; the cause of the trouble can then be traced by the methods previously outlined.

Causes of Smoky Exhausts

The issue of smoke from the exhaust may be due either to over-lubrication or to a defect in the fuel injection process. In the latter case the cause will be one of the following, viz.:

(*a*) *Incorrect fuel injection timing,* i.e., injection too late.

(*b*) *Dribble at Injection Nozzle* due to faulty design or defective nozzle. The injection valve may be stuck in its guide or the seating may have dirt or deposit on it which will prevent the valve from closing.
The injection valve control spring may not be sufficiently "tensioned" due to adjustment nut having worked back. The nozzle of the cylinder suspected should be "cut out" by stopping its fuel supply when the smoke in exhaust should cease.

(*c*) *Excessive Fuel Delivery.*—If the engine is run above its rated maximum speed, or the fuel injection period is too long, the whole of the fuel injected cannot satisfactorily be burnt, so that a smoky exhaust will result.

Most present-day designs of C.I. engine cannot stand over-running or overloading without exhibiting smoky exhausts.

Blue smoke in the exhaust, other than that due to over-lubrication, is due to faulty spraying, caused by a defective injection nozzle.

Black smoke in the exhaust is caused by excessive fuel delivery, i.e., by an over-rich mixture. If the engine has a governor on the fuel pump, it is very probable that the maximum delivery control stop has not been adjusted correctly. The stop in question should be screwed in the direction of reduced supply until the smoking trouble ceases.

(*d*) *Inlet Air Filter Choked.*—The air filtering medium on the air inlet filter may be partly blocked with dirt so that there is a reduced quantity of air to the cylinder.

(*e*) *Inlet and Exhaust Valve Seatings Defective.*—Worn or pitted valve faces and seatings will result in a reduced compression. If the latter is sufficient to "fire" the injected fuel it may, in some instances, give too rich a mixture and thus cause smoking.

Loss of Power

Although many of the items of trouble previously described are also the cause of power loss, it may be useful to the maintenance engineer to enumerate the principal causes, as follows:

(1) *Defective Injection System.*—Due to injector, pipe line, fuel pump, filter, etc.

(2) *Loss of Compression.*—Worn cylinders, pistons or piston rings, defective valves, leakages past cylinder or injector joints, cracked piston, etc.

(3) *Excessive Carbon Deposit.*

(4) *Incorrect Injection Period.*—Hand or governor controls not adjusted correctly.

(5) *Incorrect Injection Timing.*—Injection not occurring correctly in relation to piston's position near end of compression stroke.

(6) *Engine not attaining Designed Speeds.*—This may be due to (4) or (5).

(7) *Excessive Friction in Engine.*—Breakdown of lubrication system, partly seized piston, big-end or main bearing, bent rod or crankshaft would cause this. Check for this by cranking engine over by hand, with compression released (by removing injectors or using decompressor gear).

(8) *Incorrect Valve Timing.*—The engine timing should be checked against the maker's recommended settings.

Excessive Engine Knocking

As distinct from "Diesel knock" due to faulty design of the combustion chamber and fuel injection system, inherent in the engine, it sometimes happens that engines which normally run comparatively quietly will exhibit pronounced knocking.

This knocking may be due to one of the following causes, viz.:

(1) Injection timing too far advanced.
(2) Idling speed too low.
(3) Slackness in journal, big-end or small-end bearings.
(4) Incorrect valve timing causing valves, when opened or partly so, to strike pistons at top of their strokes.
(5) Loose flywheel key.
(6) Sloppy pistons, due to excessive wear in cylinder.
(7) Use of unsatisfactory grade of fuel, of low cetene value.

CHAPTER XI

GLOW PLUGS, FILTERS, FUELS, ETC.

Heater, or Glow Plugs

THE cooling effect of the cylinder walls on the air charge during the compression stroke *when starting from the cold* is such that the temperature of the compressed air is often insufficient to ignite the fuel when injected. In some cases the fuel is only partly ignited, the delayed or incomplete combustion causing exhaust smoke and, probably, also cylinder corrosion.

To obviate this defect in auxiliary chamber engines and certain other types the heater or glow plugs previously referred to are fitted. This type of plug has a resistance wire loop at the combustion chamber end which is heated to redness, electrically, so as to warm the combustion chamber sufficiently for starting purposes.

The current to the glow plugs should be *switched on for about one-half a minute* before the engine is cranked over.

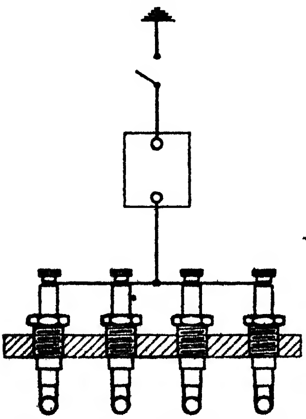

FIG. 170.—Method of connecting Single Pole Glow Plugs.

Types of Glow Plugs

There are two general types of plug, viz., the *single* and *double* pole patterns. The single pole plugs are, in the case of a multiple-cylinder engine, *connected in parallel* to a 2-volt accumulator. The double-pole plugs are insulated entirely from the cylinder metal and are *connected in series*, usually to a 12-volt battery.

The methods of making the electrical connections in each case are shown in Figs. 170 and 171. The former diagram shows four single pole plugs wired in parallel through a switch to a single cell accumulator

FIG. 168.—The Lodge Single Pole Glow Plug.

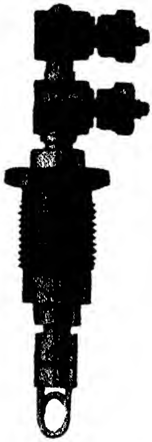

FIG. 169.—The Double Pole Glow Plug.

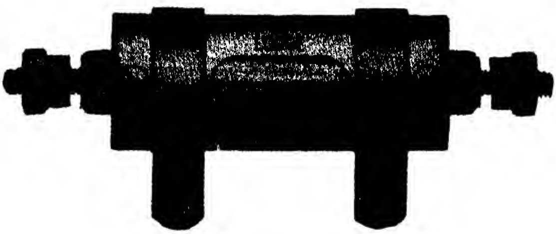

FIG. 172.—The Resistance Indicator used with Double Pole Plugs.

[*To face page* 198.

(2 volts). The latter diagram shows four double-pole plugs joined in series to a 12 volt battery, through a switch and a device known as a *resistance indicator*; the latter is made in two types for four and six-cylinder engines, respectively.

The resistance indicator should be screwed to the metal of the engine in such a position that it is convenient for observation when the engine is being started up from cold. It should be screwed to metal and not wood because it gets hot. Where a tell-tale is required at a distance an electric light bulb can be connected across the terminals of the resistance indicator.

Single-pole plugs are made in two patterns—one known as the 18 ampere type and taking from 15 to 18 amperes at 2 volts according to the state of the battery; the other is classed as 30 amperes and takes from 25 to 30 amperes at 2 volts. If a battery of sufficient capacity is employed the latter type is probably the best as it gives nearly twice the heating effect. Incidentally, a 1 volt pattern glow plug was made by Messrs. Lodge Ltd., for connecting to one cell of the nickel-iron type of battery, such as the Nife or Edison.

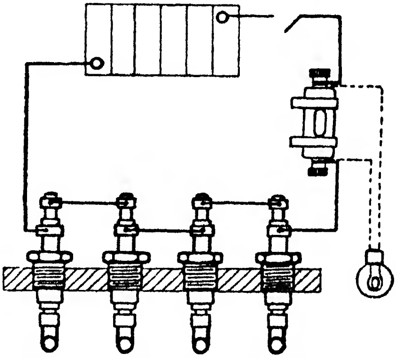

FIG. 171.—Method of connecting Double Pole Plugs.

Double-pole plugs are usually made in one pattern rated at 2 volts, 30 amperes, but can if necessary be supplied to take a smaller current. The advantage of the double-pole plug is that the whole set of four or six plugs is connected in series to a 12 volt battery from which they take only 30 amperes as compared with, say, four or six 30 ampere single-pole plugs requiring 120 or 180 amperes from a single cell.

Dimensions of Plugs

The earlier plugs had the dimensions shown in the left hand diagrams of Fig. 173, the diameter of the barrel being 0·375 in., and of the cylinder hole 0·390 in. A standard 18 mm. × 1·5 mm. pitch thread is, however, used in both the earlier and later patterns (right hand diagrams). The latter have barrels of 0·425 in. and cylinder holes of 0·437 in.; the same depths of thread and cylinder hole are employed in each case.

Fitting Notes

(*a*) Single-pole Plugs.—The hole in the engine to take these plugs should be $\frac{7}{16}$ in. (or 11 mm.) diameter × $1\frac{1}{8}$ in. long. This brings the end of the heating element flush with the inside surface of the combustion chamber. The heating element should be situated so that it is not in the direct path of any portion of the fuel spray.

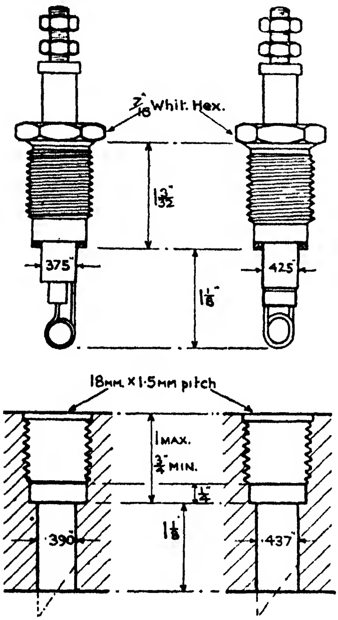

Fig. 173.
Dimensions of Glow Plugs.

In the case of a multi-cylinder engine the plugs are connected in parallel through a switch to a single cell accumulator (Fig. 170). The accumulator must be of suitable type to stand the heavy discharge. The plugs are best connected together by means of a flat copper strip, say, $\frac{1}{16}$ in. thick × $\frac{1}{2}$ in. wide. The direction of the current through the plugs is of no importance.

The switch must be of ample proportions for the current and should be of the type used for electric starters. The cable should also be of the type used with electric starters and the circuit should be kept as short as possible so as not to introduce resistance.

(*b*) Double - pole Plugs. — These require the same hole dimensions and depths as in the case of the single-pole plugs.

In the case of a four-cylinder engine, four of these plugs are connected in series with a special resistance indicator such as the Lodge R4/30, a 12 volt battery and a switch. In the case of a six-cylinder engine, six of these plugs are connected in series with another resistance indicator such as the Lodge R6/30, a 12 volt battery, and a switch. The direction of the electric current through the plugs is of no importance. (Fig. 171.)

The plugs are best connected with bare metal strip $\frac{3}{8}$ in. wide × say, $\frac{1}{32}$ in. thick, or as much thicker as is desired for mechanical strength. As the strip only has to carry 30 amperes, practically any good conducting metal can be used, but high resistance alloys, such as stainless steel, are not suitable. For the rest of the circuit use cable of sufficient size for carrying 30 amperes. The circuit should be kept as short as possible. A 6 volt bulb is used for the R4/30 and 2 volt for the R6/30 units, where dashboard resistance units are used.

Maintenance Notes

The modern glow plug is a high grade product and should have a relatively long life if used under the proper conditions.

As previously mentioned, the incandescent wire should not be situated in the direct path of any portion of the oil spray. If the wire is placed in such a position corrosion will be rapid. The best position for the incandescent wire is such that it comes approximately flush with the end of the hole into the combustion chamber, that is to say, so that it does not project into the combustion chamber. In this position it is protected from the scouring action of the burning gas.

Another point that very materially affects the life of these plugs is the way they are used. The current should be switched on for about a half of a minute before the engine starts, and must be switched off as soon as unaided ignition occurs. If the current is left switched on to the plugs for any length of time after starting, the life of the wire will be reduced. When the plugs are fitted in a suitable position in the combustion chamber, and given fair treatment in use, they can be relied on to have a long life.

In connection with the double pole plug systems fitted with resistance indicators (Fig. 171), after the current is switched on, the wire inside the resistance indicator should be examined through the window to see that it gets red hot. If it fails to heat up there is a fault in the circuit. This may be due either to a bad contact or the heating wire of one of the plugs being corroded through. In such a case see that all the contacts are tight and the switch in order, and if the wire still does not heat up short-circuit each plug in turn (with the switch on) to find out where the break in the circuit occurs. As a temporary measure the engine can be started up with the faulty plug short-circuited; but the faulty plug should be replaced at the earliest opportunity.

The Fuel Filter

As previously mentioned the plungers of the fuel pump are a precision-fit in their barrels and, provided the fuel can be kept free from solid particles, their useful working lives are extremely long. On the other hand, where cases of relatively greater plunger and barrel wear have occurred these have invariably been traceable to dirt in the fuel, due usually to a breakdown of the fuel filtering system.

Apart from the pump plungers, the delivery valves, their guides and seatings, and the injection nozzles are liable to injury or failure to fulfil their functions when dirt is present in the fuel.

It is necessary to fit a particularly efficient filter or pair of filters on the suction side of the fuel pump. The size of sand and dust particles suspended in still air is of the order 0.0008in. to 0.00008in. so that the necessity for a fine filtering medium is obvious.

The filtering media usually employed are woven fabrics in conjunction with brass or Monel metal gauze containers.

The fuel filters of C.I. engines should be cleaned or, since the fabric elements are very cheap, replaced at least once every 2,000 to 3,000 miles.

When the engine is new the filter should be inspected after the first 1,000 miles and thereafter every 2,000 to 3,000 miles. In this connection some fuels are dirtier than others so that no hard and fast rules can be laid down. Regular inspection is the best advice when using different grades of fuels.

When sediment plugs or drain-cocks are fitted to filters these should be opened every day, before the engine is run in order to draw off any water or sediment collected during the previous days run.

It is important to open the air venting or fuel priming plug when the filter is cleaned, in order to get rid of air in the fuel system.

If a filtering medium is to be used again after a thorough cleaning in paraffin or petrol its surface should be carefully examined for any small holes, cuts or tears ; if any of these are found a new filtering medium should be used.

If there is any doubt as to a fuel filter being partly choked, it can be tested by disconnecting the outlet union and turning on the fuel supply to the filter, when a free flow of fuel should occur.

Cleaning Fuel Oil before Use

It is a good plan to give the fuel oil a thorough cleaning before it is actually put into the fuel tanks of the vehicle or plant.

One large commercial firm which runs a fleet of oil engine vehicles employs a centrifugal filter in its depot for this purpose. This machine, fed from a 3,000 gallon storage tank, subjects the oil to a rotational speed of 15,000 r.p.m., whereby all fluff, grit, water and other impurities are quickly removed before the oil is passed to a 300 gallons supply tank. By this method the use of settling tanks and the consequent periodic withdrawal of sludge is avoided. Dealing with 2,000 gallons of fuel per week, the centrifugal filter extracts about ½ lb. of impurities in this period.

In this way trouble due to choked fuel filters or injection nozzles has been avoided entirely.

The C.A.V.-Bosch Fuel Filter

The Bosch fuel filter is made in two different patterns, namely, the cloth filter element one, known as the BF11B Type, and the felt filter pad one, known as the BFA11P Type; these two filters are shown in Figs. 174 and 175.

The former model, which is fitted with a cloth filter element, consists of a cast container 112*a*, with cover 112*b*, which carries the inlet and outlet connections. It has a capacity of flow with a three foot fall of 3·5—4·5 pints per minute with a relative clean condition of fabric and fuel.

The oil, on entering the container, passes through a preliminary metal filter 112*h*, which removes any coarse particles of dirt, and then through a specially prepared cloth 112*i*, which is stretched over a wire framework. This gives the oil its final filtration whence it passes through the stand pipe 112*n* and out into the main pipe line.

The filter can be dismantled with ease by removing the cap nut 112*c*, which permits withdrawal of both filter elements for inspection and cleaning. A sludge plug 112*m* is provided at the base of the container, through which dirt can be withdrawn periodically.

Whilst the cloth filtering elements of these filters can be cleaned, it is considered safer and more economical to replace them, since spares can be obtained for a few pence, protectively wrapped in cellophane to facilitate storage. This course is recommended since, if the cleaning process is not correctly carried out, the cloth may become punctured or the dirt merely transferred from the outside to the inside of the element.

The BFA11P filter has a series of felt pads 112*p*, which are built on a gauze tube frame 112*t* with metal end plates. It differs from the cloth element type in that the container, instead of the cover, carries both inlet and outlet connections.

When the filter is assembled the filter pads are tightly pressed against the spring 112*s* at the base of the housing, so that there is no possibility of fuel issuing without having passed

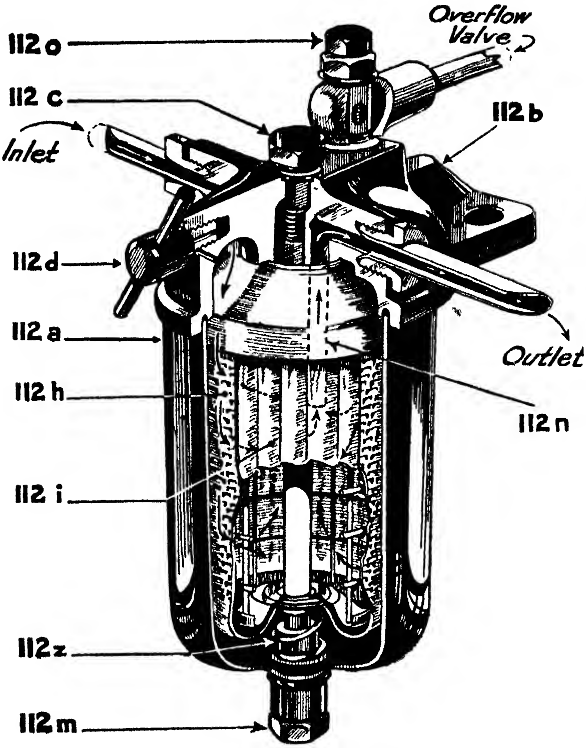

FIG. 174.—The Bosch Cloth Element Fuel Filter, Type BF11B.

112*a*	= Housing	112*h*	= Coarse filter (metal).
112*b*	= Cover.	112*i*	= Fine filter (fabric).
112*c*	= Cap nut.	112*m*	= Sludge plug.
112*d*	= Air vent screw.	112*n*	= Stand pipe.
112*o*	= Closing plug.	112*z*	= Pressure spring.

through the felt pads. Both the sludge plug and the outlet are situated at the base of the container, but owing to the design of the centre tubing 112*w* no communication is possible. By removal of the cap nut 112*c* the cover can be lifted and the element withdrawn for inspection and cleaning; when this is done the pressure of the spring 112*s* is released and a brass sleeve 112*r* is pushed up to cover the posts in the central tube, so that no unfiltered fuel can pass into the outlet pipe during the cleaning process.

The Tecalemit fuel oil filter, shown in Fig. 176, is of the bracket-mounting pattern and employs a large area felt filtering medium arranged in a cylindrical container. It is

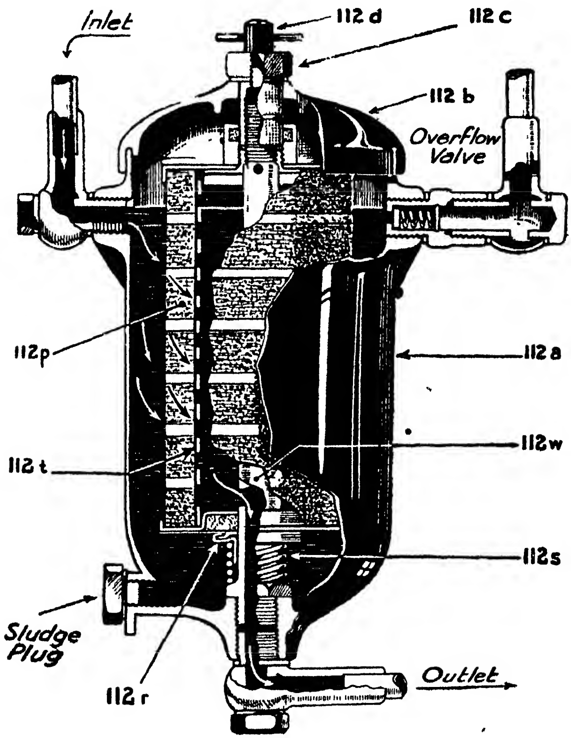

FIG. 175.—The Bosch Felt Element Fuel Filter, Type BFA11P.

112*a* = Housing	112*r* = Brass sleeve.
112*b* = Cover	112*s* = Pressure spring.
112*c* = Cap nut	112*t* = Gauze tube.
112*d* = Vent screw	112*w* = Centre tube.
112*p* = Felt filter pad.	

also made in a range of sizes, or capacities corresponding to different rates of flow; and also to suit different oil temperature and pressure conditions, in the case of lubricating oil filters.

It has been shown that particles as small as ·042mm., or about 0·0016in. diameter, are retained by the filter element.

The latter should be cleaned every 2,000 miles by flushing with clean petrol or paraffin or by the more efficient method of cleansing guns recommended by the makers. At the end of 10,000 miles the filter element should be scrapped and a new one used.

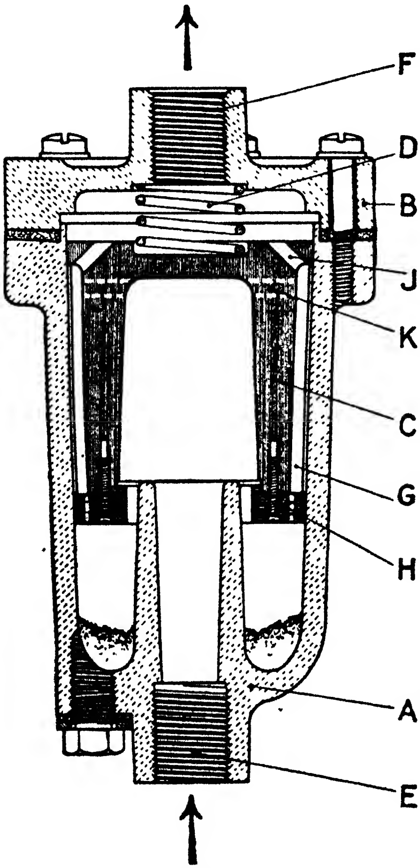

Fig. 177.—The Simm's Fuel Filter.

The filter shown in Fig. 176 has a water and sludge trap which can be cleared by removing the plug (not shown) at the bottom. Another useful feature is the provision of an air release device on both sides of the filter element. The container, being held by means of a one-bolt fixture, can readily be removed for cleaning.

The Simms' Fuel Filter

The principle employed in this filter is that of the "edge-type" flow, whereby a large number of accurately made flat discs are mounted at very small distances apart, viz., of the order, 0·001in.

Fig. 177 gives a sectional view of the Simms' filter. The interior of the body *A* is slightly tapered from top to bottom and the filter element *C* has an equivalent taper on its outer surface. The two are held in contact by the spring *D*. The unfiltered oil enters at *E*, whilst the filtered oil leaves by the tapped hole *F*. The tapered filter elements only fit accurately at the extreme ends, the remaining surface being cut away to give a clearance of 0·002 to 0·005in.

Several grooves *G* are formed on the outer surface of *C*; these grooves end a short distance from the upper end of *C*.

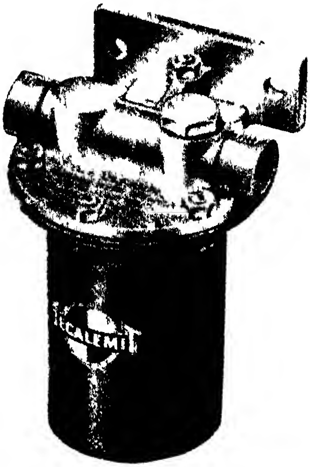

FIG 176 —The Tecalemit Fuel Filter

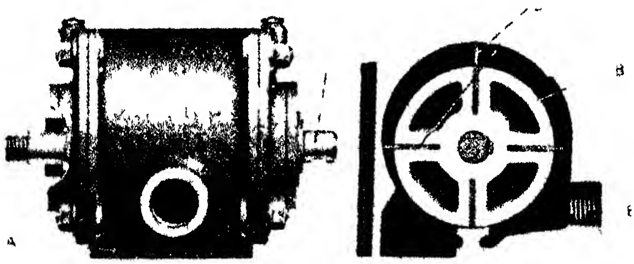

FIG 178 —The Leyland Exhauster

[*To face page* 206

The lower ends are blocked by a serrated plate *H* and these grooves at their upper ends have ports *J* connecting with the upper end of the body. A second set of ports *K* communicates between the alternate grooves (open at their lower ends) and the interior of the filtering element.

In action the oil from the central part flows *via* the ports *K* into the grooves communicating therewith. The only egress is through the clearance spaces between adjacent grooves, filtration taking place here; the filtered material gravitates downwards and is collected in the lower part of the filter, as shown. The filtered oil flows up through the ports *J* and thence into outlet port *F*.

It will be seen that filtering is accomplished by the direction of flow down the filter lines which produces a dislodging action. Vibration also tends to displace the filtered particles, which gravitate downwards.

Suitable Fuel for C.I. Engines

High speed C.I. engines will only operate satisfactorily on certain grades of fuels, generally known as Solar, Diesel and Gas Oils. The important properties of these fuels include the ignition temperature, cetene value, viscosity, flashpoint and freedom from corrosive action on metals.

Suitable fuels are obtainable from petroleum or shale and should be free from mineral acid, grit and other foreign impurities. Standard specifications for C.I. engine fuels are now issued by the British Engineering Standards Association, 32 Victoria Street, London, S.W.1.

The following is the specification for fuel used on A.E.C. engines.

Closed Flash Point.—Not to be below 175° F.

Viscosity.—Measured on the Redwood No. 1 Instrument, at 100° F., not to exceed 40 seconds.

Cold Test.—The pour point of the oil not to be above 20° F. *Method of Test.*—A.S.T.M. Serial Designation D.97.22.T. (*See* also I.P.T. Standard Methods of Testing, 1st Edition, G.O.11, page 38.) No crystalline or other deposit to form during the test above or at the specified pour point.

Water.—Nil.

Adventitious Matter.—Not to exceed 0·03 per cent.

Ash Content (Inherent).—Not to exceed 0·01 per cent.

Sulphur Content.—Not to exceed 0·75 per cent.

Spontaneous Ignition Temperature.—Depends on type of apparatus used for test. Temperature should, however, be as low as possible.

Performance.—The fuel must give satisfactorily smooth running when tested in the engine.

B.E.S.A. Specification

The Specification "A" No. 1 of the British Engineering Standards Association for Diesel oil is as follows:

Flash-point (closed)	Not to be less than 150° F.
Hard asphalt content. . . .	Not to exceed 0.5 per cent.
Ash content	„ „ 0·01 per cent.
Viscosity (Redwood No. 1) at 100° F. .	„ „ 75 secs.
Water content	„ „ 0·5 per cent.
Cold test	Oil to remain liquid at minus 20° F.

Although the specific gravity of a fuel is no criterion of its suitability as a C.I. engine fuel, it is usual for the specific gravity, at normal air temperatures of 60° F., to be between 0·840 and 0·880.

Care of The Exhauster

The vacuum creating device, or exhauster, now forms an integral part of most C.I. engines used for road transport purposes. The partial vacuum obtained is employed for operating the servo brakes and, where vacuum feed for the fuel supply is employed, for this purpose also.

The exhauster consists, usually, of an eccentric rotor having four sliding blades, as shown in Fig. 178; it is driven from the timing gear either direct or in tandem with the fuel pump. The Leyland exhauster shown is bolted over an opening in the crankcase side by means of a flange *A*, Fig. 178, formed on the casing. The rotor *B* is keyed on a shaft *C* carried in ball bearings, the shaft being mounted eccentric with the rotor barrel. Four blades *D* are a slack fit in the rotor slots, centrifugal force causing them to follow the eccentric track of the rotor barrel. Air is evacuated through a pipe connected at *E* and discharged into the crankcase. Lubrication of the rotor is by splash from the engine, greasers being provided for the ball bearings which should receive attention once a week.

A storage tank is fitted to provide a reserve vacuum and to smooth the action of the brakes, a non-return valve in the pipe line preserving the vacuum when the engine is running slowly or is stopped. An adjustable snifting valve is fitted to relieve the exhauster when the pipe line vacuum rises above 10 lbs. per sq. in. or 20in. of mercury.

A vacuum gauge is provided on the dash and should this fail to register a vacuum of 20in. while the engine is running at speed, the pipe line and snifting valve should be examined for leaks. The setting of the snifting valve should not be altered unless the gauge continually shows too low a reading. If, in a new engine, the gauge fails to show a reading when the engine is started up, the engine should momentarily be speeded up in

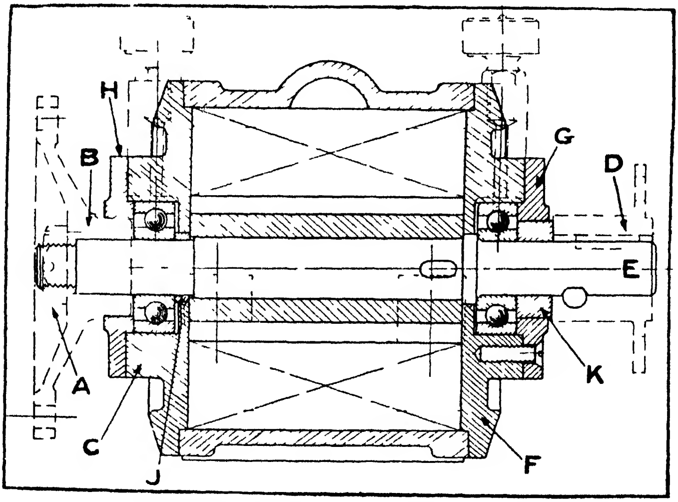

FIG. 179—Illustrating Method of Dismantling an Exhauster.

order to free the rotor blades, as the latter may be stuck with cold oil. With a vacuum of less than 10in. (on the gauge) the efficiency of the footbrake will be impaired.

If the reading is consistently low, examine the Servo control valve and joints for air leakage.

The exhauster should be dismantled and all dirt, etc., cleaned from the body every 25,000 miles, giving special attention to the blades.

The method of dismantling an exhauster of the type described is best illustrated by the Crossley C.I. engine example shown in Fig. 179.

First undo and remove nut *A*; withdraw half coupling *B* and undo cover *C*; then remove half coupling *D*; and clean off any burrs on the keyway of the shaft; lightly tap the end of shaft *E* with a lead hammer. The rotor and shaft complete will then come out of the casing with cover *C*, which can subsequently be tapped off the shaft. (If required, the other cover *F* can be taken off, and then, by removing the outer covers *G* and *H*, the bearings can be removed. It should not be necessary to dismantle these covers unless it is evident that the bearings are worn.)

When reassembling see that bush *J* is on the shaft. Replace cover *F* if it has been removed, insert the shaft and rotor, then replace the cover *C*. See that the distance bush *K* is in place, but before fitting couplings turn the shaft and "feel" for freedom of the rotor in the casing. Check this again after fitting couplings to ensure rotor is not binding against one end cover of the casing. If necessary, jar the shaft end with a lead hammer until the same "feel" is obtained.

When the exhauster is dismantled, the blades should be examined for wear by pushing the blade home in the slot, and noting the distance the tip of the blade is below the rotor diameter. When the blade wear reaches $\frac{1}{8}$ in., the complete set of blades should be replaced.

The rotor and shaft should be considered as one part, and no attempt should be made to remove one from the other.

When reassembling, care should be taken to see that the blades are quite clean and free in their slots, and that they face in the same direction as when removed.

Air Cleaners

Air cleaners of the oil-wetted wire kind should be cleaned at regular intervals by washing the wire elements in petrol and, after drying, immersing them in clean lubricating oil; the surplus oil should be allowed to drain off before replacing the filter element. The frequency of cleaning will depend upon the operating conditions, i.e., upon the use of the engine in a clean or dusty atmosphere, but under normal conditions the filters should be cleaned, in the case of road vehicles, every 3,000 to 4,000 miles.

The Leyland air filter shown in Fig. 180 is of the oil bath type and is clipped over the main air intake. It consists of a sheet metal bowl containing engine oil and a detachable cover housing a brass wool element. The unit is removed for cleaning by slacking off the clamp bolt. The cover is removed by unscrewing the hand nut on top and lifting.

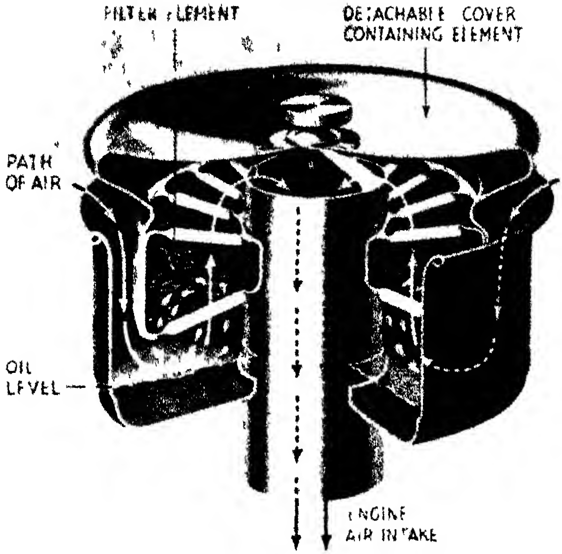

FIG 180 —The Leyland Air Cleaner

To clean the filter, remove the cover and wash the bowl with petrol or paraffin and replenish with engine oil to a depth of $\frac{7}{16}$ inch, as shown by the oil-level mark around thc bowl. Swill the element in petrol and allow it to drain before replacing.

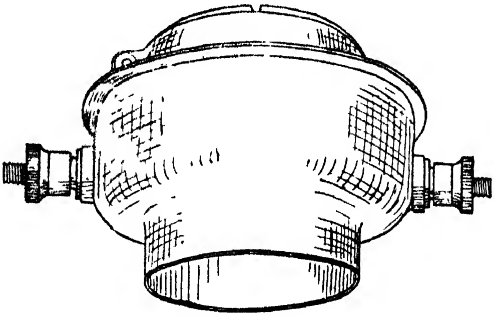

FIG. 181.—Air Cleaner and Heater for Starting Purposes.

Felt pattern air cleaners should be cleaned in a petrol bath every 3,000 miles or so, and new filter cartridges fitted about every 8,000 to 10,000 miles ; these filters are so cheap that it is not economical to clean them more than two or three times.

Fig. 181 shows an air cleaner embodying an electric resistance unit for heating the air taken into the engine prior to cold starting. This unit operates off the vehicles starting battery.

CHAPTER XII

THE C.A.V.-BOSCH FUEL INJECTION EQUIPMENT

In view of the fact that many leading makes of British and foreign high speed C.I. engines have adopted the Bosch and C.A.V.-Bosch equipment as standard, it is proposed to devote the present chapter to the various components of this equipment; these comprise the fuel injection pumps—types BPF and BPE—fuel injection nozzles and nozzle holders.

The BPE type of pump as fitted to commercial motor vehicles will be first dealt with. The BPF series are chiefly used on stationary or marine engines, but operate on the same principle.

The BPE pumps are made in the one, two, three, four and six-cylinder units, the series B, with which we are at present concerned having a constant plunger stroke of 10 mm. and plunger diameters ranging from 5 mm. to 10 mm. The former diameter gives a maximum useful output of 65 cubic mm. (·0041 cu. in.) per stroke and the latter 280 cu. mm. (·0171 cu. in.).

The two-cylinder pump, with aluminium housing weighs about 12 lbs. and the six-cylinder one 24 lbs.

We shall take as a typical example, for description purposes, the Leyland six-cylinder engine type standard C.A.V.-Bosch pump shown in Fig. 182. This pump is mounted on a platform behind the exhauster and is secured by two straps. It is driven from the timing chain through the exhauster, a flexible coupling between the two units providing a means of varying the pump timing. The pump is driven anti-clockwise as viewed from the radiator end.

The camshaft *A* is carried on ball-bearings *B* and runs in an oil bath, the cams bearing against the steel rollers *C* of the adjustable tappets *D*. The plunger barrels *E* are fixed in the casing by the set-screws *F*. The plungers *G* are located in the regulating sleeves *H* by the lugs *J* on the plungers, which operate in the slotted sleeves *H*. These sleeves carry toothed

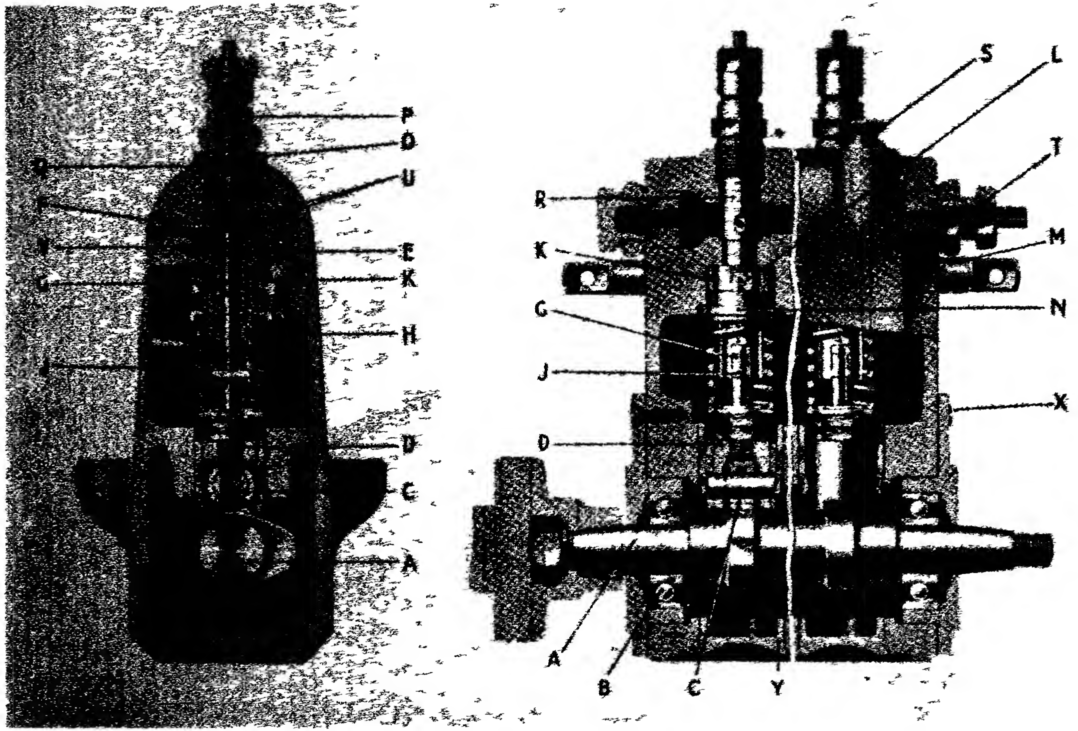

FIG. 182 —The C A V -Bosch Fuel Pump as used on Leyland Engines

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arcs *K* secured by the clamping screws *L*, a rack on the control rod *M* meshing with the teeth on the arcs *K*.

The return springs are retained between collars *N* in the housing and on the lower end of the plungers. Housed in the valve holders *R* are the delivery valves *O* together with their seatings *Q* and return springs *P*. The delivery pipes are secured to the valve holders by nipples and nuts, oil leakage being prevented by suitable packings.

The oil level in the camshaft oil bath can be checked by the dip stick *S*; the plungers do not require lubrication.

It is important to note that the plungers are a very fine fit in their barrels. *These parts are, therefore, definitely not interchangeable and must only be replaced in pairs.* This also applies to the delivery valves and their seats.

Lubrication

The oil level must be checked weekly by means of the dipstick *S*, Fig. 182, and replenished if necessary with engine oil. On later types fitted with a drain plug, the oil should be drained every three weeks and a fresh supply given.

Operation of Fuel Pump

The fuel enters the suction chamber which is common to all plungers at *T*. When the plungers are at the bottom of their stroke, two ports *U*, Fig. 182, are uncovered and fuel is drawn into the pressure chambers above the plungers. On the plungers being moved upwards by the cams, the ports *U* are first closed and the fuel is forced past the delivery valves *O*, Fig. 182, to the nozzles. Immediately the helical-edge V, Fig. 182, on the plunger uncovers the port on the right, the pressure chamber and suction chambers are in communication by way of the vertical groove *W*, and all pressure being lost, no further fuel passes the delivery valves. When the control rod *M*, Fig. 182 is moved endwise, the regulating sleeves and therefore the plungers are rotated, the control-rod rack moving the arcs *K*. Thus, as the plungers are rotated, the time of uncovering the ports by the helical edge V is varied, which has the effect of varying the effective stroke of the plunger and thus controlling the quantity of fuel delivered to the engine. As the control rod is connected to the foot throttle, the quantity of fuel delivered at each stroke is varied according to the position of the pedal.

The Pump Element

The C.A.V.-Bosch pump element is shown in greater detail in Fig. 183, the various components being given in the description below. It is important to note that the position of the plunger stroke at which the helical edge V (Fig. 182) will uncover the port is adjustable by rotating the plunger axially by means of the toothed quadrant 107*b* which is clamped to a sleeve 107*a* having slots engaging the lugs of the plunger at its lower end. The toothed quadrant 107*b* meshes with the rack 107*d* formed on the control rod. This rod is arranged to operate all of the toothed segments of the different plungers in the pump unit, simultaneously.

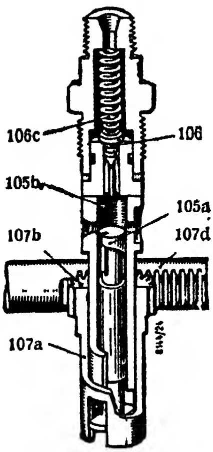

FIG. 183.
The Bosch Fuel Pump Element in sectional view.
105*a* pump plunger.
105*b* pump barrel.
106 delivery valve and seat.
106*c* valve spring.
107*a* control sleeve.
107*b* toothed quadrant
107*d* control rod.

Anti Dribble Device

A device to ensure the positive shut-off of the fuel in order to prevent "dribble" of the fuel at the injection nozzle is incorporated in each pump cylinder.

When the helical edge V of the pump plunger uncovers the port in the pump barrel near the end of the delivery stroke, the pressure of fuel is immediately reduced so that the delivery valve at once drops on its seating, thus cutting off communication between the pump and the nozzle.

The delivery valve also performs another function, viz., that of releasing the pressure in the pipe. The valve in question is designed specially for this double purpose. It effects a certain increase in volume in the delivery pipe system, so as to reduce the pressure practically to atmospheric value. The effect of this is to cause the nozzle valve in the fuel nozzle to "snap" on its seat, thus suddenly terminating the spray of fuel and eliminating "dribble."

The construction of the delivery valve is shown in more detail in Fig. 185 from which will be seen that it is an ordinary mitre faced valve with a guide which has a circular groove cut in it, dividing the guide into two parts. The lower part has four longitudinal grooves communicating with the circular groove. The upper part of the guide forms a small piston

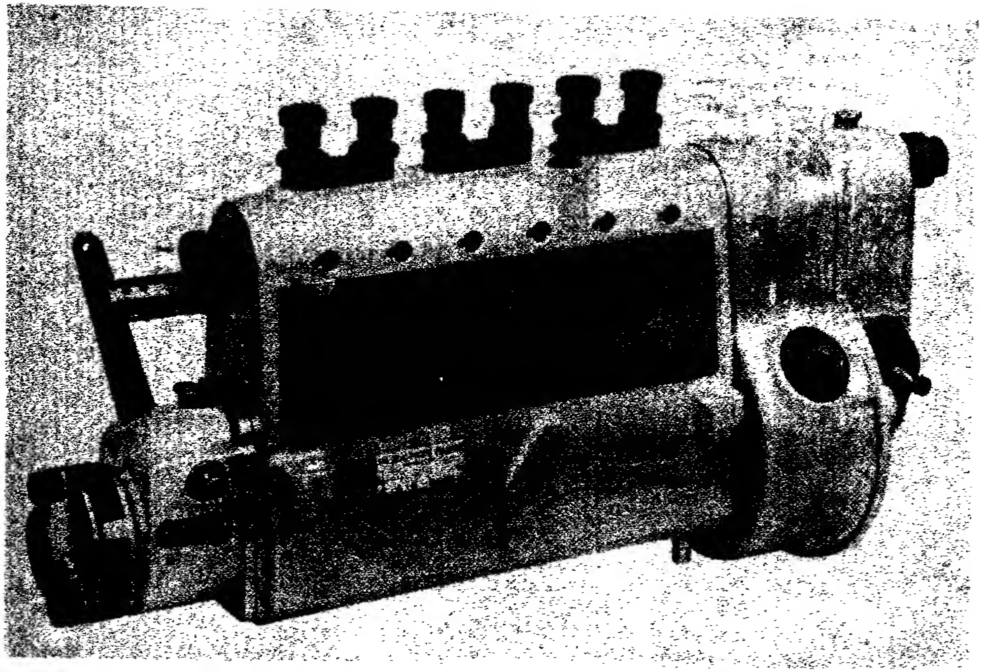

FIG. 184.—The C.A.V.-Bosch Six-Cylinder Type Fuel Injection Pump.

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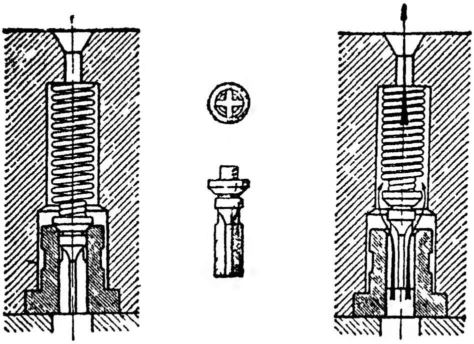
which is a highly-ground plunger fit for the valve seating which is also internally ground. When the pump is on its delivery stroke, as the pressure of the fuel rises, the delivery valve is pushed up until the pressure fuel can escape through the longitudinal grooves over the valve face to the nozzle. Immediately the pump plunger releases the pressure in its barrel, the delivery valve (under influence of its spring and the great difference in pressure between the pump barrel and the delivery pipe) resumes its seat, causing the small piston parts of the guide to sweep down the valve seating with a plunger



Closed. Open.

FIG. 185.—The Bosch Fuel Pump Delivery Valve

action, thus increasing the space in the delivery pipe (by an amount equal to the volume of the small piston part of the valve guide) before the valve actually seats itself.

Fuel Control Device

The ordinary non-governing type of fuel pump has an output control actuated by means of the control rod 107*d* (Fig. 183). The word " stop " and an arrow engraved on one end of the pump casing in line with the control rod 107*d* indicate which way the control rod should be moved to stop the engine.

Referring to Fig. 186, showing a six-cylinder type of pump the three positions *A*, *B* and *C* of the control rod correspond, respectively, to the " Engine in Starting Position," " Engine at Normal Load " and " Engine Stopped." The other components indicated by the lines and numbers are given in the caption below.

It is desirable on certain classes of engine to afford some means by which the commencement of injection can be advanced or retarded in order either to facilitate starting or to select the instant of injection most suited to the engine in

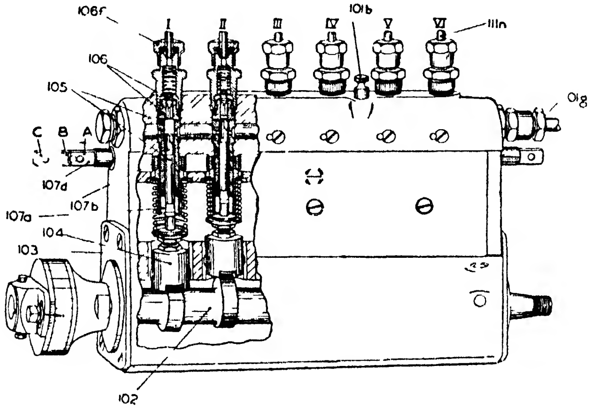


FIG. 186.—Illustrating the Method of Controlling the Fuel Output.

101*b* Lubricating oil gauge rod, 101*g* Fuel inlet connection, 102 Camshaft, 103 Bearing end plate, 104 Plunger guide and tappet roller, 105*a* and *b* Pump barrel and plunger, 106*a* and *b* Delivery valve and seating, 106*f* Delivery nipple nut, 107*a* Control sleeve, 107*b* Regulating toothed quadrant, 107*d* Control rod, 111*n* Delivery pipe

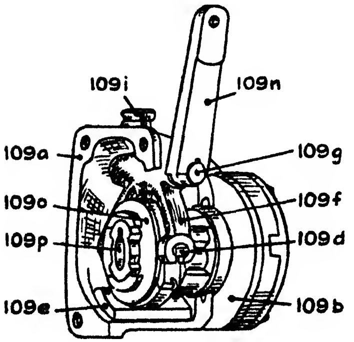


FIG. 187.—The Fuel Injection Advance Device.

109*a* Housing, 109*b* Half coupling paws, 109*d* Clamp for splined bush, 109*e* Felt pad, 109*f* Adjusting stirrup, 109*g* Spindle, 109*i* Lubricating oil cup, 109*n* Adjusting lever, 109*o* Splined bush, 109*p* Splined cone.

question. This variation is provided for in an efficient manner by the compact C.A.V.-Bosch injection advance device which is recommended especially for commercial vehicle high-speed oil engines, etc. This device is available in two models, giving respectively variations of 8° and 12° measured in terms of pump camshaft rotation. On a 4-stroke cycle engine, therefore, it will be seen that the period represented is twice that mentioned above, when measured on the engine crankshaft.

The adjusting lever 109*n* (Fig. 187) is connected by a small shaft and fulcrum with the stirrup 109*f* carrying a loose clamp 109*d* which is located between the collars of a female splined bush 109*o*. This bush engages with the two paws of the half coupling 109*l*, and the inclined spline on the inner cone 109*p* in which the pump camshaft is fitted. It will be seen that the splined bush 109*o* can be made to slide longitudinally along the paws of the half coupling by movement of the adjusting lever 109*n*, the action of the inclined splines on the inner splined cone causing an angular displacement between the pump camshaft and the engine driving shaft.

Adjusting Governor Type Fuel Pump

In connection with the governor type of fuel pump illustrated in Fig. 160 and 161, when the engine rotates at a speed below the idling limit (e.g. by electric starter), the centrifugal force generated by the governor weights is insufficient to swing them out enough to compress the " idling " springs. In this condition the weights will rotate close to the shaft and will impart, through the medium of the bell crank 110*g* (Fig. 161) a clockwise rotary movement to the floating lever 110*r* about the eccentric 110*l*, as shown in Fig. 161, with the result that the control rod, unless limited in travel, will move away from the " Stop " and thus may provide more fuel than can be usefully consumed. To prevent this, a control rod stop 101*m* is provided, the adjustment of which is illustrated in Fig. 187.

The output of the pump is regulated by the travel of the control rod. This travel is limited by two means, namely, by the control lever set screw stop (Fig. 188) and the pinned control rod sleeve stop (Fig. 187).

When the governor controls have to be re-adjusted after bench tests of a new or reconditioned engine adjustments are made to these two stops so that the maximum rated power is obtained at the required engine speed. These conditions are generally attained just before the exhaust approaches a smoky nature and with a fuel consumption of a

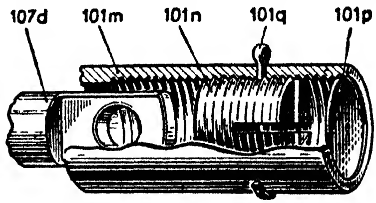


FIG. 187A.—Control Rod Stop.
107*d* = Control rod.
101*m* = Control rod stop.
101*n* = Control rod stop screw.
101*q* = Split pin 101*p* = Dust cap.

low order. The stops are usually sealed with these adjustments.

With the engine developing the desired power and speed and with a clean exhaust, the control lever stop (110*ma*, Fig. 188, consisting of stop screw and lock nut) is adjusted to such a position as to limit the control lever angular movement to keep the engine running with clear exhaust. After doing this and with the engine still running, the control stop 101*n* in Fig. 187A (contained in the control rod sleeve 101*m*) should be screwed in until it just touches the control rod end 107*d*; this can, of course, only be done after removing the dust cap 101*p* and pin 101*q* provided in the sleeve.

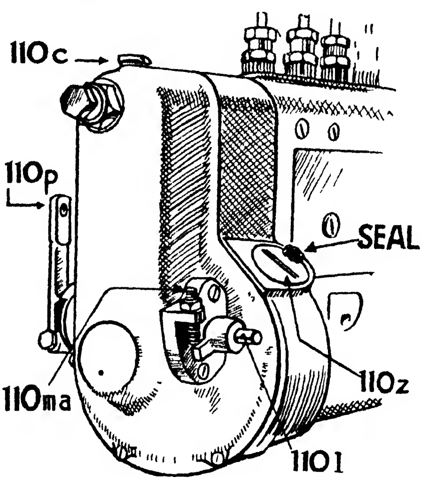


FIG 188 —The Governor Control Lever Stop Adjustment

110*c* = Oil cup
110*l* = Eccentric shaft.
110*ma* = Control lever stop.
110*p* = Control lever.
110*z* = Access plug

The alternative form of governor stop arrangement shown in Fig. 189 provides for adjustment for idling as well as maximum speeds and is useful where long linkage between the governor and control lever or accelerator pedal is necessary, or where it is most convenient to have the stop at the pump rather than the control end of the linkage, or intermediately. The stop assembly consists of a spring loaded plunger *A* (Fig. 190) with a screw adjustment provided by sleeve *B* and lock nut *C*. A crescent-shaped stop pawl *D* replaces the lever in the normal stop assembly and at idling speeds bears against the plunger without external pressure other than that of the control pedal return spring; by adjusting the stop sleeve *B* it is possible to correct the fuel delivery to give the most desirable engine performance within the range of idling speed possible, lock nut *C* being provided to secure it in the final position. The engine can be stopped by increasing the pressure of the pawl *D* on the plunger *A* until the resistance of loading spring *E* is overcome. This is usually effected by lifting the accelerator pedal upon release of which the pawl returns to the normal idling position.

A similar form of maximum delivery stop to the normal is fitted on this stop and comprises stop screw F and lock nut G. Adjustment is effected (usually by the engine builders) to limit the maximum possible delivery according to specific operating conditions and often sealed by the addition of cover *H*, to prevent subsequent interference.

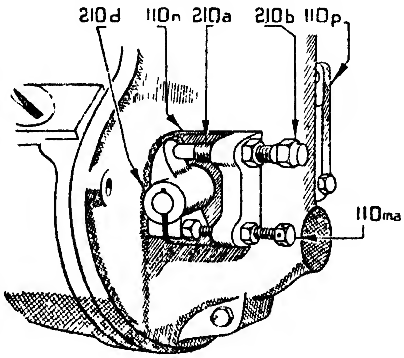


FIG. 189.
Idling and Maximum Speed Stops.
210 *a* = Idling control screw.
210*b* = Idling control adjusting head.
210*d* = Crescent-shaped pawl.
110*p* = Control lever.
110*n* = Bracket
110*ma* = Control lever stop.

Now, with the engine stationary and preferably cold, starting tests should be made to ascertain whether the permitted amount of fuel control opening is sufficient for good starting. Should it not be so, then the "Stop" 101*n* (Fig. 187) must be further withdrawn, say half a turn at a time, until good starting is obtained, when the pin will be replaced securing the "Stop" 101*n* in position.

When adjusting the controls a compromise may be necessary between good starting and fair exhaust conditions at starting. To do this, with engine stopped and control lever opened to the maximum permitted by set screw 110*ma* (Fig. 188), the control rod stop 101*n* may be screwed into sleeve until it contacts with the end of the control rod 107*d*. Now it may be turned in still more to the extent of about ¼ in. against the pressure of the control rod until a considerable resistance is felt, or until the control lever stop just leaves its limiting screw 110*ma*. The control rod stop 101*n* screw may now be unscrewed the required amount to facilitate starting. The adjusting screw must be secured with the split pin 101*q*, and the dust cap 101*p*, afterwards inserted into sleeve. When the engine is started and the speed of revolution rises above that of idling, the control rod opening will be limited automatically to that originally determined by the control lever stop 110*ma* adjustment.

Removing the Fuel Pump

To remove the pump from the engine, disconnect all delivery pipes at the unions and cover the pump unions with the brass shield provided in the tool kit. This obviates the possibility of dirt falling into the pump outlets and causing nozzle trouble. Disconnect the feed pipe, remove the control rod jaw-end and loosen the straps so that the pump can be lifted off.

Dismantling the Fuel Pump

This requires the services of a skilled mechanic trained in this class of work.

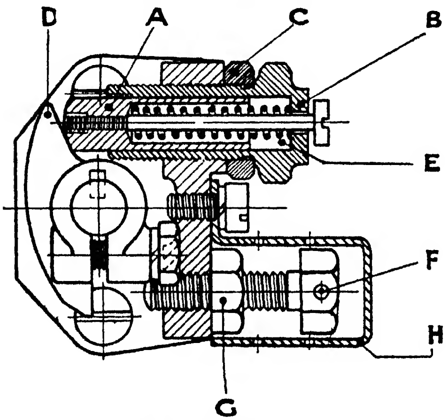


Fig. 190 —Idling and Maximum Speed Stops

Strict cleanliness should be observed when preparing to dismantle fuel injection pumps, care being taken that all iron filings, dirt, grit, dust, etc., have been removed from the bench on which the work has to be done. The bench should then be covered with a sheet of clean grease-proof paper and a number of small clean containers provided for the various parts removed. It is also advisable to have a thoroughly clean covered vessel available containing a supply of fresh clean paraffin for washing these parts. If permanent facilities are installed for the servicing of injection equipment, the bench should be covered with zinc sheeting or linoleum or a similar easily cleaned material.

The following are the parts of the C.A.V.-Bosch pump which may be changed by the skilled mechanic: *Camshaft and ball bearings, delivery valve holder, delivery valve with seating, upper and lower spring plate, spiral spring for plunger, inlet closing plug* and *oil gauge rod.*

Those parts which should only be repaired or replaced by the

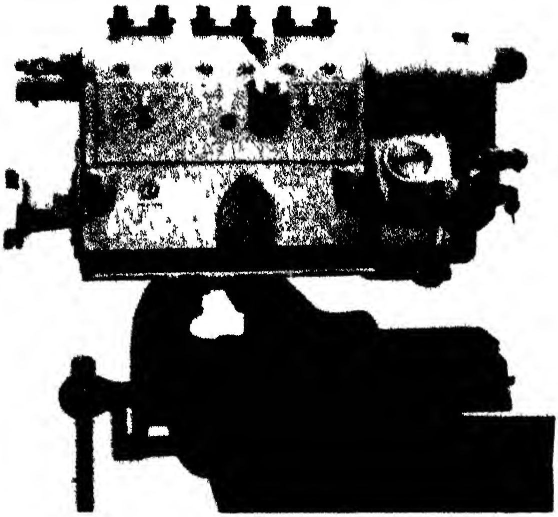


FIG 191 — Method of Holding Fuel Pump in Vice by means of special Fixing Plate F I 8056 (Fig 192)

[*To face page* 221

Bosch Service Agents are: *The roller tappet, pump barrel with plunger* and *the regulating sleeve with toothed quadrant.*

It is important to remember that a pump plunger should never be separated from its barrel, or used in another barrel, for it will only fit the barrel into which it was originally lapped. If any wear has occurred a new plunger and barrel unit should be fitted.

Similarly, with the delivery valve and its seating, these must always be kept together as they have been accurately matched. If trouble is experienced after cleaning they should be replaced with a new pair.

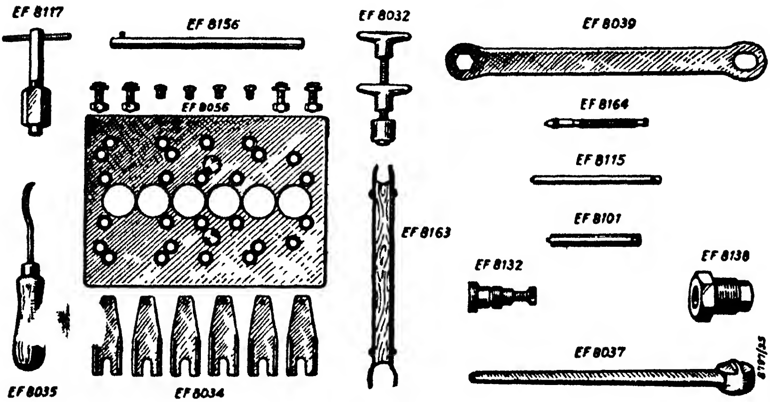


FIG. 192.—Showing Special Tools for dismantling Bosch Fuel Pump.
EF 8032 or 8117 Delivery valve seat extractor, EF 8034 Tappet holder, EF 8035 Tappet lever, EF 8037 Angle screwdriver, EF 8039 Cap Nut Spanner, EF 8056 Fixing plate with screws for fastening the pumps on the fixing plate, EF 8132 Coupling Extractor, EF 8156 Plunger gripping device, EF 8163 Tappet forceps, EF 8164 Nozzle cleaning pin.

Tools Required

Special tools (Fig. 192) are supplied by the makers for dismantling their pumps and these should always be used.

Further, in order to facilitate the manipulation or fixing of the pump for repair or replacement purposes the makers provide a special *fixing plate* (Fig. 192, Part EF 8056) with screws for attachment to the base of the pump. Two projecting pegs enable the plate (with the pump attached) to be held in the vice.

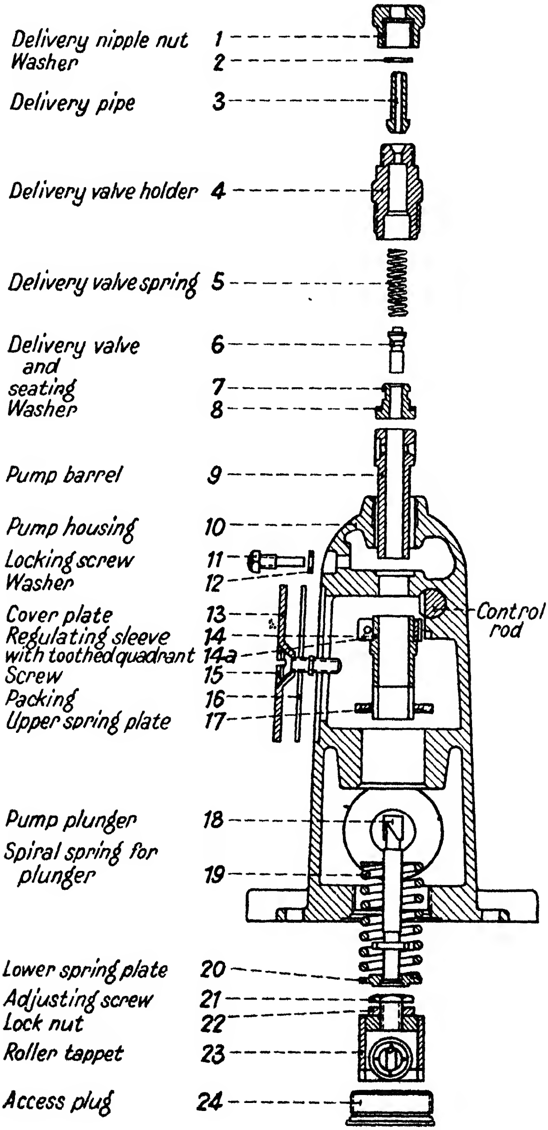


FIG. 193.
Component Parts of C.A.V.-Bosch Fuel Pump.

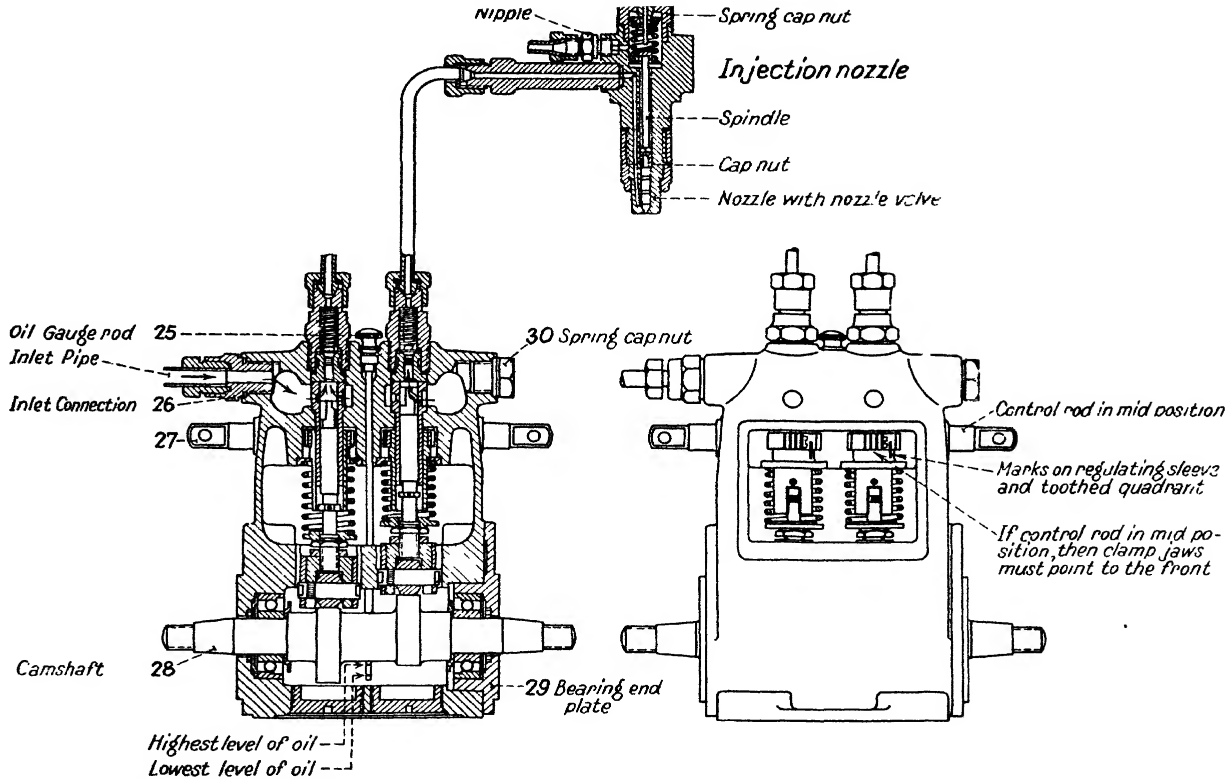


FIG. 194.—The C.A.V.-Bosch Two Cylinder Fuel Pump, showing above, the Injection Nozzle and Connecting Pipe.

Pump Components

The various components of the pump, Type PE, are shown in Fig. 193 so that the method of assembly and dismantling can readily be followed.

To Remove Coupling or Injection Advance Device

Hold the coupling with the aid of a spanner, then unscrew fixing nut with a 22mm. socket wrench. Screw the withdrawing device *EF* 8132 into coupling, then screw in hexagonal screw until the coupling has freed itself from the taper of the shaft (Fig. 195); the coupling must not be knocked or prized off. Before pulling out the injection advance device unscrew the four fixing screws, hold coupling, and screw off fixing nut. Screw in the withdrawing device *EF* 8132 in place of the fixing nut until the splined cone is freed from the taper on the shaft; then remove injection advance device (Fig. 187).

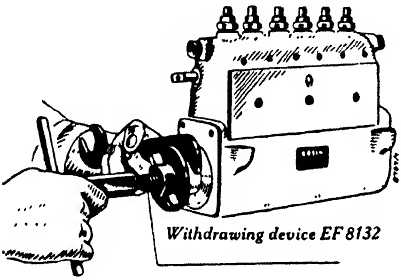


Fig. 195.
Withdrawing Pump Driving Coupling.

To Remove Camshaft

For this operation it is necessary to fix the pump on to its *fixing plate* (Fig. 192 *EF* 8056) and then hold the latter in the vice by means of the two pegs under same (Fig. 191). Unscrew the inspection cover plate 13 (Fig. 193), then turn the camshaft 28 and push in the tappet holder (Fig. 192 *EF* 8034) for all roller tappets in the direction of the arrow, as shown in Fig. 196. Unscrew one bearing end plate 29 and take out the camshaft 28 (Fig. 194). Take care to remember the position of the mark on the front of one

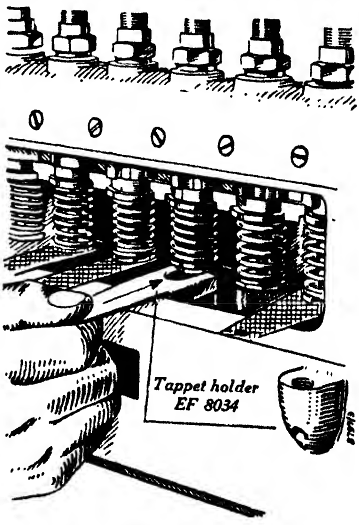


Fig. 196.
Illustrating Use of Tappet Holder.

of the threaded shafts. When re-assembling the camshaft this mark is used to determine the correct firing order of the engine. When looking towards the cover plate the mark is on the left for pumps with numbers 100, 101, 102, whilst for those with numbers 200, 201, 202 it is on the right.

Replacing Ball Bearings

Remove the camshaft. Take off the ballcase and pull off ball bearing race on the shaft by means of the special device provided by the makers. Put on oil thrower for camshaft and adjusting washers and then press on the new ball bearing. Pull ball bearing race off bearing end plate by means of with-drawing device and bell-shaped support, then press on new ball race. Finally, replace camshaft with a longitudinal play of 0·1 to 0·2 mm.

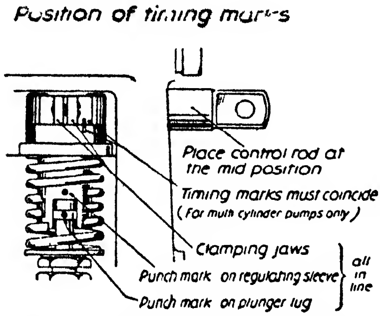


FIG. 197—Replacing Plunger Spring.

To Replace Plunger Spring

Unscrew coupling or injection advance device. Remove camshaft. Loosen base closing plug 24 (Fig. 193) with angle

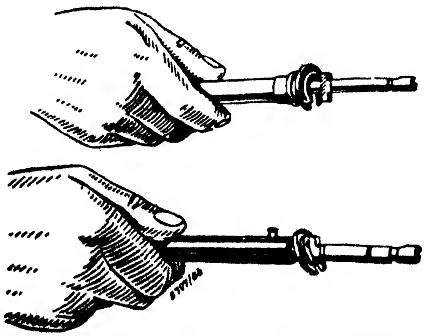


FIG. 198.—Showing the special Plunger Gripping Device, holding the Pump Plunger and Spring Plate placed in position.

screw driver (Fig. 192, *EF* 8037) and then unscrew it. Force up the roller tappet 24 with tappet clamp (Fig. 192, *EF* 8163) and then remove tappet holder (Fig. 192, *EF* 8034). Remove roller tappet 33, lower spring plate 20, pump plunger 18 and spring 19 for plunger. Put in the new spring 19 for plunger and insert pump plunger 18 and lower spring plate 20 with plunger holder *EF* 8033 and 8117. The punch mark on the plunger lug must correspond with that on the regulating sleeve, as shown in Fig. 197.

Place roller tappet 23 on tappet clamp *EF* 8163, then bring it into the pump body and force it up until the tappet holder *EF* 8034 can be inserted between adjusting screw 21 and lock nut 22 (Fig. 193).

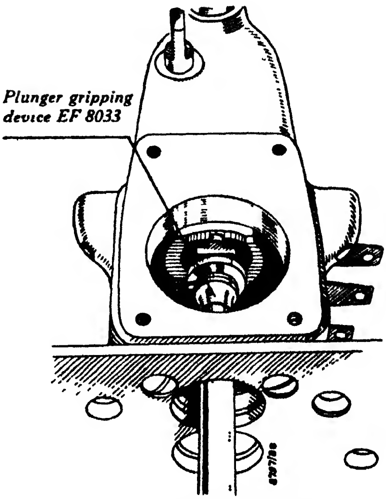


FIG. 199.—Illustrating method of Inserting Plunger Gripping Device in the Pump.

To Exchange Delivery Valve and Seating, Spring and Holder

Unscrew delivery valve holder 4 with a 22 mm. spanner; remove delivery valve spring 5 (Fig. 193). Pull out valve seating 7 with the aid of the delivery seat extractor (Fig. 192 *EF* 8032). The slot of this extractor must be pushed over the two surfaces on the valve seating and then given a quarter of a turn. It then grips the valve seating in the manner of a bayonet catch; the seating can then be withdrawn by turning the nut on extractor to the right (Fig. 201).

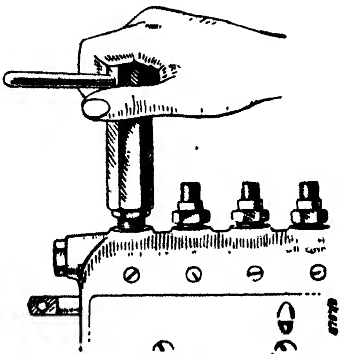


FIG. 200.
Unscrewing Pump Delivery Valve with 22 mm. Spanner.

The delivery valve of the later pump models is threaded inside instead of being fitted with an extractor claw. The order No. of the new valve seat extractor is *EF* 8117. Its inner tube is screwed on to the delivery valve and the latter extracted by turning the outer hexagon to the right.

Put in the new valve seating 7 with delivery valve 6 and washer 8. Make sure the valve surfaces are scrupulously clean. Insert delivery valve spring 5 and screw in; well tighten delivery valve holder 4.

Assembling Multi-cylinder Pumps

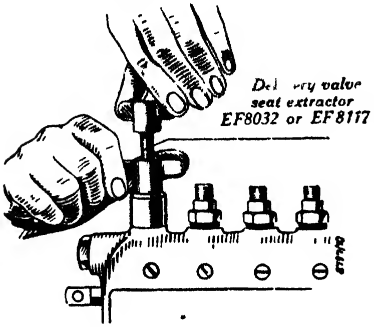


FIG. 201 —Extracting Fuel Pump Delivery Valve.

When mounting the camshaft watch the mark on camshaft 28 (Fig. 194) on the front of one of the threaded shafts. This mark is determinative for the firing order of the engine; according to position of camshaft and direction of rotation this order differs.

When looking towards the cover plate, the mark is on the left, for pumps having no number of execution.

For pumps with execution numbers 100, 101, 102 the mark is on the left.

For pumps with execution numbers 200, 201, 202 the mark is on the right.

Cover the flat rim of the bearing end plate (29) with putty (Hermetic, and if this is not to be had, with talc or grease), then replace bearing end plate and screw on to housing. Tighten fixing screws well and secure them. (Longitudinal play of the camshaft 0·1–0·2 mm., see under II, C 1).

Screw in closing plug (24) and tighten very well with angle screw driver EF 8037.

Turn camshaft (28). Remove tappet-holders EF 8034. Make sure that the lock-nut of the tappet screw is firm; if loose, adjust it in such a manner that the space between the screw head and the nut agrees with

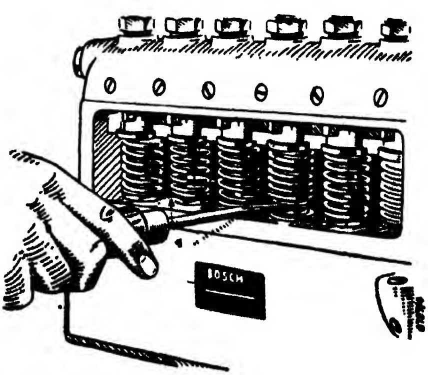


FIG. 202.—Testing Plungers for Clearance, after assembly.

the others. Then control, that the plungers do not touch at the top, they must still have a play, at the top dead centre, of at least 0·3 mm. in the vertical direction (Fig. 202).

Fill in as much oil at the oil gauge rod hole until it reaches the level between the two marks of the oil gauge rod 25 (Fig. 203); finally screw on the inspection cover plate 13.

Fuel Pump Troubles and Their Remedies

Although most of the information on fuel pump troubles given in Chapters VIII and IX are applicable to the C.A.V.-Bosch pump, the following Table will, no doubt, be found more convenient as a means of locating the causes of possible troubles and curing these.

Trouble	Probable Cause	Suggested Remedy
Pump does not deliver fuel	1. Fuel tank empty	Refill tank with fuel
	2. Fuel tank cock closed	Open cock
	3. Fuel inlet pipe choked or filter element dirty	Clear the pipe, cleanse filter element in clean paraffin
	4. Air lock in pump	Prime the fuel system
	5. Pump plunger remains suspended in its barrel	Send the complete pump to the nearest C.A.V.-Bosch Branch for examination
	6. Plunger guide remains suspended in its guide sleeve	Dismantle pump and withdraw the plunger guide. If badly damaged replace parts, as required, from spares
	7. Deliver valve remains suspended	Remove and examine valve face and guide, as well as seating face. If either are damaged, the pair should be replaced from spares.
The pump does not deliver fuel uniformly.	8. Air lock in pump shown by air bubbles, issuing when the delivery valve holder has been unscrewed	Proceed as at 4.
	9. Delivery valve spring broken.	Replace from spares.
	10. Deliver valve damaged either on face or guide.	Fit new pair from spares (i.e. new valve and seating complete).
	11. Plunger spring broken.	Replace from spares.
	12. Tappet roller is worn.	Fit new plunger guide from spares.
	13. Pump plunger occasionally remains suspended in barrel.	Dismantle, thoroughly clean and refit. If trouble still continues, proceed as at 5.
	14. Supply of inlet fuel to pumps insufficient.	
	(a) Inlet pipe choked or filter element dirty.	Proceed as at 3.
	(b) The "head" between the tank and the pump is too small.	Increase the "head" or install fuel feeding pump.
Quantity of fuel delivered per stroke insufficient.	15. Delivery valve leaky.	Fit new pair (i.e. valve and seating) from spares.
	16. Leaky joints in the pressure system.	Clean, joint faces and tighten down.
Quantity of fuel delivered per stroke excessive.	17. Clamp screw of regulating tooth quadrant is slack (only in case of multi-cylinder pumps).	Adjust quadrant with mark on control sleeve and tighten screw hard.
The movement of injection commencement has altered.	18. The adjusting tappet in the plunger guide has worked loose.	Re-adjust and tighten nut hard.
	19. Cam profiles are damaged.	Send the complete pump to the nearest C.A.V.-Bosch Branch to have a new camshaft fitted.
Control rod has jammed.	20. A pump plunger has seized or the control rod toothed rack is coated with dirt or other foreign matter.	Dismantle and cleanse.

The C.A.V.-Bosch Nozzles and Nozzle Holders

The injection unit consists of two parts, viz., the spraying nozzle valve and the nozzle holder.

The C.A.V.-Bosch nozzles are of the " closed " type, so named because the nozzle is closed with a valve after each injection. They are available in a wide range of sizes to suit all classes and sizes of C.I. engine.

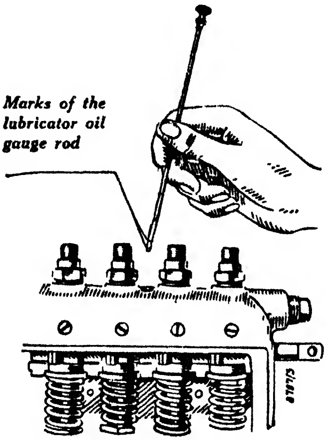


FIG. 203.
Checking the Oil Sump Level.

The two most popular sizes, known as the " S " and "T," respectively, employ five different kinds of valve, known respectively as the *Pintle, Delay, Single Hole, Multi-hole* and *Long Stem.* These are illustrated in Fig. 204.

The nozzles of " S " size are fitted to nozzle holders of which the barrel diameter is 25 mm., and are usually recommended for use in conjunction with the BPEB or BPFB group of injection pumps.

Nozzles of the " T " size are recommended for use with the BPEC or BPFC injection pumps and are held in nozzle holders having a barrel diameter of 32 mm.

A complete nozzle consists of two parts, the nozzle valve and nozzle body—shown at Figs. 205 and 206. The nozzle valve takes the form of a circumferentially grooved barrel which, after being casehardened, is ground to fit the nozzle body with the finest possible limits with which it will work freely. On one end of the nozzle valve a stalk is provided, whilst at the other end it is reduced in diameter to produce a stem upon which a valve face is formed.

Fuel is fed to the mouth of the nozzle through small tunnels bored vertically in the nozzle body which terminate in an annular reservoir or " gallery " just above the valve seat (see Fig. 206). When the nozzle valve is raised from its seat in the nozzle body by the pressure of fuel being fed from the injection pump, the accumulated fuel in the " gallery " is pressed with great force through the hole or holes in the nozzle, thus forming a " spray " in the engine combustion chamber.

Types of Injection Nozzle

There are five principal types of nozzle, each type being designed for use in a particular design of combustion chamber ; the nozzles in question are illustrated in Fig. 204.

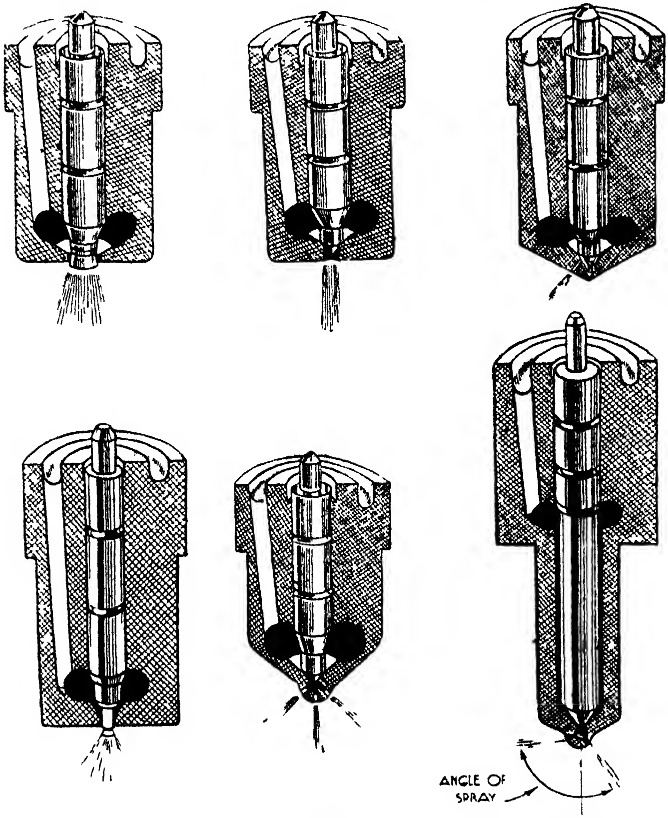


FIG. 204 —Types of C.A.V.-Bosch Fuel Injection Nozzles.
A.—Pintle. *B* —Single Hole. *C*.—Conical End (Single Hole).
D.—Delay. *E* —Multi-hole. *F*.—Long Stem.

Pintle Nozzles.—If the nozzle is of the pintle type, for use in an " air-cell " or pre-combustion chamber engine, for example, the stem of the nozzle valve, already described, is further extended to form a pin or pintle which protrudes through the mouth of the nozzle body. By varying the size and shape of the pintle, cones of spray from 4° upwards can be provided, depending upon the needs of the engine.

Delay Nozzles.—Certain engines, usually of the pre-combustion chamber type, require nozzles with modified spray characteristics in order that they can produce a stable performance when idling. These results are produced by a modification of the pintle by means of which the rate of injection increases towards the end of the delivery, the effect of this being briefly to lengthen the periods of injection at idling speeds without affecting combustion at higher speeds. The nozzle referred to is called the " delay " nozzle and it should be noted that this does not necessarily improve idling in any pre-combustion chamber engine.

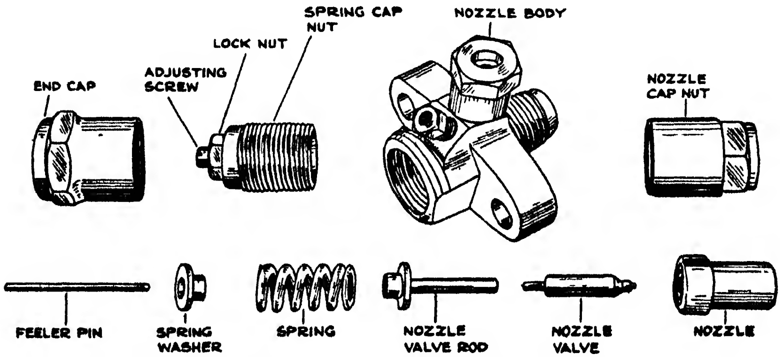


FIG. 205.—Showing Component Parts of Bosch Injection Nozzle.

Single Hole Nozzles.—In the single hole nozzle it will be seen that the mouth consists of one hole bored centrally through the nozzle body and closed by the nozzle valve. The hole can be of any diameter from 0·2 mm. (0·008 in.) upwards. A variation of the single-hole type is also shown and is known as the conical end type. One hole only is used, but it is bored at an angle to the vertical centre line of the valve as required.

Multi-Hole Nozzles.—Multi-hole nozzles can have any number of holes up to seven bored in a " dome " or " teat " under the nozzle mouth. These holes are usually arranged radially in a circle with even pitch, about the axis of the nozzle—the number, size, and " hole angle " of holes depending upon the requirements of the engine. The holes can be provided from 0·2 mm. (0·008 in.) bore upwards by 0·5 mm. steps, whilst the hole angle may be from 20° upwards as required.

Long Stem Nozzles.—For direct injection engines where, owing to limited space between valves in the cylinder head it is not possible to provide for cooling the nozzle in the usual way, an alternative form of multi-hole has been developed. This type is known as the " Long Stem " nozzle, and has an extended body of reduced diameter, in the tip of which is provided the usual valve seating and dome for the injection holes. The valve stem is also elongated, but is a clearance fit in the body, the lapped part of the barrel being located at the portion of the nozzle remote from the seat.

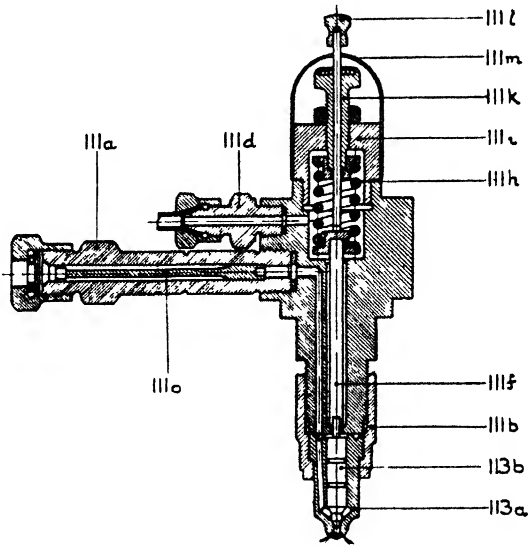


FIG. 206.—Sectional View of C.A.V.-Bosch Nozzle Holder with Multi-hole Nozzle.

111*a* Fuel inlet connection, 111*b* Nozzle cap nut, 111*d* Leak-off nipple stud, 111*f* Spindle, 111*h* Valve spring, 111*i* Spring cap nut, 111*k* Compression screw, 111*l* Feeling pin, 111*m* Protecting cap, 111*o* Edge type filter, 113*a* Nozzle body, 113*b* Nozzle valve.

Nozzle Holders

The nozzles described are held in the correct position in the combustion chamber in special nozzle-holers (Fig. 206). This holder carries the valve spring 111*h* against which the nozzle valve opens under the fuel injection pressure. At the lower end of the holder is a highly-ground face which forms a joint with the flange of the nozzle body 113 *a*, when tightened by means of the nozzle cap nut 111*b*. Fuel is fed through the piping connected to the fuel inlet connection 111*a* through a boring in the nozzle holder ending in an annular semi-circular groove at the ground face of the flange of the nozzle body 113. The nozzle valve 113*b* is held down on its seat by means of the spring 111*h* acting through the spindle 111*f*, and the compression of the spring is adjustable by means of the screw 111*k*.

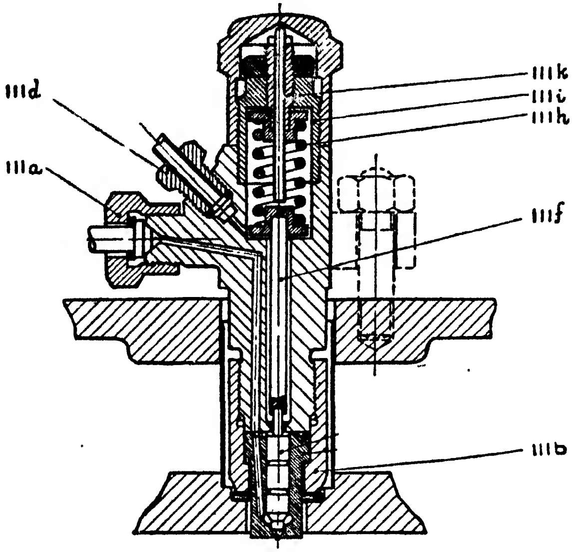


FIG. 207.—The C.A.V.-Bosch Nozzle Holder, Type BKB-S24, showing Packing Washer.

111*a* = Fuel Inlet Connection.
111*b* = Nozzle Cap Nut.
111*d* = Leak-off Nipple Stud.
111*f* = Spindle.
111*h* = Valve Spring.
111*i* = Spring Cap Nut.
111*k* = Compression Screw.

The slight leakage of the fuel which usually occurs within the nozzle holder can be led away by a pipe connected to the leak-off nipple stud 111*d*.

Fig. 207 illustrates the BKB—S24 type of nozzle holder and shows how the packing washer is fitted.

Fitting Nozzle Holders

The nozzle holder is fitted into place in the cylinder or combustion chamber head, using a special copper-asbestos washer (supplied by the makers) for making the joint between the nozzle cap nut end and the cylinder head. The metal of the cylinder, the faces of the copper joint ring and the nozzle cap nut should be cleaned thoroughly in order to obtain a leakproof joint.

The joint washer should be an easy, but not a loose fit on the nozzle body.

When fitting the nozzle holder care should be taken to see that it is an easy fit in the cylinder head tunnel and on the holding-down studs, so that it can be placed down on the copper joint *without force of any kind.* The nuts on the flange

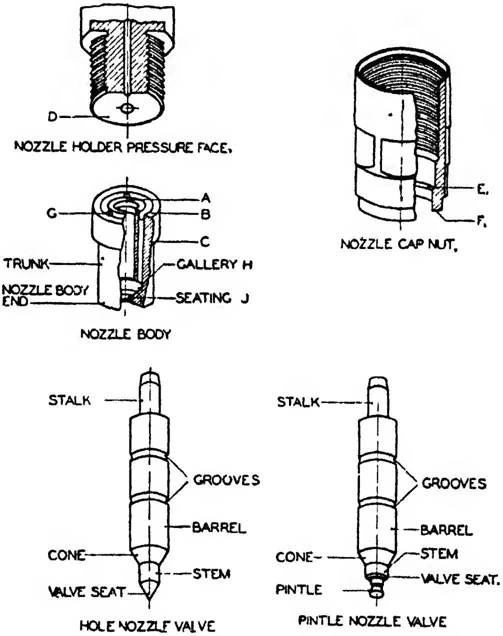


FIG. 208.—Components of C.A.V.-Bosch Nozzles.

should then be tightened down evenly in order to prevent the nozzle being canted and so " nipped " in the cylinder head. This is very important, since any unevenness in tightening down may cause distortion of the nozzle, resulting in its failure.

Provided that the nozzle is fitted satisfactorily, is adequately cooled and clean fuel used no trouble will be experienced over long periods of running. The nozzle should, however, be cleaned at regular intervals, viz., 2,000 to 3,000 miles for road vehicle engines and about once every 6–8 weeks or longer, according to operating conditions, for marine engines.

Cleaning the C.A.V.-Bosch Nozzles

Each of the three types of C.A.V.-Bosch nozzle (hole, multi-hole and pintle) can be dismantled for the purpose of examination and cleaning. The makers supply a special set of tools for this purpose.

Fig. 208 shows the various components of the nozzle.

When dismantled the three small borings shown at *G*, Fig. 208, should be examined to see that they are clean and clear; the valve stem boring in which the nozzle valve slides should also be inspected. The surface should be clean and

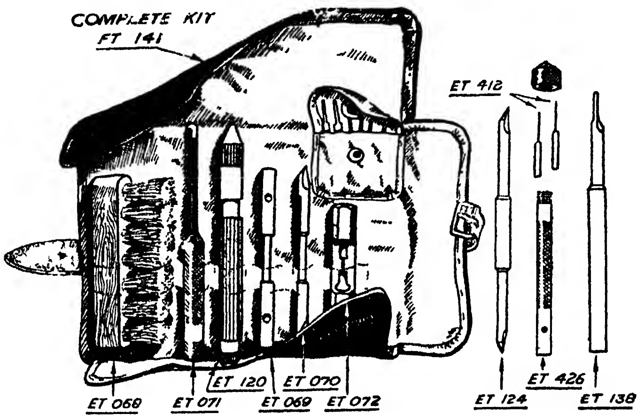


FIG. 209—Cleaning Tool Kit for Nozzles and Nozzle Holders.

bright and free from high spots or scratches or dull patches. The valve seating *J* (Fig. 208) should now come under observation under a strong light to ensure that it is free from dirt or carbon. If this is not so, and indeed, in any case, it is advisable to use the soft brass seat scraper ET070 to remove any carbon or particles that may be imprisoned on the seat. The gallery *H* (Fig. 208) should now be examined with the aid of the special soft brass groove scraper ET071 supplied in the tool kit (Fig. 209), to ensure that it is quite clean and clear.

The above remarks apply to each of the ***hole type***, ***multi-hole*** and ***pintle type*** nozzles. In the case of the two former nozzles, the hole or holes should be probed with the special tool ET120 supplied.

Assuming the spray holes have been properly cleaned, then the nozzle body can be placed in a vessel containing clean paraffin, or preferably assembled in the nozzle flushing tool (ET427 or ET137 (Fig. 210)—for long stem) and thoroughly flushed to ensure that all carbon particles have been removed from the nozzle interior.

The orifice in the end of *pintle nozzles* is cleaned with a special soft brass pintle hole cleaner ET069 supplied in the tool kit.

The nozzle valve should now be taken up and polished by rubbing with a perfectly clean cloth—a piece of used boiled cotton cloth is best—upon which there is no suggestion of fluff. Special attention should be paid to the valve seat. This, and the cylindrical portion above it, called the *stem* and *cone* (Fig. 170) can be cleaned with a fine wire brush.

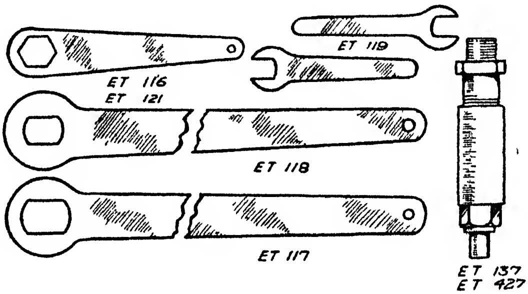


FIG. 210—Spanners and Cleaning Tools for use with Nozzles and Nozzle Holders.

To ensure that the stem and cone are free from any particles the soft brass stem cleaner ET072 should be applied with a rotary action, pressing the nozzle valve into the cleaning tool with the fingers. In the case of pintle type nozzle valves, the pintle projection should be cleaned carefully with the brass wire brush ET068. A piece of *soft* wood is also very useful for this purpose, pressing the nozzle valve pintle into the wood and turning with a rotary action by the fingers.

It is important that the greatest care should be taken with the nozzle valve and the pintle to prevent any damage to either, which may result in valve leakage or spray distortion, with consequent bad engine running.

After ensuring that the exterior of the nozzle is clean and free from carbon, the valve and body may be assembled together. This should be after the two parts have been thoroughly washed in clean paraffin or fuel oil and placed together, preferably with the fingers whilst immersed in the clean oil.

Nozzle Holder Maintenance

The nozzle holder should now receive attention and the highly ground face *D* should be clean and free from scratches. It should be washed carefully in clean paraffin, and whilst being handled, protected from receiving any damage. This face must register with the nozzle flange cleanly and squarely to form a high pressure joint, and so must be in perfect condition. The exterior of the nozzle holder, of course, should be cleaned thoroughly from dirt and grease in the usual manner. At infrequent periods, it is advisable to dismantle the interior of the nozzle holder to examine the spring 111*h* (Fig. 206), spring plate 111*g*, and nozzle spindle 111*f*. When dismantling, the special spanners ET117 and ET118 (Fig. 210) should be applied for the removal of the nozzle holder spring cap 111*i* (Fig. 206) which is revealed after removal of the covering protection cap. The interior of the nozzle holder and the parts removed should be washed carefully to remove any dirt or moisture. Care should be taken when dissembling these parts that the spring adjusting screw 111*k* (Fig. 206) is not altered in any way and is firmly secured with its locknut. If the spring and the parts are in good condition, they should be re-assembled carefully and preferable after having been slightly coated with, say, lubricating oil. The cap nut 111*i* should be screwed home securely with the special spanner so that it will not loosen with subsequent use.

The nozzle holder and nozzle may now be assembled carefully, after having immersed the pressure faces of each in clean paraffin or fuel oil, to ensure that they are free from any particles of dirt. The nozzle cap nut 111*b* should be screwed on to the nozzle holder by the use of the special spanner.

With the latter it is not possible to apply excessive leverage, so that there is no risk of damaging the nozzle or distorting it.

The nozzle holder and its nozzle should finally be tested on the nozzle testing outfit and the compression spring adjusted to give the correct injection opening pressure. If the pressure at which the spray breaks is not that recommended by the engine manufacturers, it should be adjusted by the spring adjusting screw and lock nut using the spanner ET119 (Fig. 210).

The C.A.V. Bosch Fuel Feed Pump

This feed pump, which is illustrated in Fig. 137 on page 135, requires very little maintenance attention. As the interior circulation of fuel oil acts as a lubricant, the only oiling required is the occasional application at the priming lever bearing pins and the connecting rod. Periodically, also, the gauge of the preliminary filter (if fitted) should be withdrawn and washed in petrol or paraffin ; it should be inspected for breakages.

The possible causes of feed pump trouble, with suggestions for their location and remedy, are given on the opposite page.

1. Feed Pump does not deliver Fuel

	Possible Cause	*Location.*	*Condition or suggested remedy for correct working.*
(*a*)	Fuel tank empty.	Fuel tank.	Must contain an adequate supply.
(*b*)	Fuel cock closed.	Fuel cock.	Must be open to its full extent.
(*c*)	Preliminary filter choked.	Preliminary Filter, Gauze.	Remove by loosening round nut and lifting fixing strap. Wash in clean petrol or paraffin. If damaged, replace by a spare part. Take care to replace washer.
(*d*)	Inlet or outlet valves fouled or damaged.	Valves *F.* & *H.* (Fig. 136.)	Remove by unscrewing hexagon plugs. Clean in fuel oil or paraffin. Take care to screw plug into its full extent when replacing.
(*e*)	Plunger or tappet spindle fouled or damaged.	Plunger *L* and tappet spindle *N*.	Extract after removing priming lever rod and unscrewing cap. Clean in fuel oil or paraffin.

2. Feed Pump does not deliver sufficient Fuel

(*a*)	Connection or pipes between the feed pump and injection pump leaking.	Connection Pipes.	See that all joints and pipes are perfectly air-tight.
(*b*)	Inlet or outlet valves leaking.	Valves *F.* & *H.* (Fig. 136.)	Treat as for 1*d*.
(*c*)	Plunger leaking	Plunger *L*.	Treat as for 1*e*.
(*d*)	Plunger spring damaged.	Plunger Spring *G*.	Replace by a spare part.
(*e*)	Preliminary filter obstructed.	Preliminary Filter, Gauze.	Treat as for 1*c*.
(*f*)	Main pipe line filter obstructed.	Main Filter.	Clean and air vent.
(*g*)	Air locked system.	Main Filter.	Air vent by opening vent screw on main filter and allowing fuel to flow until perfectly free from bubbles.

DIESEL ENGINE FAULT-FINDING CHART

SYMPTOM	*PROBABLE CAUSE*
ENGINE STOPS OR REFUSES TO START	Fuel supply to pump exhausted. Fuel pump out of action. Fuel leakage from pump. Air lock in main fuel line to pump. Fuel injection timing incorrect. Fuel pump wrongly connected to engine drive shaft. Choked fuel filter.
ENGINE FIRES INTERMITTENTLY	Choked injection valve. Dirt on injection valve seating. Partly choked fuel filter. Leakage of fuel from one or more pipe lines between pump and cylinder. Sticking injection valve. Broken valve spring in fuel pump plunger. Faulty or worn plunger. Shortage of fuel supply to pump. Broken pump tappet roller. Incorrect injection timing of advance. Inlet or exhaust valve of engine stuck up. Broken inlet or exhaust valve. Broken inlet or exhaust valve spring. Air lock in fuel supply pipe. Leakage at fuel pipe unions on pump or injection valves. Distorted fuel injection valve.
ENGINE LOSES POWER OR GIVES POOR ACCELERATION	Intermittent firing (see above). Incorrect injection timing. Incorrect injection period. Poor engine compression. Incorrect inlet or exhaust valve timing. Lubrication trouble. Unsuitable fuel. Shortage of fuel due to partially choked filter, or insufficient supply. Worn injection valves. Excessive carbon in combustion chamber. Decompressor gear not fully inoperative.
SMOKY EXHAUST	Defective fuel injection valve causing dribbling at nozzle. Injection timing too far retarded. Injection period too long. Unsatisfactory nature of fuel. Loss of compression (causing delayed combustion). Wrong size of fuel pump or injection nozzle.
ENGINE REFUSES TO RUN SLOWLY	Fuel pump control rod stop incorrectly adjusted. Governor idling stop incorrectly adjusted. Dribble of fuel at nozzle. Injection timing too far advanced.

APPENDIX I

A.E.C. OIL ENGINE SERVICING NOTES

THE following notes are intended to supplement the information given in the A.E.C. Service and Instructional Manuals :

HEATER PLUGS.—These should be examined at least once every two months, and care should be taken to see that the element does not become damaged or make contact with the cylinder head.

Bad starting can often be traced to defective heater plugs.

There should always be a small air gap between the coils of the element. All connections to the plugs should be kept tight.

INJECTORS.—It is a good plan to remove and clean injectors once in 2,000 miles, and whilst this operation is being carried out, they should be tested for pressure. The correct setting is 95 atmospheres, or approximately 1,400 lbs. per sq. in. On no account should injectors be allowed to operate for more than 5,000 miles without cleaning and examination. Suitable testing equipment is available at all C.A.V.-Bosch and A.E.C. Depots.

CYLINDER HEADS.—Owing to high gas pressures, it is very essential to keep the cylinder heads tight, and A.E.C. recommends that they should be checked over fairly frequently. A normal length tommy bar should be used in conjunction with the box spanner. This will prevent undue strain on the material. After retightening the nuts which actually make contact with the cylinder head, those holding the rocker gear should be treated in a like manner, and the tappets should always be checked afterwards.

VALVE GRINDING.—This should be undertaken at 20,000 miles. Whilst this is being done the opportunity should be taken to de-carbonise.

LUBRICATING OIL AND OIL PRESSURE.—It is recommended that the oil pressure should be set to register 10 lbs. per square inch when idling.

Lubricating oil which conforms to A.E.C. specification should be used ; failure to follow this advice is almost certain to lead to trouble.

After having disturbed main or connecting rod bearings, the opportunity should be taken to force oil into the crankshaft through the holes in each journal. This will avoid any possibility of oil shortage during the first revolutions when the engine is re-started. This applies to all pressure fed engines.

Should the lubricating oil pump be disturbed, this should always be primed before re-assembling.

Exhauster.—This needs very little attention because the rotor and blades are lubricated from the engine crankcase.

Two greasers are provided for the purpose of greasing the ball races, and these should receive attention regularly. It is also important to see that the securing bolts are kept tight.

Fuel Pump.—When an engine is tested, the fuel pump timing is set to give the best all-round engine performance. Advancing the pump will only result in increasing the gas pressures, and a falling off in actual horse power. Increased gas pressures mean extra loads on the pistons, bearings and cylinder heads, and serious failures are sure to be experienced; therefore, it is important *not* to over-advance the fuel pump.

Should it be necessary to replace the fuel pump, the replacement should be set as indicated in the Instruction Book.

In terms of pounds-per-square-inch, one division on the coupling scale on the front of the fuel pump is equal to an increase in gas pressure of from 250 to 300 pounds per square inch.

It is important to see that the pump is lubricated at regular intervals.

The fuel pump is a special unit, and under no circumstances whatever should any attempt be made to dismantle it. If the pump is suspected to be at fault, arrangements should be made to have it tested.

Oil Engine Crankcase Drain Plugs.—When the engines leave the manufacturer's works the drain plugs in the bottom halves of the crankcases are wired in position to prevent them subsequently unscrewing, and by sudden oil loss to cause damage to the power unit. It is strongly recommended that when being replaced after removal these plugs should always be rewired to safeguard against any possibility of their working out whilst vehicles are on service.

Bearings.—Main and big end bearings are made with one shell white metal and the other lead bronze lined; the lead bronze half in both cases taking the gas pressures. This type of bearing requires more clearance than when white metal is used for both halves. When re-fitting bearings, it must be remembered that the clearances should be:

Connecting Rods.	Minimum.	Maximum.
Clearance on diameter	·0045 in.	·0055 in.
Side clearance	·006 in.	·008 in.
Main Bearings.		
Clearance on diameter	·005 in.	·007 in.
Side clearance on front bearing which takes the thrust	·008 in.	·010 in.

Batteries.—It is essential that batteries should receive proper attention as regards topping up, etc., and that they are kept in good condition. The battery connections must be kept tight, otherwise the posts will be burnt away.

TIMING CHAINS.—It is recommended that timing chains should be renewed at the annual overhaul or somewhere between 50,000 and 60,000 miles. This is an inexpensive replacement, and by following the above suggestion, it is felt that operators will avoid any possibility of breakages

ENGINE OIL.—It is advisable to change the engine oil at regular intervals, and on no account should a period greater than 5,000 miles be run without changing it.

EXHAUST.—Black exhaust is the result of too much fuel oil being injected into the engine. A stop is supplied on the fuel pump so that this can be regulated. This stop is set when the engine is tested, and it is afterwards sealed. Should an operator experience any difficulty in this direction, he would be well advised to have the assistance of a depot or agent rather than attempt to correct it himself. White smoke is the result of air in the fuel line, a retarded fuel pump, or sticky or otherwise faulty injector.

TAPPETS.—These should be checked over at least once a week. Too much clearance on the inlet valve causes a vacuum to be created, so that when the valve does open, it results in a distinct knock, which often causes undue apprehension. The correct tappet clearance is ·008 in. to ·010 in.

PISTONS.—The pistons are fitted with oil scraper rings, and the pistons themselves are drilled with oil drain holes in the scraper ring grooves. It will be found advisable to clean all carbon from the rings and grooves at alternate valve grinding periods. When fitting new piston rings, the gap should be adjusted to ·010 in.

APPENDIX II

THE GARDNER L.W. ENGINE SERVICING NOTES

THESE engines are of the direct injection type employing Gardner design injectors and Gardner-C.A.V.-Bosch injection pumps. They are available in 3, 4, 5, and 6-cylinder units and operate at maximum speeds up to about 1,700 r.p.m.

The temperature of the cooling water should be maintained at not less than 180° F., the radiator being blanked off in part, if necessary.

LUBRICATION.—The oil delivery filter should be removed and cleaned every 1,000 miles, washing in paraffin and replenishing the container with clean oil before restarting engine.

If the oil pressure reading is too low, examine seating of pressure release valve for solid deposits and clean, if necessary. If adjuster screw is removed for access to valve spring and ball, make a note of the number of exposed threads, to facilitate replacement. The crankcase sump oil should be changed every 3,000 miles. The primary filter in the base chamber should be removed for examination and cleaning every 25,000 miles.

DECARBONISING.—Goods vehicles should have their engines decarbonised every 10,000 miles; passenger vehicles, every 15,000 miles. The method of decarbonising recommended by the makers [1] is as follows:

The nuts on the cylinder heads are readily accessible from the top and through the valve rocker chambers after the cover plates have been removed. Before lifting a cylinder head, the injectors should be removed, as their nozzles project beyond the surface of the head. Carbon usually deposits in the region of the valve ports and, in addition to the normal procedure, care should be taken to clear any traces of carbon from the upper portions of the exhaust valve guides. The inlet valves are so formed as to provide a deflector action to control the air swirl, the correct position of these deflectors in relation to the combustion chamber being of paramount importance. There is, however, no risk of making any mistake while replacing the valves, as their position is governed by collars which work against machined faces on the sides of the valve rocker chambers. These collars and the valve stems are drilled off-centre to receive the split pins, thus ensuring their correct positional assembly. The collars should not be screwed farther along the

[1] Modern Transport.

valve stems than the amount necessary to permit easy entry of the split pins, and there should be a minimum clearance of 0·008 in. between the exhaust valve stems and their guides; and of 0·003 in. in the case of the inlet valves. After the cylinder heads have been tightened down finally, the clearance between the tappet rod ends and the valve rocker heels should be 0·010 in. for all valves.

When replacing the starting mechanism, incorporated with the cylinder heads, it is essential that the gear wheels are remeshed accurately with their quadrants, two teeth on each of the former and one tooth on each quadrant being marked for the purpose. By moving the quadrants to the decompression position, the cam lifts the heel of its inlet valve rocker, the amount of valve opening being regulated by means of an adjustable screw, which requires setting to give a valve lift of 0·040 in. The pistons and connecting rod assembly can be withdrawn either through the bottom of the crankcase or by lifting the cylinder blocks, except in the case of the three cylinder units, for which the latter method only is employed. New piston rings require gaps of 0·015 in.; and, since special cast-iron is used for the two upper rings of each piston, these should not be interchanged with the others.

BEARINGS.—These seldom need attention. When renewals are necessary hand scraping is recommended for fitting new bearings to their journals. Care is necessary to ensure that the oil grooves in the main bearings register with the crankshaft feed holes, since they can be fitted the wrong way round.

The end clearance of the two main bearings at the flywheel end is ·001 in. In all the others the clearance should be ·040 in. to allow for heat expansion of crankcase.

TIMING THE VALVES.—Timing marks are given on the flywheel, chain wheels and timing case. The flywheel rim has a series of three lines for the timing of each cylinder and there is a zero mark on the crankcase at the base of the rear cylinder.

When the piston of No. 1 cylinder is on its T.D.C. the camshaft should be in a position such that No. 1 inlet valve is about to open and No. 1 exhaust valve is just closing. Replace the timing chain and rotate crankshaft until the piston of No. 1 cylinder is on is T.D.C. Then the two centre dots on periphery of the camshaft should be visible through a sight hole in the chain wheel. The top dot should be in the same line as the two dots on the machined face of the timing case and the two dots on the outer periphery of the chain wheel.

FUEL INJECTION TIMING. (See page 172.)

TIMING CHAIN.—The timing chain should be inspected and adjusted, if necessary, every 8,000 miles; it should run for 100,000 miles before requiring replacement.

SLOW-RUNNING ADJUSTMENT.—The slow-running speed is adjustable by the knurled screw and lock nut next to the accelerated lever. The proper idling speed is 390 r.p.m. The adjustable friction device in the boss mounting, which eliminates any reaction between the pump cams and the advance mechanism, should be inspected every 8,000 miles and, if at idling speeds any vibration is noticed, it should be tightened enough to stop this.

The correct position of the governor-operated slider bar is such that when the governor weights are parted to their full extent the governor bar connecting link is so adjusted as to give the slider bar a position of $\frac{1}{32}$ in. from its maximum stroke towards the timing case.

APPENDIX III

THE VICTOR OIL ENGINES. MAINTENANCE NOTES

THE following are brief instructions for the maintenance of these opposed cylinder small engines.

MAINTENANCE.—Keep the engine clean. Use clean fuel oil and good quality clean lubricating oil, preferably as recommended. Keep the fuel supply pipe lines free of air bubbles, and the unions tight.

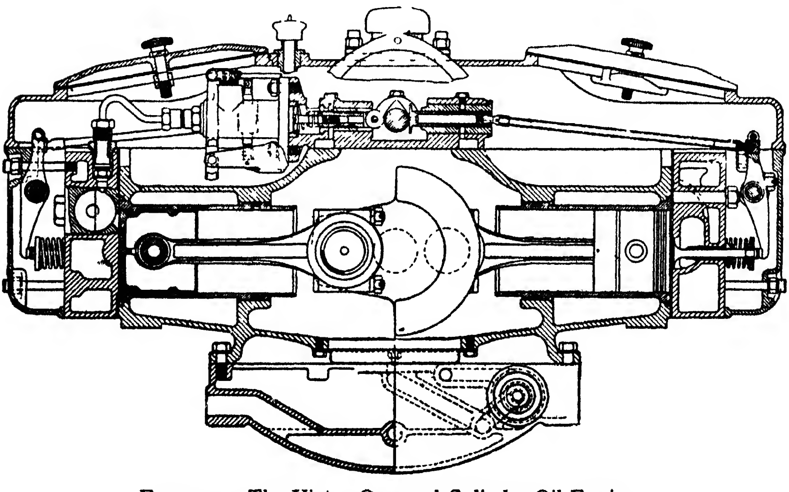


FIG. 211.—The Victor Opposed Cylinder Oil Engine.

The only mechanical adjustment required is that of the valve clearances. The clearances with cold engine should be 6/1000ths inch between rocker and valve stem. Adjustment is made at top end of rocker.

FUEL INJECTION EQUIPMENT. (C.A.V.-Bosch).—The timing of injection, the quantity, delivery and the injection pressures are carefully set at works, and should not require any attention for a considerable period. Therefore do not disturb fuel pump tappets, or linking rod between pump controls under top cover or pressure setting screws on top of nozzle holders. Injection timing using "pump spill" method is marked on the flywheel. Nozzle pressures are 2,000 lbs. per square inch.

The nozzles may require occasional cleaning. It will usually be sufficient to work the carbon off face of nozzle and pintle valve projection with a wood chip and a rag. If, however, the pintle plunger is suspected to be dirty, unscrew collar holding nozzle to nozzle holder. With nozzle removed, extract pintle plunger and clean carefully. In dismantling any parts of nozzles or pumps, observe strict cleaniness, using paper rather than rags. Never scrape, except with wood, and flush thoroughly with fuel oil. Never use grinding paste, rouge or polish.

If the nozzles are functioning properly they can be distinctly heard when the engine is decompressed, full throttle applied, and the engine slowly turned by hand.

LUBRICATION.—Pressure lubrication is to all parts, oil being drawn from the water-cooled oil pump, *via* an "Auto Klean" filter in the sump. The filter handle should be given one complete turn in either direction each day of use. At the back of the filter assembly are the detachable emergency filter by-pass valve and the pressure control valve. The dipstick at the front of the sump shows maximum and minimum oil level marks. The oil in sump should be renewed completely after every 100 hours running.

VALVE TIMING.—Air Inlet Valve Opens at 2° before T.D.C.
Air Inlet Valve Closes at 43° past B.D.C.
Exhaust Valve Opens at 38° before B.D.C.
Exhaust Valve Closes at 3° past T.D.C.

FUEL INJECTION TIMING.—Fuel Injection Commences at 35° before T.D.C. and at full load closes at T.D.C.

VALVE CLEARANCES.—Inlet Valve Tappet Clearance, ·004 inch.
Exhaust Valve Tappet Clearance, ·006 inch.

TRACING TROUBLE AND CORRECTING FAULTS. (VICTOR ENGINES.)

Trouble.	Cause.	Fault.	Remedy.
Engine will not start.	Lack of compression.	Incorrect valve adjustment.	Adjust tappets ·006 clearance.
		Leaky valves.	Grind in.
		Leaky nozzle seats.	Tighten.
		Leaky air cell.	Tighten retaining collar on outside of cylinder head.
		Leaky cylinder head gasket.	Tighten cylinder head bolts or reseat.
	Bad injection.	Dirty nozzles.	Clean.
		Nozzles not evenly held down.	Adjust holding down nuts equally.
Lack of power or smoky exhaust.	See above. Choked exhaust.	Sooted exhaust, ports, pipes or silencer.	Clean out.
Uneven or poor running.	Overheating.	Stoppage in water pipe lines. Dirt or foreign matter lodged in water passages in crank-case. Exhaust ports made with soot.	Detach adjacent pipes and flanges. Clean out thoroughly all water passages and check for equal flow from each cylinder. Leave all ports clean and clear. In sandy or dust-laden atmosphere an air intake filter must be fitted, and customer should notify us when ordering.
Rough running and vibration.	Overloaded engine.	Mis-alignment or transmission friction losses.	Check and correct.

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