ISSUE No. 257.

THE 150-h.p. B.R.1 ENGINE.

("Bentley Rotary"—formerly "Admiralty Rotary.")

BENTLEY ROLLS

INSTRUCTION MANUAL,

January, 1918.

FOR THE CONFIDENTIAL USE OF MEMBERS OF THE AIR SERVICE.

Issued by
TECHNICAL INFORMATION SECTION,
T.3.F.,
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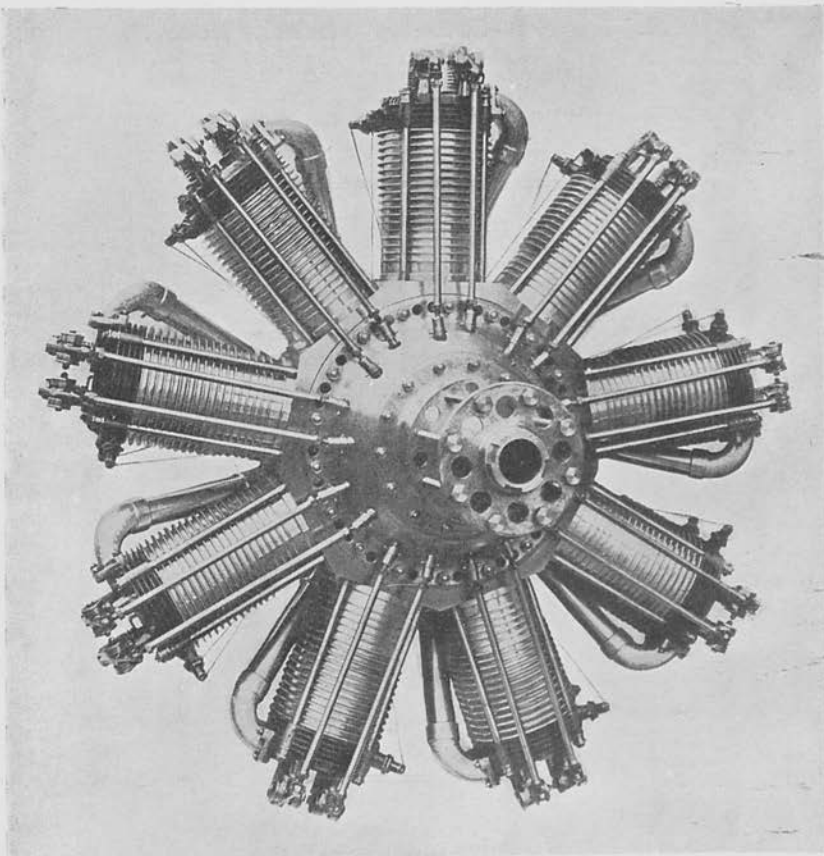
[Frontispiece



FRONT VIEW OF 150-H.P. B.R.1 ENGINE.

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INDEX OF ILLUSTRATIONS.

Since this Manual went to press, the material of which the Cylinder Liners were composed has been altered from **cast iron to steel.**

LEADING PARTICULARS OF THE 150-H.P. B.R. 1.

Bore	... ...	120 m.m.
Stroke	... ...	170 m.m.
Normal R.P.M.	... ...	1,250.
Normal B.H.P.	... ...	150.
No. of cylinders	... ...	Nine.
Cooling	... ...	Air.
Weight ("dry")	...	408 lbs., including 2 magnetos, oil and air pumps, and gun gear.
Type of cylinder	... ...	Aluminium, castiron liner, steel head.
Valves	... ...	Two per cylinder, mechanically operated.
Lubrication	... ...	By force pump, through hollow crankshaft.
Carburettor	... ...	One Bloctube, Tampier patent.
Magnetos	... ...	Two M.L.; fixed firing point.
Control	... ...	By throttle, and fine adjustment of petrol supply.
Petrol consumption	...	13 gallons per hour.
Oil consumption	...	1.5 gallons per hour.
Direction of rotation	...	Right hand tractor, or left hand pusher.
Oil pressure	... ...	20 lbs. per sq. in.

INTRODUCTORY NOTE ON ROTARY AERO ENGINES.

The rotary is one of the lightest types of aero engine. The short crankshaft and small crankcase, which it shares with the radial engines, save much weight as compared with the Vee and vertical engines ; and as its rotation renders air-cooling practicable, it is also lighter than water-cooled radial engines. Being comparatively extravagant in fuel and oil, it is best suited for small and speedy scouts, as the weight of the necessary tanks may counterbalance the lightness of the engine if it is used for long distance work. The shallowness of the engine, measured from front to back, helps the designer in perfecting planes which are quick on their controls and swift in manœuvre.

The basic principle of the rotary engine is illustrated in the accompanying diagrams. The crankshaft is immovably fixed in supports bolted to the fuselage of the plane, with its single

FIG. 1.

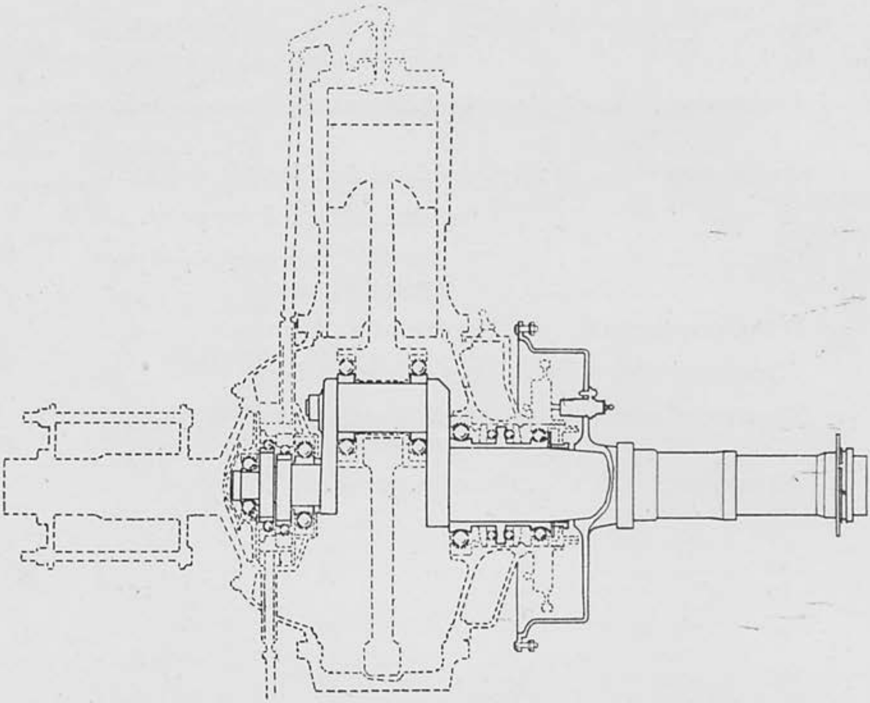


Diagram distinguishing rotating and stationary components. The stationary parts are shown in solid line and the rotating parts in dotted line.

throw or crank vertically above the crankshaft axis. The crankcase, containing the cam gears and thrust bearings, and carrying the cylinders, rides on ball bearings, mounted on the crankshaft, and is free to spin round the fixed crankshaft, on receiving a suitable impulse. (Fig. 1.)

The rotary impetus is imparted as follows :—The cylinders rotate in a circle of which the crankshaft axis (the point A in Fig. 2) is the centre ; the pistons and connecting rods rotate in a path which is approximately circular, of which the crank-pin axis (the point B in Fig. 2) is the centre.

FIG. 2.

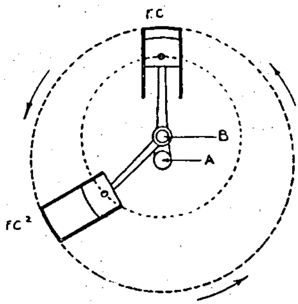


Diagram illustrating basic principle of a rotary engine. The cylinders rotate round the centre A, the pistons rotate round the centre B ; consequently the pistons are at the top of their stroke when vertical above the crank AB, and at the bottom of their stroke when vertical below the crank AB.

Fig. 2 indicates the effect of the difference in the centres of these two paths. The pistons reach the top of the stroke in the cylinders towards the top of their swing, and are at the foot of the stroke towards the bottom of their swing. Suppose that cylinder FC has just fired. Something must give under the force of the explosion. The cylinder cannot blow off, because it is firmly bolted down upon the crankcase. The piston cannot slide down in the cylinder, as it does in an ordinary vertical engine, because its crankpin is immovable.

But it is obvious that if the cylinder can swing round in the direction of the arrow, the space between the piston head and the cylinder head will be gradually increased, because the centre (A) of the cylinder path is below the centre (B) of the piston path. The cylinders were already rotating in the direction of the arrow when the explosion occurred in the cylinder FC ; for the mechanic pulled the propeller round to start the engine. So the explosion assists this rotation. The leading face of the piston presses on the leading face of the cylinder wall ; and as cylinder FC swings down, an explosion occurs in the next cylinder to fire, and a further rotary impulse is imparted.

Rotary engines always have an uneven number of cylinders, because an even turning movement, or "torque," is essential to eliminate vibration and to secure a steady drive for the propeller. Thus with a nine cylinder engine and each cylinder firing at every other revolution, there will be nine power strokes in 360° by 2 (twice round the circle) or an impulse every 80° regularly. With an 8 or 10 cylinder engine, power strokes could not be obtained at regular intervals, the vibration would be abominable, and the propeller would drive spasmodically. "Two line" rotary engines of 14, 18 or 22 cylinders have been built, but these are really two separate engines of 7, 9 or 11 cylinders apiece, coupled together.

The connecting rods of a single line rotary, or of each half of a two line rotary, all share a common crankpin. The firing order of a nine-cylinder is always 1, 3, 5, 7, 9, 2, 4, 6, 8. The rotating parts of the engine act as a flywheel. Castor oil is employed as the lubricant, because vegetable oils do not mix with petrol and the crankcase is used as a part of the induction system.

A certain prejudice has existed against rotary engines, because uneven cooling led to cylinder distortion in the earlier types. For example, the front of an uncowled engine was exposed to the draught created by the speed of the plane, whilst the back of the engine was shielded ; again, the leading face of the cylinders met the draught caused by the rotation of the engine, whereas the trailing edge of the cylinders revolved in a partial vacuum. These and other difficulties have now been surmounted ; and the rotary engine, subject to the special merits and defects outlined above, is well established as a reliable type, of particular value for certain purposes.

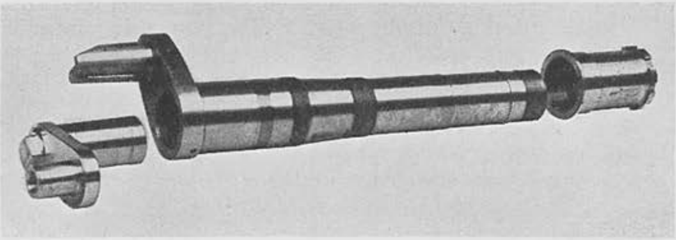
GENERAL DESCRIPTION OF THE B.R. 1 ENGINE.

For convenience in description, the propeller end of the engine is termed the front, and the end remote from the propeller is termed the rear. This happens to be accurate at the time of writing, as the engine has so far been exclusively fitted to tractor machines. Should the engine in future be fitted to a pusher machine, the propeller end, termed the front in this manual, would actually face towards the tail of the plane.

The Crankshaft.

The crankshaft is built up of three pieces as shown in Fig. 4, viz., the long end (A), the short end or "maneton"

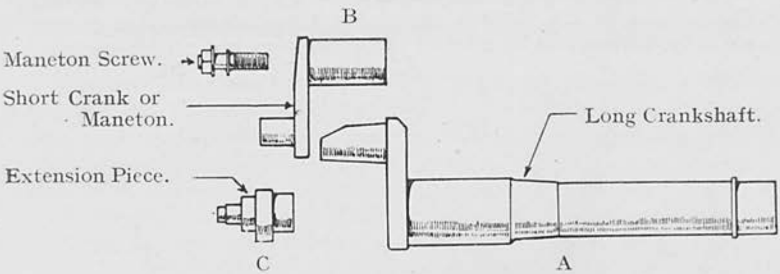
FIG. 3.



The long and short ends of the crankshaft dismantled. The short end is also known as the maneton.

(B), and the extension piece (C). The long end is of hollow steel, and comprises the inner part of the jointed crank, the rear crankpin web, and the long straight portion behind the rear crankpin web. As is normal in rotary engines, the crank-

FIG. 4.



The crankshaft shown dismantled.

shaft is immovably mounted in its supports, and serves the following purposes :—

(i) It forms a means of attaching the engine to the plane.

(ii) The explosive mixture is sucked from the carburettor to the crankcase along its hollow centre.

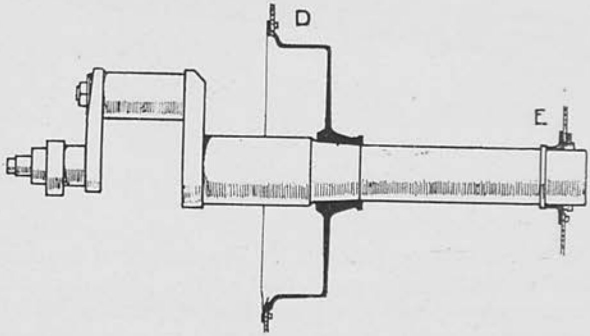
(iii) The oil delivery pipe runs inside the crankshaft.

(iv) It acts as a spindle on which the rotating parts of the engine revolve.

(v) Its crankpin is the fixed point against which the force of the explosion acts.

The above points may now be studied in detail. The crankshaft is attached to two supports (Fig. 5), the central support at D and the rear support at E, both being bolted to suitable plates in the fuselage of the plane. The respective functions

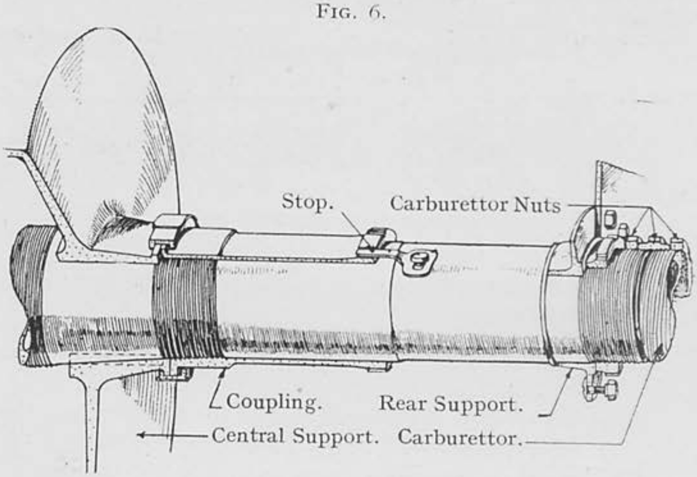
FIG. 5.



The crankshaft fixed in the central support (D) and the rear support (E).

of the two supports are as follows. The central support takes the weight of the engine, maintains the crankshaft in alignment by means of a long taper joint and keys and carries certain

FIG. 6.

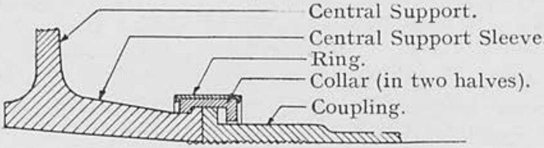


Details of crankshaft mounting.

auxiliary fittings, such as the magnetos and pumps. The rear support steadies the engine, and transfers the pull of the engine to the plane.

The details of the crankshaft attachment to the central support are shown in Fig. 6. The central support is a stationary disc, bolted to a ring bearer plate on the fuselage. In its centre is a tapered sleeve, into which the crankshaft is

Fig. 7.



Crankshaft coupling (in section).

entered from the front ; two keys and keyways serve to fix the crankshaft immovably, and also to position it so that the crank is vertical. An internal thread on the coupling engages with an external thread on the crankshaft ; and by means of the half collars, draws the crankshaft right home in the tapered sleeve during erection. Similarly, when the coupling is unscrewed during dismantling, it forces the crankshaft forwards, and frees it from the taper and keys in the sleeve. The rear end of the crankshaft protrudes through the rear support, behind which it is secured by a ring nut ; and the carburettor is then screwed on to the thread at its rear extremity.

The mixture from the carburettor is sucked along the hollow straight portion of the long end, and passes from the orifice at the foot of the rear crankpin web, into the crankcase and through the nine holes communicating with the inside of the gas chamber. (Figs. 20 and 48.)

Reference to Fig. 31 will show that the oil pump feeds oil through an external pipe to an orifice drilled in the long end of the crankshaft ; from this point a copper pipe inside the crankshaft conducts oil to the duct drilled in the rear crank web.

The forward extremity of the long end forms the inner part of the crankpin, and is cut away, as shown in Fig. 4, to facilitate threading the master connecting rod into position when assembling the engine. The short end of the crankshaft (also termed the "short crank," or the "maneton") provides the outer portion of the crankpin ; the joint between the long and short ends is made by a taper, key, securing screw, nut and locking washer. The oil duct in the crank is continued down the front web, and conducts lubricant to the cam gear box. The crankshaft terminates in a short extension piece, which is pushed into place in the front of the short end, and secured in position by the construction of the cam gear box, as shown in Fig. 48.

The Crankshaft Bearings.

The bearings on the crankshaft are all of the ball type, and comprise eight journal bearings and a double thrust bearing, the latter rendering it possible to use the engine on a tractor or a pusher. (Figs. 1 and 48.) The rear portion of the crankcase, termed the thrust box, rides on two large journal bearings, between which the double thrust bearing is located. The front portion of the crankcase, known as the cam gear box, rides on two large journal bearings, carried on the crankshaft extension. Between these are two smaller ball bearings, which carry the inlet and exhaust eccentrics and cams. Two large ball bearings on the crankpin carry the connecting rod assembly.

FIG. 8.

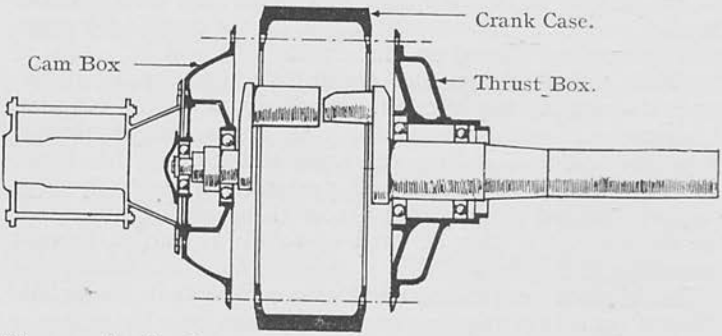
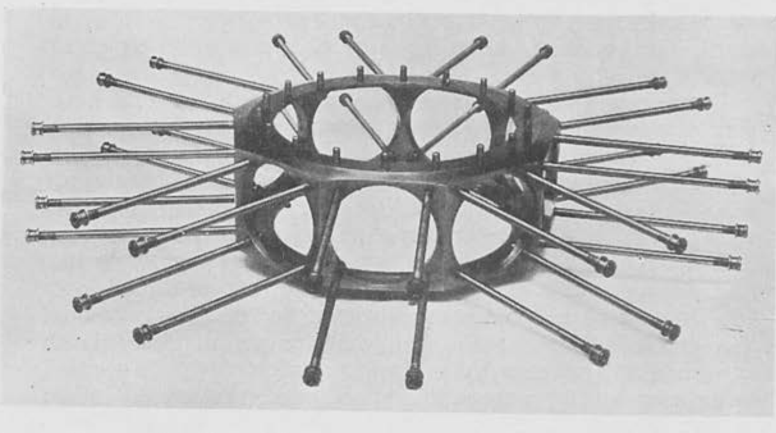


Diagram showing how the crankcase is supported. Its front face is bolted to the cam box, and its rear face is bolted to the thrust box.

FIG. 9.



The crankcase, with the holding-down bolts of the nine cylinders in position.

The Crankcase.

The crankcase is the member to which all the rotating parts of the engine, except the connecting rod assembly, are attached. As shown in Fig. 8, it consists of three main portions :—

(i) The crankcase proper ; a light central steel skeleton, to which the nine cylinders are bolted radially. (Fig. 9.)

(ii) The cam gear box, bolted to the front face of the crankcase. (The nosepiece, which carries the propeller, is bolted to the front of the cam gear box.)

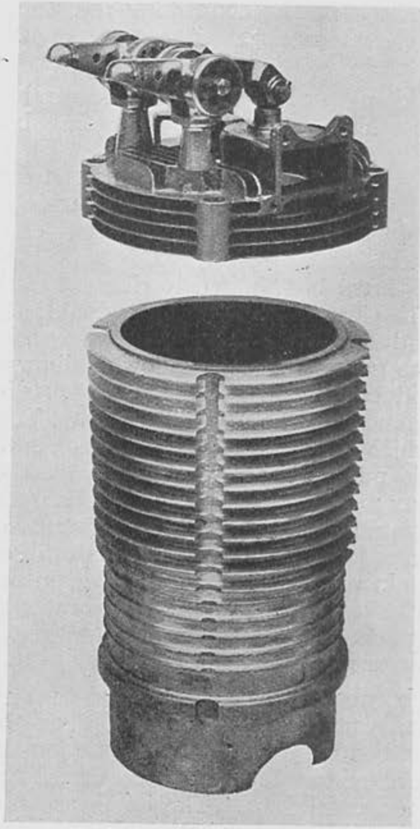
(iii) The thrust box, bolted to the rear of the crankcase. The thrust box houses the double thrust bearing, and in conjunction with the gas box forms the gas chamber ; the lower elbows of the nine induction pipes are bolted to ports in the circumference of the gas chamber. The gear wheel which drives the two magnetos and the oil and air pumps is screwed on the rear of the thrust box ; and in front of this gear wheel is mounted the high tension distributor disc. The outer periphery of the distributor disc is fitted with a skew gear for hand starting purposes, and also with a double cam which operates the gun firing attachment. The handstarter gear is intended for use on sea planes.

It should be noted that the crankcase proper, or central steel skeleton, is not *directly* supported upon the crankshaft. The cam gear box rides on the two front journal bearings of the crankshaft, and the thrust box rides on the two rear journal bearings of the crankshaft. The crankcase proper is bolted and spigoted to the cam gear box, and to the thrust box, and is supported by them, having no bearings of its own.

The Cylinders.

The cylinder barrels are of cast aluminium, shrunk on to cast iron liners, which terminate just above the top of the piston stroke. The lower end of the barrel is formed with a spigot, which fits loosely into an orifice in the crankcase, thus allowing for expansion during running. The spigot protrudes about 2 ins. into the crankcase, and is drilled with oil holes, forming vents for oil flung by centrifugal force into the outer corners of the crankcase. Above the spigot is an external flange, which beds down on to the face of the crankcase. Immediately above the flange are five shallow stiffening ribs ; and the remainder of the barrel is made with deep radiating

FIG. 10.



A cylinder with its combustion head shown detached. The joint between the cylinder barrel and liner is visible at the top of the cylinder.

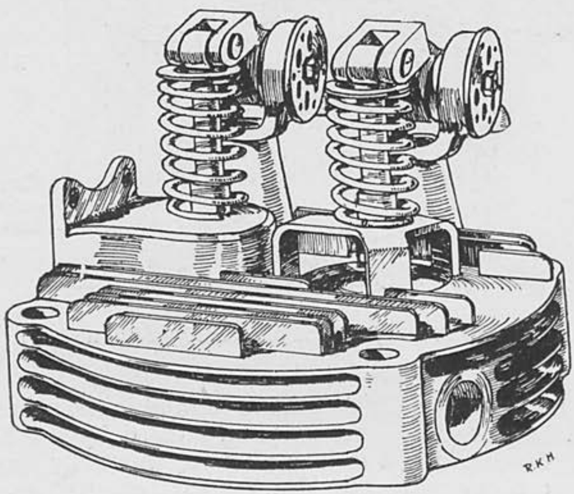
fins. The cylinder spigot is cut away at both its leading and trailing edges to give clearance for the connecting rods.

NOTE.—The cylinders are numbered 1, 2, 3, 4, 5, 6, 7, 8 and 0; the number 9 is not used, because it would be confused with 6, as the engine is turned round.

The Combustion Heads.

The combustion heads are of machined steel. They are made in one piece with the induction pockets, into which steel inlet valve guides are pressed. The exhaust valve cages, into which cast iron valve guides are pressed, are also in one piece with the heads. Steel brackets, screwed into the heads, carry the rocking levers operating the valves. Two sparking plug holes are drilled in the leading face of each head.

Fig. 11.



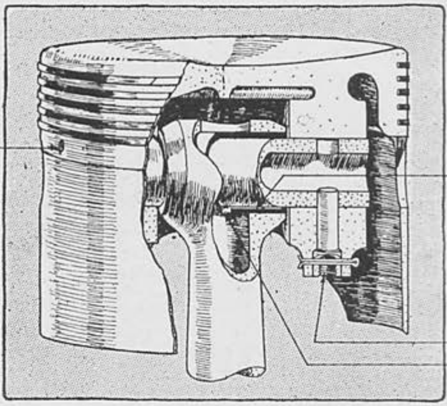
The combustion head.

The combustion heads and cylinders are attached to the crankcase by four long bolts per cylinder, the joint between the cylinder head and liner being of the plain ground type. The four bolts are located at the corners of the cylinder, and the cooling fins are cut away to allow 1 mm. clearance all round the bolts. The bolts are inserted from inside the crankcase, their heads being slotted to take a screwdriver. Castellated nuts screw on to the outer ends of the holding down bolts, and are locked by split pins.

The Pistons.

The pistons are of aluminium alloy, and have slightly concave heads. No obturator or scraper rings are fitted; five very shallow cast iron rings are set in grooves near the top of the piston. The gudgeon pin lugs project downwards from the piston head, instead of being cast on the sides of the piston skirt. The trailing edge of the piston skirt is cut away to clear the following piston; and the skirt is drilled with holes, to allow the oil from inside the piston to escape on to the cylinder walls.

FIG. 12.



Piston, showing method of securing gudgeon pin.

The hollow steel gudgeon pin is a push fit in the piston, and is held in place by a locking plug, secured by a split pin. Both gudgeon pin and locking plug are internally threaded, and special tools are provided for extracting them, when necessary. The piston must, of course, be heated (*see* p. 43) before any attempt is made to remove the gudgeon pin. The hollow gudgeon pin receives its supply of lubricant through the hollow connecting rod by centrifugal force (*see* p. 35).

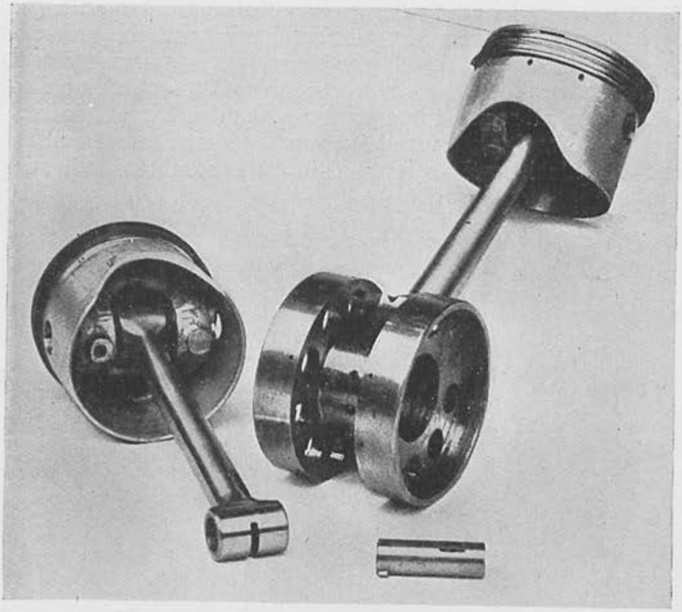
The Connecting Rods.

The connecting rods are of tubular section steel, and with the exception of No. 1 (the " master rod ") are bushed with phosphor bronze at both ends. The " master rod " is bushed with phosphor bronze at its piston end, but its large end (*see* Fig. 48) rides on the two large ball bearings mounted on the crankpin.

The laige end of the master rod is formed with two large hollow flanges, which serve as housings for the two crankpin ball bearings, and are drilled with holes to accommodate the eight wristpins, on which the big ends of the eight ordinary connecting rods are mounted. Each wristpin is located in its housings in the master rod by a pin stop, which prevents it from rotating, and registers its oil leads.

The oiling arrangements of the connecting rod assembly are dealt with on p. 34.

FIG. 13.



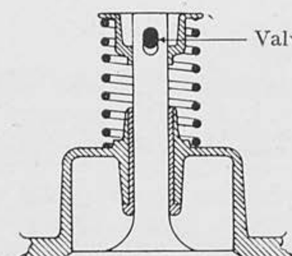
Auxiliary connecting rod and piston (on left). Master connecting rod and piston. Wristpin of auxiliary connecting rod (at foot).

Obviously, the connecting rod assembly can only be removed or replaced when the maneton is withdrawn from the long end of the crankshaft.

The Valves.

The exhaust valves, which are of the ordinary solid type, measure 61 mm. in diameter, and are located towards the

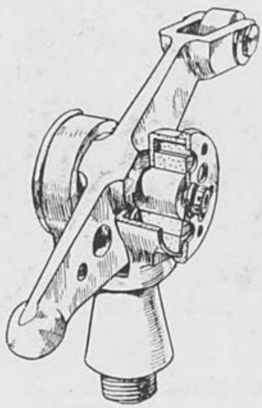
FIG. 14.



Inlet valve.

leading edge of the combustion heads for cooling purposes. They work in cast iron guides, pressed into light tripod cages made in one piece with the combustion heads. No exhaust pipes or silencers are fitted, the waste gases passing direct from the valves into the cowl. Single springs of the coiled pattern are used, secured by spring caps and cotters of normal design. The rocking levers pivot on hardened steel rollers, mounted in steel brackets screwed into the combustion heads.

FIG. 15.



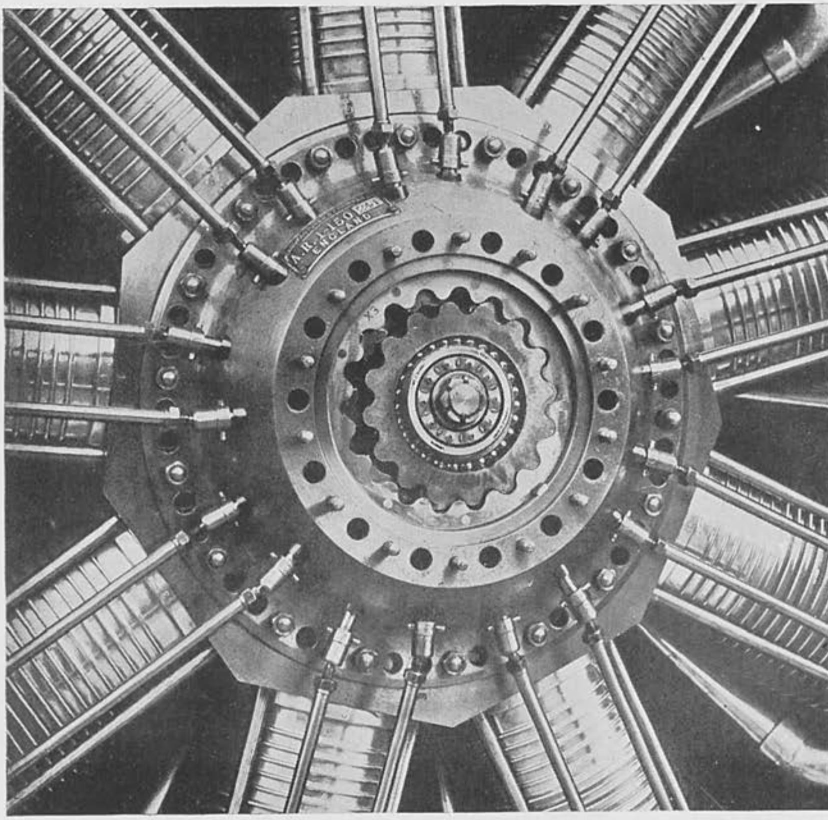
Valve rocker and bracket.

The valve end of each rocker is fitted with a roller. The other end of the rocker is attached to the push rod by a ball joint, protected from disengagement by a spring clip. The push rod has a screwed adjustment at both top and bottom. The inlet valves, which are 55 mm. in diameter, work in steel guides, pressed into induction pockets made in one piece with the combustion heads.

The Cam Gear.

The cam gear box consists of a circular steel casing, bolted to the front of the crankcase. It revolves upon the two front crankshaft ball bearings, between which are the two smaller ball bearings which carry the valve gears and cams. The 18 tappets work in phosphor bronze guides, pressed into the outer periphery of the cam gear box and projecting from it. Each tappet is connected to its push rod by a ball joint. The cam gear is arranged as follows :—Two large internally toothed rings, known as the inlet and exhaust " gear rings," are fixed

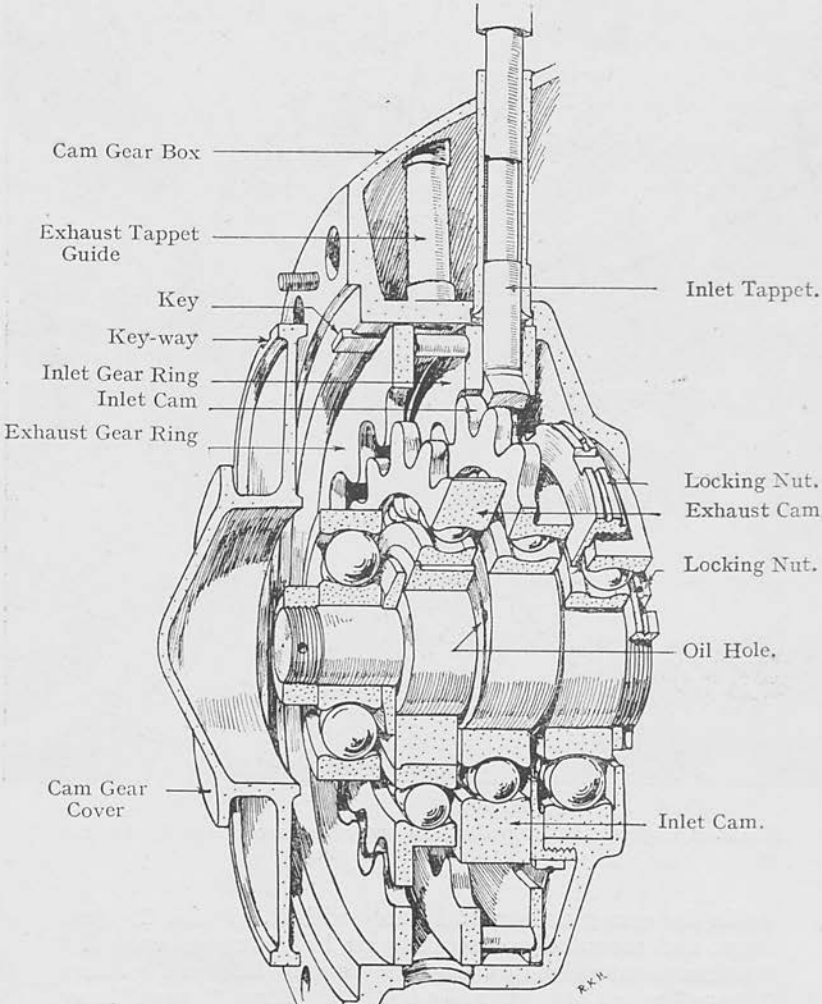
Fig. 16.



Front of engine with propeller hub and nosepiece removed, showing cam gear and cam gear ring.

inside the cam gear box, and rotate with it. Inside the gear rings, and mounted eccentrically on ball bearings upon the crankshaft extension are the corresponding inlet and exhaust "gears" which are externally toothed. These "gears" have 16 teeth, as against the 18 teeth of the "gear rings." The gear rings thus drive the gears at nine-eighths of engine speed, and the gears overtake the gear rings once in eight revolutions. Each gear has four cams on its rear face, so that in eight revolutions of the engine, each tappet is lifted four times, *i.e.*, once in every two revolutions, exactly as with a normal type of distribution gear on a vertical engine. (Note.—A novice may easily fail to identify the cams in his first

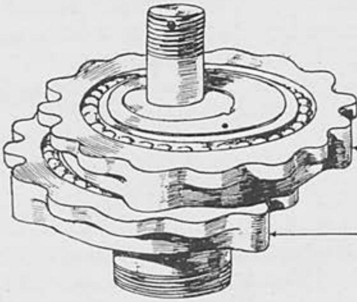
FIG. 17.



Perspective section through cam gear box.

examination of the engine. The engaging teeth of the gears and gear rings have rounded camlike contours and the four cams on each gear are simply rearward continuations of the

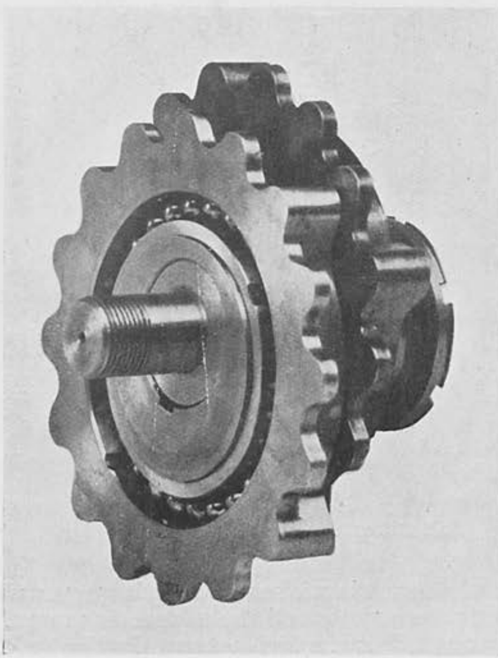
FIG. 18.



The cam gears.

rounded teeth.) The entire contents of the cam gear box are lubricated from a sprayhole in the crankshaft extension, the oil being distributed by centrifugal force.

FIG. 19.



The cam gears.

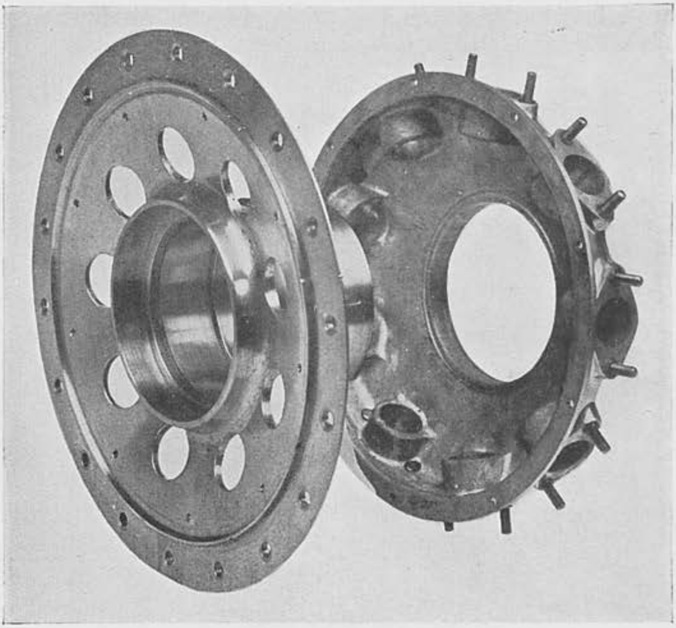
The Nose Piece.

The built-up nose piece used on the earlier engines is now obsolete, and the latest pattern is interchangeable with it. The nose piece and hub are made in one piece, and bolted to the front of the cam gear box. The loose front flange is splined to the hub barrel.

The Thrust Box.

The thrust box is bolted to the rear face of the crankcase, and consists of a rotating case, which embodies the external housings of the two rear main journal bearings, and the double thrust bearing, together with the gas chamber, from ports in which the nine induction pipes lead to the cylinder heads. On

FIG. 20.



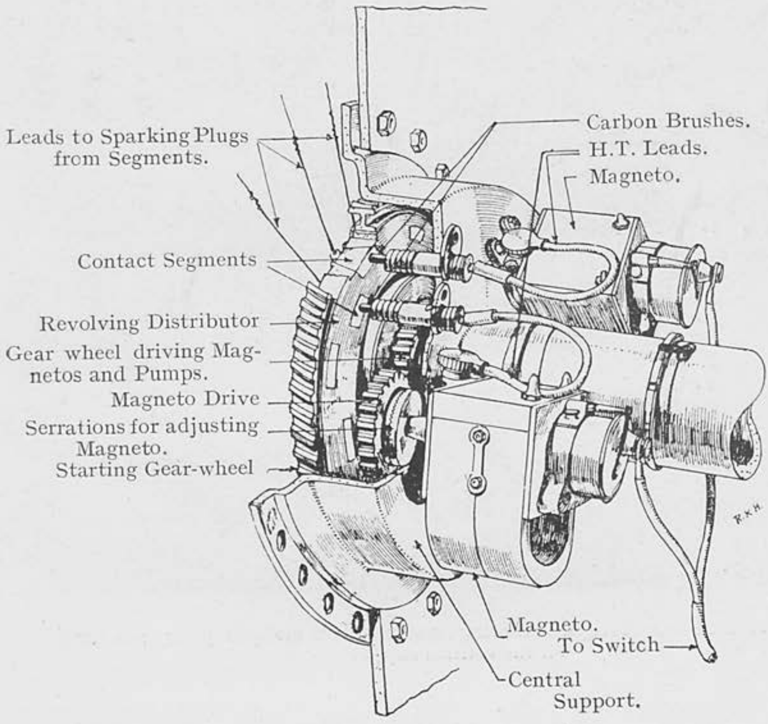
The thrust box (left) and gas box (right).

the rear of the thrust box is screwed the large gear wheel which drives the two magnetos and the oil and air pumps. In front of the gear wheel is the high tension distributor disc, which also carries a skew gear for the handstarter, and two cams for the gun firing attachment. (See Fig. 21.)

The Central Support.

The central support does not take the main pull of the engine, but carries its weight, supports its auxiliary fittings, and aligns the crankshaft. It consists of a circular disc, bolted to a ringplate in the fuselage. At its centre is a coned sleeve, into which the crankshaft is drawn by a special coupling, and in which the crankshaft is located by two keys so that the crank is always vertical. Four holes are cut in the support,

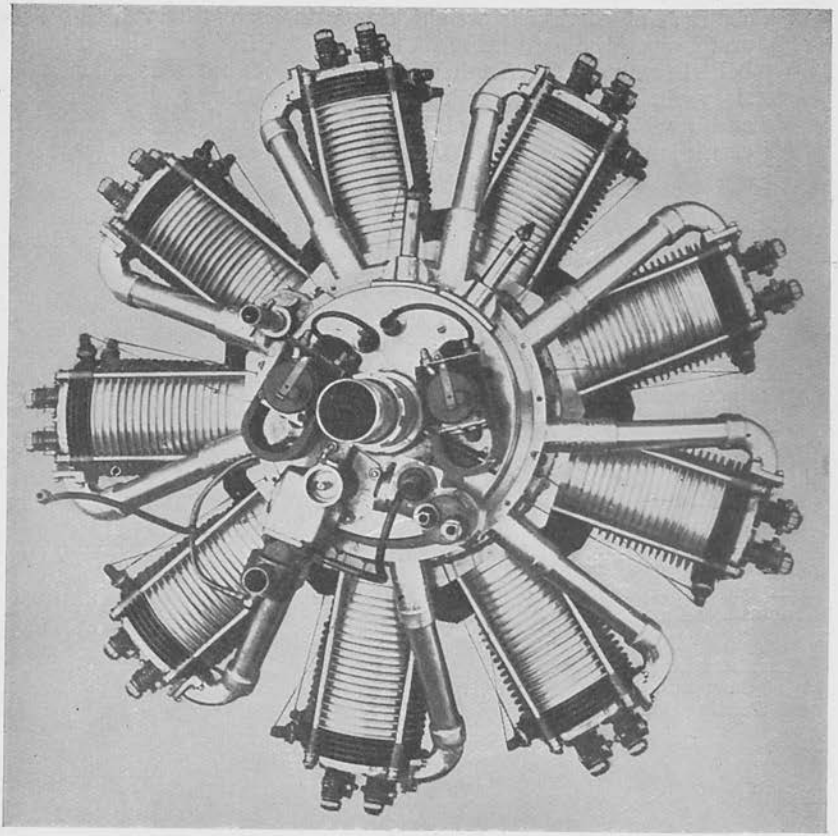
FIG. 21.



Ignition details in perspective.

through which the driven pinions of the pumps and magnetos project to mesh with the gear wheel on the thrust box, suitable attachments being provided for them on the rear of the support. The single high tension lead from each magneto is connected to a carbon brush, mounted in an insulated holder in the central support. The brush projecting from the front of the support makes contact with the revolving distributor fixed to the thrust box.

FIG. 22.

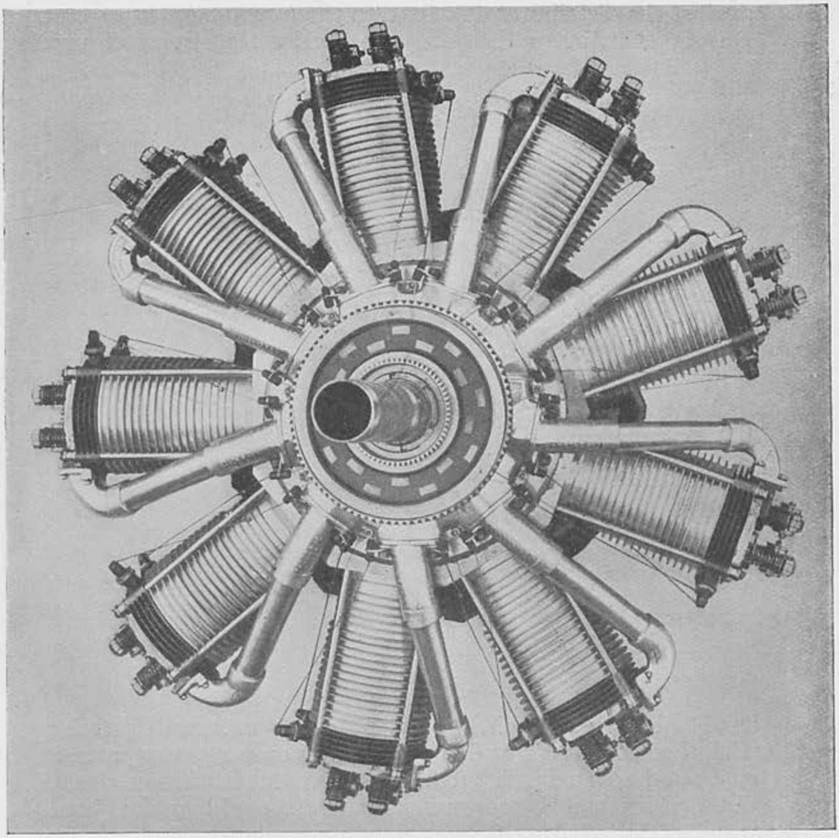


View of rear of engine, showing how magnetos and pumps are mounted on the central support.

The Ignition.

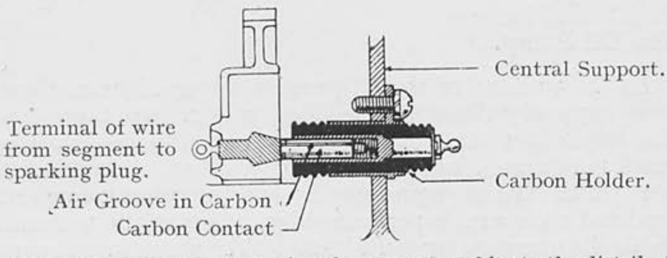
Ignition is provided by two M.L. magnetos, of the revolving armature type, giving two sparks per revolution. As they are geared to make nine armature revolutions to four revolutions of the engine, they furnish nine sparks apiece for each two engine revolutions. Each magneto supplies a separate set of sparking plugs, and the circuit is as follows :—The high tension current is picked up by a carbon brush from the collector ring on the armature, and is led by a cable to an insulated terminal

FIG. 23.



View of rear of engine, showing distributor disc exposed.

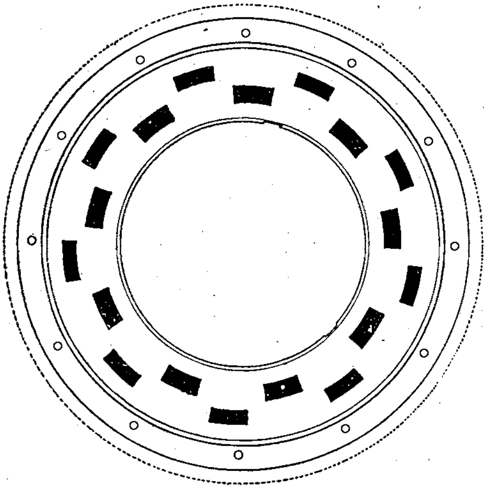
FIG. 24.



Details of carbon brush connecting the magneto cables to the distributor disc.

fixed in the (stationary) central support. From this terminal the current goes to a brush, which is pressed by a light spring against the distributor disc fixed to the (revolving) thrust box. On the distributor disc are two concentric circles of nine

FIG. 25.



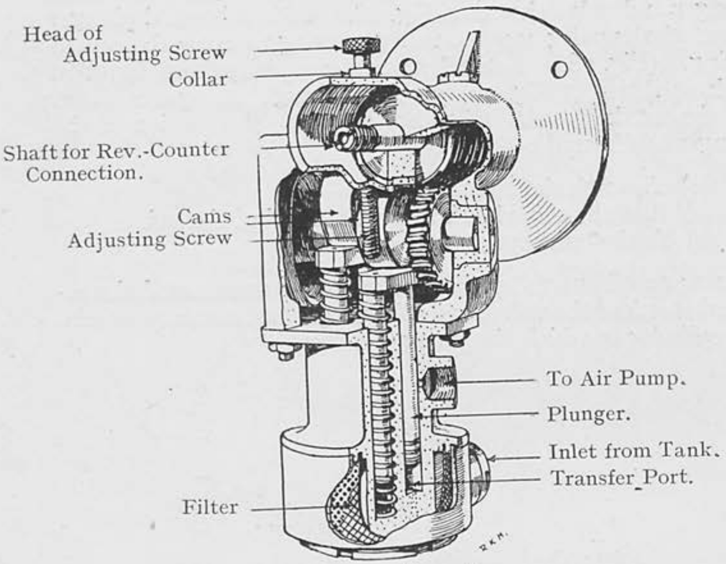
Distributor disc.

insulated contacts each, the inner ring of contacts registering with the lower brush and *vice versa*. Each contact segment is connected to an insulated terminal on the front face of the distributor ; and these terminals are connected by naked brass wires to the sparking plugs. As the distributor terminals are not very accessible after the engine is assembled, thick brass wire is used for the lower half of the sparking plug cables, and lighter wire for the upper half. The wires are held clear of the cylinders by small insulators, carried in brackets.

The Oil Pump.

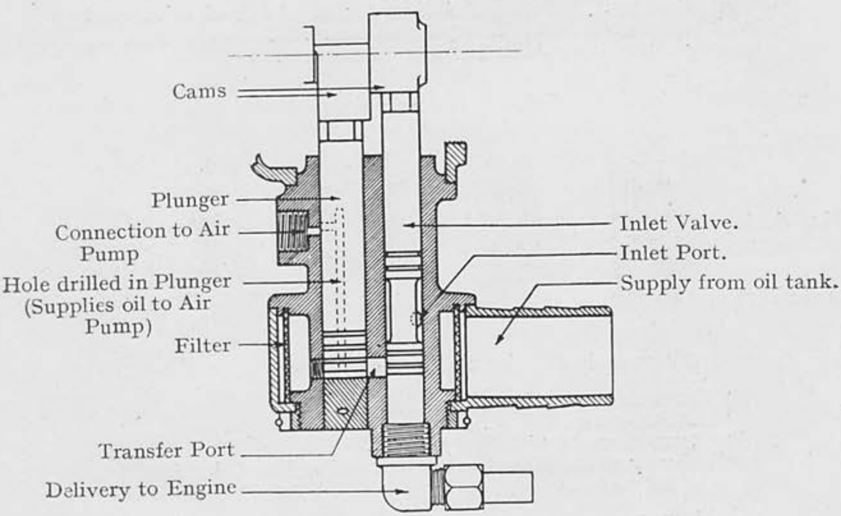
As the working of the oil pump is somewhat complicated, it is copiously illustrated in Figs. 26–31. Its large size is due to the fact that it can only conveniently be driven by a small pinion meshing with the large gear wheel on the thrust box, which runs at engine speed ; and the gearing down, thus rendered necessary, is performed by the worm and wormwheel inside the pump casing (*see* Fig. 26). The worm wheel operates

Fig. 26.



Oil pump in section.

Fig. 27.



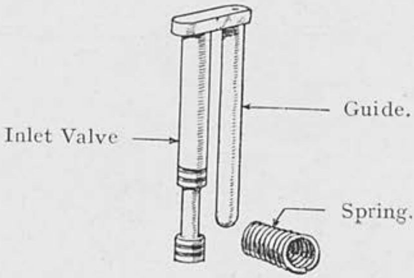
Lower portion of oil pump in section.

two cams, or eccentrics, which actuate the flat bases of the plunger and valve shown in Fig. 28. Both valve and plunger are of the two-leg type, one leg serving to carry the return spring. (Fig. 26.) The oil reaches the pump from the main tank as shown in Fig. 26, passing through the gauze filter. On the intake stroke (Fig. 29, i and ii), the suction of the plunger is directed :—

(*a*) Through the transfer port.
(*b*) Past the thin shank below the head of the valve.
(*c*) To the intake port.

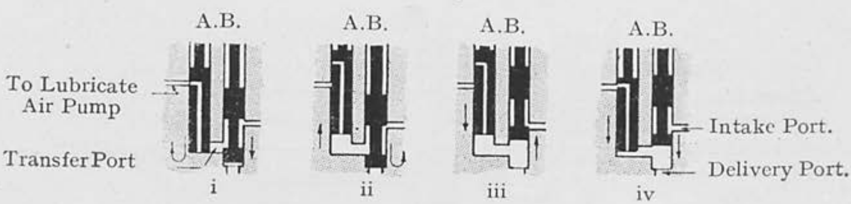
Thereupon oil enters by the intake port, passes round the reduced shank of the valve, and so through the transfer port into the cylinder in which the plunger slides.

FIG. 28.



Valve of oil pump. Note reduced diameter in shank of valve, past which oil enters on intake stroke of pump. The right hand leg merely serves as a spindle for the return spring.

FIG. 29.



Diagrams illustrating action of oil pump.

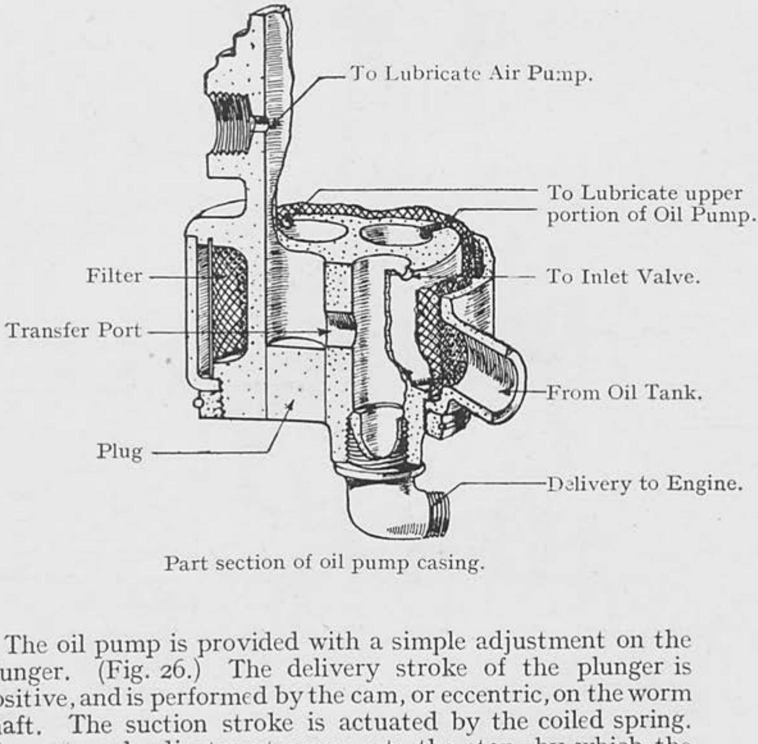
(i) Commencement of suction stroke.
(ii) Suction stroke.
(iii) Commencement of delivery stroke.
(iv) Delivery stroke almost completed and residue being forced to air pump.

A.—Plunger. B.—Inlet valve.

On the delivery stroke (Fig. 29, iii and iv), the valve closes the intake port, and the plunger forces the oil back through the transfer port into the valve cylinder; but the oil is now above the head of the valve, instead of below it, as previously. Then the valve reverses its direction of travel, and the valve head forces the oil out at the delivery port.

On the delivery stroke of the plunger, a small percentage of the oil is squeezed down the fine passage drilled in the plunger (Fig. 29); this passage turns at right angles towards the base of the plunger, and registers near the end of the stroke with an orifice cut in the side of the cylinder, through which a little oil is forced into the auxiliary delivery pipe connected to the air pump.

FIG. 30.



Part section of oil pump casing.

The oil pump is provided with a simple adjustment on the plunger. (Fig. 26.) The delivery stroke of the plunger is positive, and is performed by the cam, or eccentric, on the worm shaft. The suction stroke is actuated by the coiled spring. The external adjustment screw sets the stop, by which the length of the suction stroke is determined. The collar threaded beneath the head of the adjusting screw must on no account be removed; it is dimensioned to prevent the stroke of the plunger being unduly shortened. The pump springs are coppered to distinguish them from an earlier spring of a different type, which sometimes broke, when the oil supply totally ceased. Black pump springs must on no account be fitted.

The Lubrication System.

The delivery pipe from the oil pump leads to an orifice in the crankshaft immediately behind the central support. A

Fig. 31.

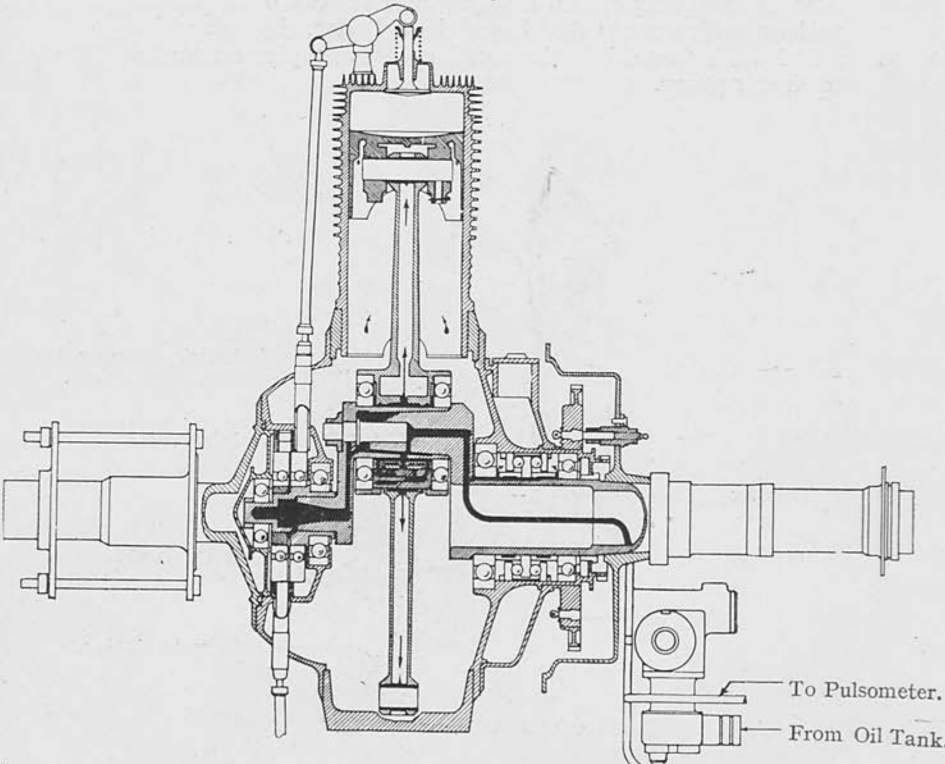


Diagram of lubrication system. The oil leads are shown black.

copper pipe inside the crankshaft conducts oil from the above orifice to a duct in the base of the rear web of the hollow crank-pin. (Fig. 31.)

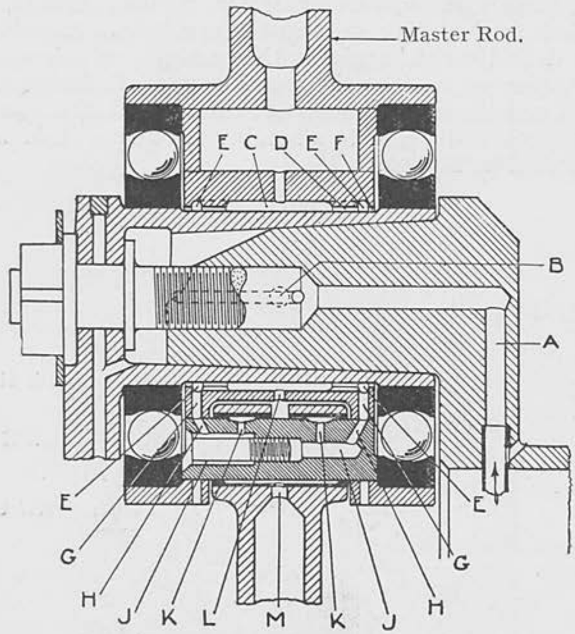
Supply to the Thrust Box.

Just below the junction between the pipe and the duct, a bypass conveys oil to a groove in the crankshaft below the thrust bearings ; this oil passes through special grooves in the distance pieces, and is distributed through the thrust box by centrifugal force. This bypass at the foot of the rear crankpin forms the sole supply of oil for the thrust box and its contents.

Supply to the Cam Gear Box.

The bulk of the oil forced along the pipe inside the crankshaft travels up the duct in the rear web, and reaches the crankpin, where the stream diverges again into supplies for the connecting rod assembly, the pistons, and the cylinders, on the one hand ; and for the cam gear box, on the other hand. The

FIG. 32.



Lubrication details of master rod assembly.

A.—Duct in rear web of crank.
B.—Oil hole from A to
C.—Annular oil space between crankpin and big end.
D.—Oil grooves from C to
EE.—Circumferential gutters in flanges of master rod, big end.
F.—Notches by which oil from EE lubricates the ball bearings.
GG.—Oil holes from the gutters EE into the 8 wristpin sockets.
HH.—Holes in wristpin sockets registering with GG.
JJ.—Oil chambers in ends of wristpin.
KK.—Holes conveying oil from JJ to the auxiliary big end bushes.
LL.—Oil spraying holes in master rod big end, forming outer wall of annular oil space C.
M.—Hole through which oil enters hollow (auxiliary) connecting rods.

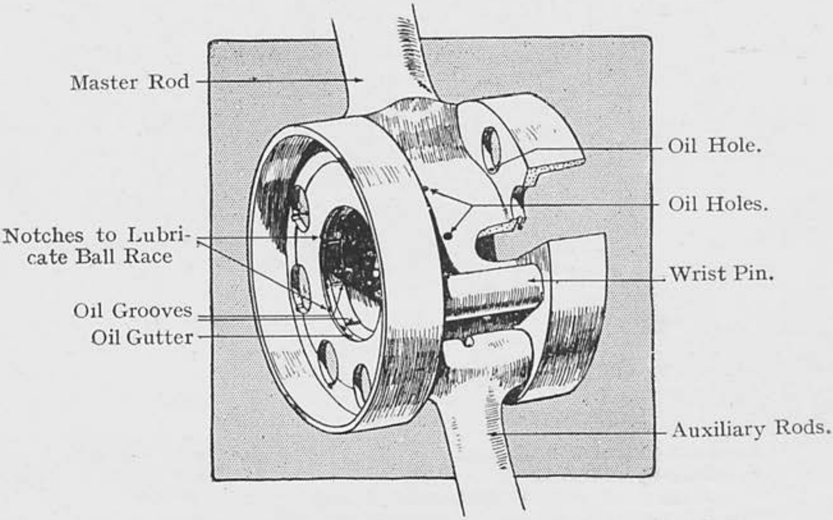
pump supplies more oil than can find an outlet at the crankpin, and the remainder continues on down a duct in the front crank web to the cam gear box. Emerging between the cam gears from a hole drilled at right angles to the crankshaft axis, it is sprayed out under pressure, and lubricates the contents of the cam gear box by centrifugal force.

Lubrication of the Connecting Rod Assembly.

This demands particular attention, as the effect of centrifugal force tends to swirl the oil away from the centre of the engine, and rather complex arrangements are needed to insure an ample supply.

As previously stated, the oil passes up the duct, A, in the rear crank web, and along a duct in the crankpin. A goodsized hole, B, drilled at right angles to the crankpin axis, conducts a liberal supply of oil into the annular space, C, between the crankpin and the inner diameter of the big end of the master rod. This oil is directed to a number of outlets, all of which are indicated in Fig. 32.

FIG. 33.



Lubrication details of master rod assembly.

From the annular space the oil is forced to the right and left along suitable grooves, D, and fills two circumferential gutters, EE, cut in the inner diameters of the flanges of the big end of the master rod. A small portion of the oil from these gutters passes through the notches, FF, to lubricate the two large ball bearings of the master rod ; any oil escaping from these bearings is thrown up into the cylinders by centrifugal force.

Each of these gutters is drilled with eight holes, GG, leading through into the sockets in which the wristpins are mounted ; corresponding holes, HH, in the wrist pins themselves are accurately registered by means of the pinstops in the wrist pins. Thus an oil supply is assured to both ends of each wrist pin. (Fig. 32.)

An oil chamber is formed in both ends of each wrist pin ; the rear end of the wrist pin is solid, and the front end is sealed by a screwed brass plug, the end of which forms a partition between the two oil chambers, JJ, inside the wrist pin (*see* Fig. 32). These two oil chambers are filled with oil from the circumferential gutters, EE, by the leads and holes, GG and HH.

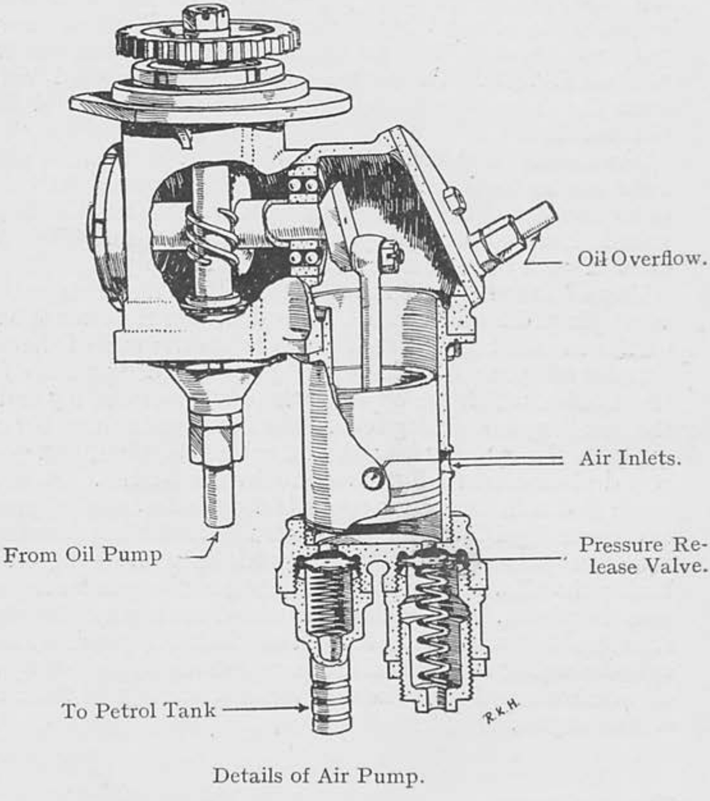
From each oil chamber a duct, K, drilled in the wrist pin, at right angles to its axis, conveys oil into grooves cut on the outer surface of the wrist pin, from which oil is distributed round that end of the phosphor bronze bush. Thus both ends of each bush possess a separate oil supply.

There is, further, a separate oil supply to the centre of each wrist pin and bush. Holes, LL, are drilled in the central barrel of the master rod big end, which forms the wall of the main annular oil space, C. The oil is sprayed under pressure from these holes, which are opposite the centres of the big ends of the auxiliary connecting rods. Slots are cut in these big ends opposite the spray holes ; the oil enters the slots, and passes round circumferential grooves cut in the bushes. Holes, M, are drilled in these grooves opposite the tubular connecting rods, and centrifugal force flings the oil up the hollow connecting rods. It passes up the tubular rods into the gudgeon pin bush ; the oil which escapes from the gudgeon pin bush passes into the piston. A ring of oil holes is drilled round the piston skirt, just below its head, through which this oil passes on to the cylinder walls ; it is joined in the cylinders and pistons by any oil which escaped from the nine big end bearings at the centre of the engine.

The Air Pump.

A large diameter air pump is provided to furnish pressure to the petrol tanks, and is mounted on the rear of the central support. Its driven pinion projects through an orifice in the support, and meshes with the large gear wheel on the thrust-box. The pump is geared down by means of a worm and worm wheel, enclosed in its casing ; the worm shaft terminates in a crank which actuates a short connecting rod and piston in the ordinary way. The air intake ports consists of four holes cut in the cylinder wall immediately above the lowest position of the piston head. During the brief time for which these ports are uncovered, the suction which has previously accumulated in the cylinder, induces a fierce rush of air, which the piston compresses as it rises again. Two steel disc valves are situated in the head of the cylinder. One is an adjustable release

FIG. 34.



Details of Air Pump.

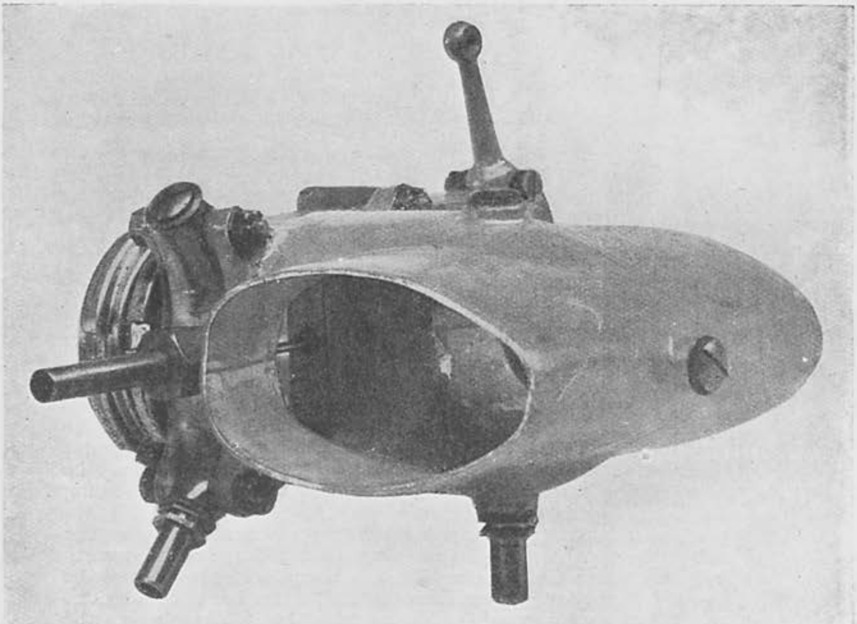
valve, by means of which the pressure can be set to the desired figure ; the other is the non-return valve in the base of the pressure pipe leading to the tanks.

The air pump is oiled by a special bypass from the plunger of the oil pump, as described on p. 29. The position of the oil entry, and the provision of an overflow, obviate all danger of the air pump becoming flooded with oil.

The Induction System.

The carburettor is screwed on to the extreme rear of the long end of the crankshaft, and the explosive mixture passes along the hollow crankshaft to the orifice at the foot of the rear web of the crank, whence it passes into the main crankcase. From thence it is sucked through a ring of holes into the gas chamber, which rotates with the thrust box. The lower elbows

FIG. 35.



The Bloctube carburettor.

of the induction pipes are bolted to orifices cut in the outer periphery of the gas chamber, and the upper elbows of the induction pipes are bolted to the induction pockets cast in one piece with the cylinder heads. The induction pipes consist of upper and lower elbows, secured by ingenious taped joints (*see* Figs. 36 and 37) to a straight length of aluminium piping.

Fig. 36.

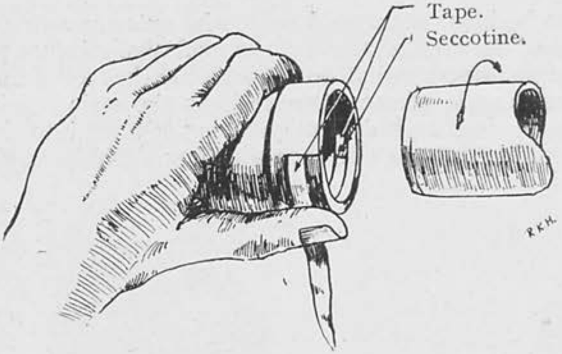
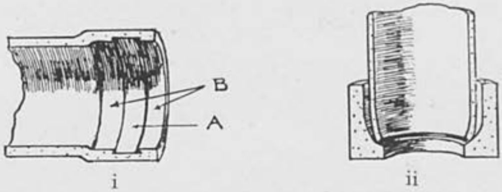


Fig. 37.



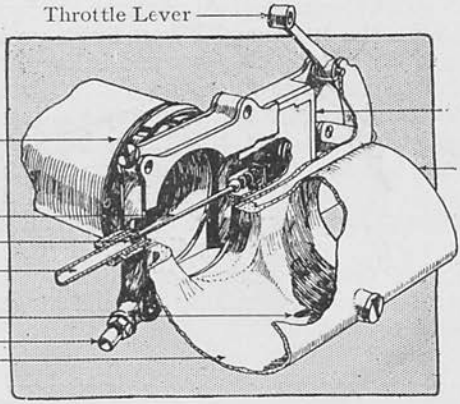
Tape joint on induction pipe.—About 7 feet of tape are required for each joint. The tape is taken through the slot and half-way round the groove A (Figs. 36 and 37 (i)). A drop of lubricating oil is then put on each bearing surface B (Fig. 37 (i)) to prevent the pipe seizing. A drop of seccotine is placed on the inner end of the tape, to make it adhere to the pipe, which is twisted in a clock-wise direction until practically all the tape is wound. Care must be taken to keep the tape flat and taut during the process by holding the thumb against it, as shown.

To remove the pipe, a little lubricating oil should be put on the end of the tape (which projects through the slot) and allowed to soak in. This usually suffices to ease the joint. The ends of the pipe are slightly reduced in diameter and if this has not been done with new spares, it may be accomplished by lightly tapping the pipe into a cup-shaped jig, as shown in Fig. 37 (ii).

The Carburettor.

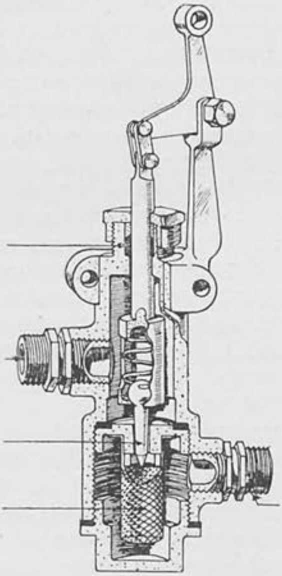
The Bloctube carburettor is illustrated in Fig. 38. Its body consists of a tubular extension screwed to the rear end of the crankshaft. The jet projects at right angles into the tubular body immediately opposite the throttle; and the effective aperture of the jet is varied to suit the throttle opening by means of a tapered needle mounted on the throttle, which is inserted into the jet or withdrawn out of the jet as the throttle is opened or closed. The throttle is a brass slide, mounted in guides, to move at right angles across the tubular

FIG. 38.



Bloctube carburettor in section.

FIG. 39.



Fine adjustment petrol valve and filter.

body of the carburettor. In shape it resembles a shallow box, set on edge ; the face next the engine is hinged, and is kept tightly pressed against the guiding slide by internal springs, so as to make a tight joint. Behind the throttle is a streamlined lug, in which the ends of twin air pipes are fixed, with their intakes outside the fuselage. Petrol drain pipes are fitted to the base of the mixing chamber and below the junction of the twin air pipes. Alongside the pilot's throttle lever is mounted a second lever, controlling a fine adjustment valve, which adjusts the flow of petrol to the carburettor, and serves four purposes. It acts instead of a float chamber. In conjunction with the variable jet it enables a skilled pilot to set his carburettor to supply a perfect mixture at all engine speeds and under all atmospheric conditions. Further, it forms a means of correcting the mixture for altitude, as it enables the flow of petrol to be substantially reduced at great heights: and it includes a petrol filter.

DISMANTLING AND RE-ASSEMBLING.

Introductory Note.

The usual routine is to dismantle the front half of the engine after about 40 hours' flying, leaving the crankshaft undisturbed in its supports, and the supports bolted to the plane. After about one hundred hours' flying, the engine should be dismounted from the plane, and completely overhauled.

The sequence of operations of dismantling and reassembling is set out below in tabular form for both partial and complete overhauls; and the handling of any units which are detached from the engine in a complete form is dealt with separately.

Before any dismantling operations, precautions should be taken to **prevent the engine from being accidentally started up**, as the engine must be turned round at various points in the work. Such precautions may either take the form of disconnecting the two high tension leads from the magnetos to the central support; or of emptying the engine of gas, by shutting the fine adjustment valve as the engine slows down, and finally opening the throttle wide just as the engine is about to stop. The former operation shuts off the petrol supply; the latter insures that any petrol present in the crankcase will be sucked out and exhausted.

During re-erection, see that all inside components are CLEAN and OILED, and that all oilways are full of oil. A force pump should be used to fill the oilways with castor oil; such parts as the wrist pins should be dipped in oil; the cam gear box and thrust box should have oil poured into them; and so on. Pure castor oil only must be used.

The distributor should be cleaned at frequent intervals.

To facilitate starting, a clean set of nine plugs should be put in after every four hours, when convenient. Thus each plug does eight hours before cleaning.

PARTIAL OVERHAUL AFTER 40-50 HOURS' FLYING.

(Engine is NOT removed from aeroplane for this purpose).

Sequence of Operations (Dismantling).

1. Remove nose piece.
2. Free push rods from rockers.
3. Remove cam gear box.
4. Withdraw short end of crank ("maneton.")
5. Remove pistons and connecting rods.
6. Remove cylinders and examine liners.

(NOTE.—If the crankshaft is not disturbed in its supports, the magnetos and pumps may be dismantled at any time without special precautions, but if the crankshaft has been loosened or freed from its supports, the magnetos and pumps should not be replaced until the crankshaft has been drawn right home again ; *see* p. 52 for full explanation.)

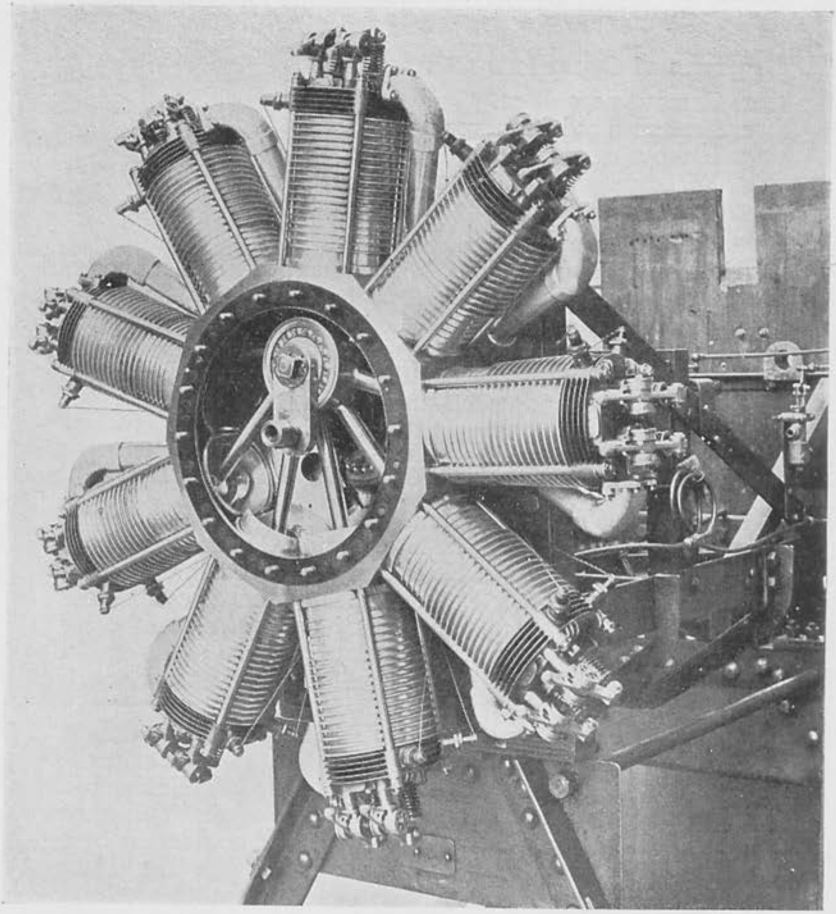
DETAILS OF PARTIAL OVERHAUL (DISMANTLING).

A brace type of tube spanner saves time where numerous small nuts are concerned, as in loosening the cam gear box. The engine should be turned to free any push rods which happen to be lifted ; whilst the engine is being turned, other loose push rods must be held up to prevent their tappets from fouling the cam gear. The cam gear box usually sticks to the crankcase, if the goldsized washer was well fitted when the engine was last erected ; but if two or three men distribute their pull round its circumference, it will usually come away without the aid of the special tool (No. 10 in Fig. 47). Should the extractor be required, the front cover of the distribution box must be prised off before the tool can be employed. This cover is pressed into its seating, and is prevented from turning by a key located between cylinders Nos. 1 and 0. Prising is best attempted along an imaginary diameter drawn through the key.

The short end of the crank, or maneton, comes away easily when its nut (right hand thread) and locking washer are removed ; but it does not always bring away the ball bearing with it. In this case, one operator should turn the nut securing the short end into the long end, whilst a second operator gently taps all round that part of the master rod which houses the bearing.

Next unscrew the brass plugs from the front ends of the eight wrist pins, and withdraw the wrist pins by means of the special tool (No. 1 in Fig. 47), commencing with wrist pins Nos. 5 and 6. Lower one of the pistons thus freed into its cylinder,

Fig. 40.



Photograph of engine with cam box removed.

but be careful not to lower it below the end of its stroke, or its rings will spring out over the head of the cylinder barrel; and the combustion head will then have to be removed to get it out. Either lower it against compression, or check it by hand from sinking too far into the cylinder. There will then be sufficient clearance to withdraw the other piston and its rod; leaving No. 1 piston (that upon the master rod) to the last, withdraw each of the other pistons separately. The end of the crankpin is cut away, to facilitate wriggling out the master rod, and the engine should be turned until the most convenient position for doing this is found. After the above parts have been removed, it will generally be found that there is nothing much amiss. Possibly some of the piston rings will be discoloured through gas blowing past them. The top and second rings, if discoloured, should be interchanged with two of the lower rings ; the lower rings have less work to do, and discoloured rings will soon polish up if transferred to the lower grooves. If a new ring has to be fitted it should be tested in the gauge provided in the tool kit ; it requires about .005 more clearance than the existing gauge allows. Remove piston balancing plugs (if fitted), as they work loose, and drop into the crankcase when the engine stops.

The gudgeon pins should on no account be removed from the pistons unless a new piston rod or gudgeon pin bush requires to be fitted. In such cases the procedure is as follows :—Remove the split pin and withdraw the locking plug by means of the special tool (No. 27 in Fig. 47). Place the piston head downwards in a vessel of oil just deep enough to cover the piston. (Water will do in emergencies, but is not as good as oil). Heat the liquid to 160° Centigrade (320° Fahrenheit). After maintaining this temperature for four minutes lift out the piston, insert the extractor tool (No. 27 in Fig. 47) into the screwed end of the gudgeon pin and pull it sharply out. To replace the gudgeon pin, heat the piston as before. Screw the extractor into the gudgeon pin. Lift the piston out of the oil. Hold the little end of the connecting rod in line with the piston bosses, and push the gudgeon pin home, taking care to register the locking plug holes in the pin and boss respectively. If the pin does not go in quickly, and the piston cools down, heat it up again, leaving the gudgeon pin half-entered. Never try to get the pin home in a cold piston. Finally replace the locking plug and its split pin.

Removing the Cylinders.

Directions were given in the original B.R.I. manual that the cylinder heads and barrels should only be disturbed in the event of a damaged liner.

The removal of the heads and barrels is now recommended after 40–50 hours' flying in order to remove carbon, grind in the valves (if necessary), and to examine the cylinder liners for cracks at the upper end. The liners cannot be thoroughly examined unless the cylinders are removed from the crankcase.

Removal is carried out as follows :—

Ease the nuts on the bottom elbow of each induction pipe with the special spanner provided (No. 23 in Fig. 47). Remove the four screws which attach the upper elbow of the induction pipe to the induction pocket in the cylinder head.

In removing the induction pipes, do not disturb the toped joints at the end of the straight portions, but lift off each pipe, complete with its elbows, in one piece.

Take out the split pins from the castellated nuts in the holding down bolts, and remove these nuts with the special spanner (No. 9 in Fig. 47).

The head will then come away, and the barrel may be withdrawn.

* * * *

During a partial overhaul, the following parts would naturally receive attention :—

Clean, and if necessary re-set, the sparking plugs.

Inspect the magneto contact breaker and the two high tension brushes on the central support.

Lubricate the valve rocking lever bearings with thin oil.

See that the rocking lever bearing cap bolts are slack enough to be turned by the thumb and finger.

Remove the magnetos and clean the distributer.

SEQUENCE OF OPERATIONS (RE-ASSEMBLING).

1. Replace cylinders (if they have been removed).
2. Replace pistons and connecting rods.
3. Replace short end or maneton.
4. Replace cam gear box.
5. Verify valve timing.
6. Replace nose piece.

These operations will now be described more fully.

Replacing the Cylinders.

Before replacing the cylinder barrels examine them carefully for cracks at the top end of the liners.

Before replacing, grind the head and the barrel carefully together, to insure a gastight face : this is most IMPORTANT. Use only the finest grinding-in paste, until the pair seat perfectly on each other all round : finish off with rouge, and joint with gold size. (Failing gold size, use boiled oil).

Then enter the barrel in the crankcase, and replace the head, making sure that the two are concentric : in the works a dummy piston, minus its connecting rod, is used for this purpose.

It is absolutely ESSENTIAL that the four castellated nuts on the ends of the holding down bolts should be tightened evenly. After running them up finger tight, one half of a turn only should be given to each in order.

There should be a clearance of 1 m/m. between the holding down bolts and the cylinder all the way round.

In replacing the induction pipe, renew the two face washers, if necessary: they are made of brown paper, smeared with gold size.

Replacing the Pistons.

To facilitate the entering of the pistons in the cylinders, a wide spring ring is provided in the tool kit (No. 11 in Fig. 47). Slip this over No. 1 piston; turn No. 1 cylinder to the bottom; hold the spring ring compressed around the piston rings with the palms and fingers of both hands, and when it is in accurate register with the cylinder barrel, use both thumbs to push the piston down through the spring ring into the cylinder. Beware of letting any piston sink so far into its cylinder that its rings can expand above the cylinder barrel, and note that the cut-away side of the piston skirt must be on the trailing side, *i.e.*, the left hand side when the cylinder is at the bottom. Replace the big end of the master rod on the crank pin. Next enter Cylinder Nos. 2 and 0, after which the remaining pistons may be entered consecutively, either towards the right or the left. The wrist pins may be replaced as each piston is entered, until the last two pistons are reached; both of these must be put in their cylinders before either of their wrist pins are engaged. DIP THE WRISTPINS IN CASTOR OIL BEFORE REPLACING THEM. Be careful to fit the correct wrist pin to each connecting rod; their numbers are stamped on them. The snug or pinstop should be very carefully aligned with its bed before the wrist pin is pushed home; clumsiness or force may cause damage. Should a wrist pin be falsely entered with its snug out of line, the extractor provided in the kit enables it to be withdrawn with ease from the front. When all the connecting rods are assembled, screw up the brass wrist pin plugs tightly.

Put the short crank back in position, and as it is tightened home by the squareheaded nut, notice that :—

(i) The ball bearing is entering its housing in the master rod.

(ii) The key and keyway are in accurate register.

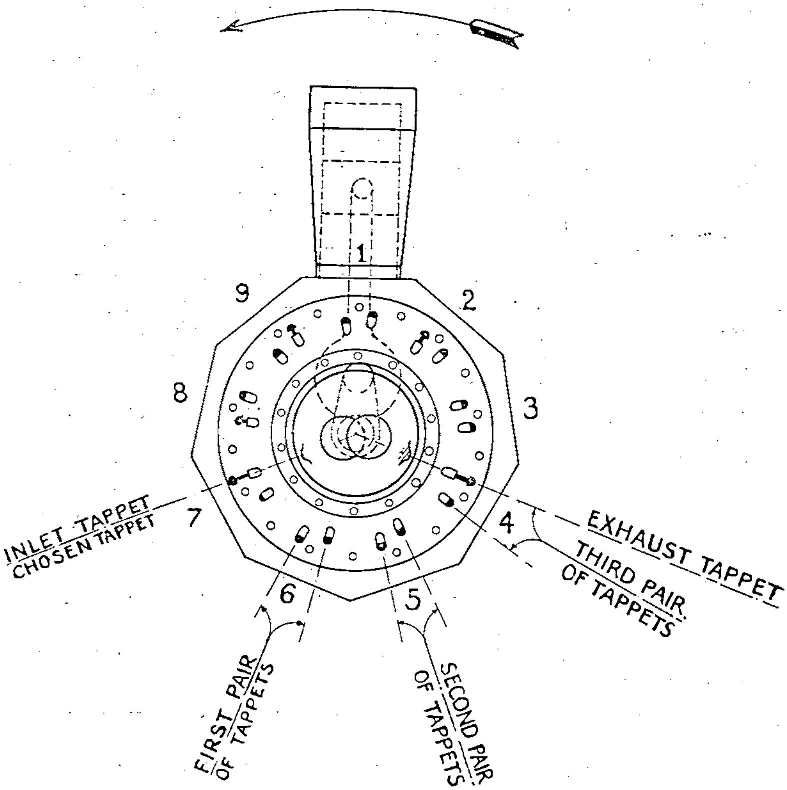
Then release the square-headed nut one turn, and place the distance plate (No. 16 in Fig. 47) between the face of the main crank and the master rod bearing. Tighten up the square-headed nut fully, after which a second operator should hold the distance plate and pull it out as soon as the first operator has released it by unscrewing the square-headed nut. Finally tighten up the square-headed nut once more. The locking plate and its two split pins should then be replaced.

Replacing the Cam Gear Box.

(Directions for dismantling the cam gear box are given on p. 49. This should not be necessary after 40 hours' flying.)

1. Turn the engine till No. 1 cylinder is on the top dead centre. (NOTE.—If the magnetos are already in position, it is of course necessary to see that No. 1 cylinder has its ignition correctly timed. To check this, turn the engine 22½° CLOCKWISE from top dead centre position of No. 1 cylinder.

FIG. 41.



Valve timing diagram.

Verify this by protractor ; an error of one serration either way will give a reading of 20° or 25° ; an error of one tooth either way will give a reading of 17° or 27½° ; the protractor must show 22½° exactly. When correct, the platinum points of the magneto contact breaker should just be about to break at 22½ measured clockwise from the top dead centre of No. 1 cylinder with the high tension brushes making contact with the No. 1 segments on the distributor disc. (Full ignition timing instructions are printed on p. 52.)

2. The tappets marked I on cam gear box should now be placed at the top.

3. Turn the cam gear (*i.e.*, the *inner* rings, with *external* teeth) to the position shown in Fig. 41, *i.e.*, with inlet tappet (fully lifted) just below the horizontal centre line on the left hand side, and the exhaust tappet (also fully lifted) just below the horizontal centre line on the right hand side.

4. The accuracy of the above cam setting is automatically checked by the keyway and key. If the operation has been correctly carried out, the keyway on the extension piece of the crankshaft will register with the key in the short end. The cam gear box can then be pressed into place, and its nuts, and spring washers replaced.

5. Press the front cover of the cam gear box into place, registering its key accurately. Force a quantity of castor oil into the cam gear box before replacing the nose piece.

6. Bolt on the nose piece.

COMPLETE OVERHAUL AFTER 100 HOURS' FLYING.

Sequence of Operations (Dismantling).

1. Remove nose piece.
2. Free push rods from rockers.
3. Remove cam gear box.
4. Withdraw short end or maneton.
5. Remove pistons and connecting rods.
6. Remove carburettor and all nuts behind rear support.
7. Remove magnetos and pumps.
8. Free crankshaft from rear support.
9. Lift engine out of plane.
10. Place engine, front downwards, on stool.
11. Remove induction pipes and sparking plug wires.
12. Remove nuts securing thrust box to crankcase.
13. Lift out crankshaft with thrust box still upon it, from crankcase.
14. Unscrew with special tool the nut behind large gear wheel on rear of crankshaft.
15. Remove crankshaft from thrust box.
16. Remove cylinders.

DETAILED INSTRUCTIONS FOR COMPLETE OVERHAUL (DISMANTLING).

Operations Nos. 1–5 in the above sequence have already been described (*see* pp. 41, etc.). The remaining operations are now described in detail; but the dismantling of individual components, such as the cam gear box, is not described until the end of the sequence, and commences on p. 49; where time is urgent, and spare hands are available, additional mechanics will, of course, dismantle these components whilst the general dismantling of the engine is in progress.

6. In removing the carburettor, the directions of the threads must be remembered. The fixing nut has a right hand thread on to the crankshaft, and a left hand thread on to the carburettor; the locking nut has a left hand thread.

7. The magnetos and pumps can be lifted off after their attaching nuts are removed, as their driven pinions will slide out of engagement with the large gear wheel.

8. It is not necessary to remove the doping and oil pipes from the central support.

Remove the stopscrew (No. 31 in Fig. 48) of the coupling sleeve. Unscrew the coupling sleeve (No. 32 in Fig. 48) by means of the special spanner (No. 20 in Fig. 47); it has a right hand thread. The coupling will then push the crankshaft out of its coned and keyed joint in the sleeve. There is no need to remove the half collars and sawn containing ring (Nos. 33 and 34 in Fig. 48). Operations Nos. 9, 10, 11 and 12 require no explanation.

13. The engine is now resting, front downwards, on the wooden stool. Take off the induction pipes (complete, without breaking the taped joints at the top and bottom elbows), sparking plug wires, and the nuts securing the thrust box to the crankcase.

Withdraw the thrust box, crankshaft, and accompanying fittings in one block from the crankcase.

Undo the rear crankshaft nut (No. 37 in Fig. 48) [right-hand thread] with the special spanner provided (No. 30 in Fig. 47).

The crankshaft is now free for withdrawal from the thrust box, and can be removed by bumping the threaded end on a block of wood; it will probably bring the front or main ball bearing with it.

(Note.—Instructions for reassembling the above parts commence on p. 51.)

DISMANTLING UNITS WITHDRAWN AS COMPLETE.

Dismantling the Cam Gear Box.

The cam gear box having been removed as per p. 41, draw out the centring plate; remove the split pin; unscrew the front nut (No. 4 in Fig. 48 to which all part numbers refer).

Draw off the front ball bearing (No. 18) and remove the distance washer (No. 19). Insert the special clips (No. 12 in Fig. 47) under the ball caps (No. 20) of tappets. Draw off the front or exhaust eccentric (21) with ball bearing complete. Undo nut (No. 27) and spring locking ring.

Draw out extension piece of crankshaft complete with rear or inlet eccentric (No. 23) and ball cam bearing. If the tappets are to be removed, drive out the taper pins (No. 24) from the tappet ball caps. Draw off the ball caps. The tappets can then be removed, together with the exhaust cam gear ring (No. 25). Do not try to drive out the bronze tappet guides, which must be regarded as part of the cam gear box. To remove the rear ball bearing, draw out the fixed disc (No. 26); remove the ring stop; and unscrew nut (No. 29).

Re-assembling the Cam Gear Box.

Replace ball bearings, nut and stop rings.

Put in fixed disc (No. 26) with its RADIUS FACING THE BALL RACE.

Replace inlet gear ring.

NOTE.—In the remaining operations, distinguish clearly between :—

(*a*) The continuous teeth on the front edge of the inlet and exhaust gears (also termed "cams" and "eccentrics") which are driven teeth, engaging with the teeth of the internally toothed gear rings; and

(*b*) The four spaced cams, identical in shape with the above teeth, on the rear edges of the gears, cams or eccentrics; these are the actual cams which operate the valve tappets.

Take the crankshaft extension, with inlet cam ball bearing attached, and turn the outer race so that one of the cams is in line with the greatest radius of the eccentric, *i.e.*, at its maximum lift.

Insert this assembly in the cam gear box so that the cam tooth which has just been placed at a maximum is in line with ANY inlet valve tappet; this tappet will thus be held fully lifted.

Leaving the extension shaft in the cam gear box next insert the exhaust cam gear ring (25), *i.e.*, the outer of the two internally toothed rings.

Take the exhaust eccentric with its cam bearing attached, and turn the outer ball race so that a cam tooth comes in line with the extreme throw of the eccentric, *i.e.*, at a maximum ; this will always be in line with the keyway.

Count three pairs of tappets in an ANTI-CLOCKWISE direction from the inlet tappet previously set at maximum lift.

Slide the exhaust eccentric on to the shaft with the fully lifted exhaust cam tooth in line with the centre of the exhaust tappet of the third pair of tappets, as above ; this exhaust tappet will thus be held at its maximum lift.

Check the above by noticing whether the keyway on the extension shaft registers with the key in the short end of the crankshaft. Should it fail to do so, an error has been made in counting the tappets.

Fix nut (27) and ring stop on the inner end of the crankshaft extension. Place the distance washer (19) on the outer end of the extension shaft, with its BEVELLED EDGE OUTWARDS.

Press on the ball bearing (18).

Screw on nut (4), and fix it with the stop pin. The cam gear can now be revolved freely, without affecting the relative position of the cam teeth. DO NOT LEAVE THE ASSEMBLED CAM GEARS LYING ABOUT for fear of a nut or other foreign object getting inside them.

Dismantling the Thrust Box.

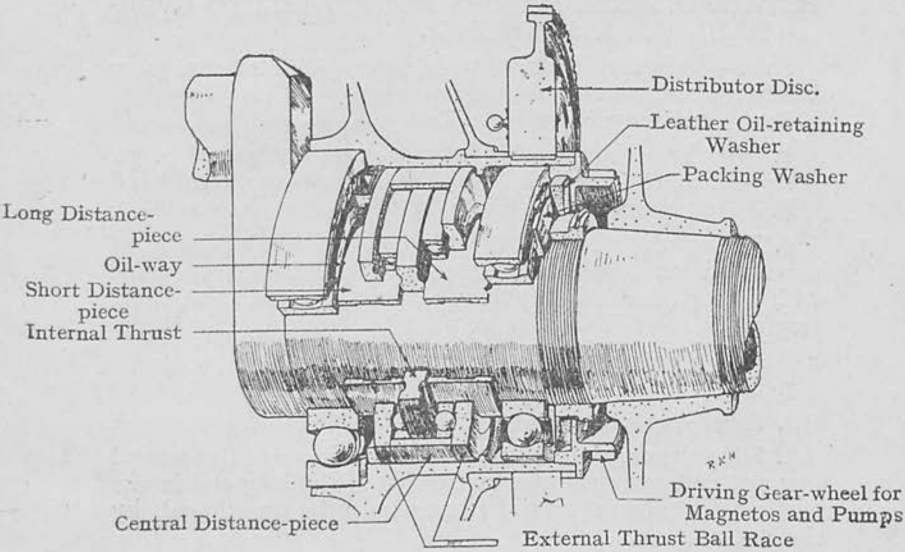
(The part numbers refer to Fig. 48.)

Unscrew the front nut of the thrust box (No. 38 right hand thread) with the special spanner provided (No. 18 in Fig. 47). Take out the parts in the following order :—

1. Front distance piece (39).
2. Front thrust race (40).
3. Front thrust ball cage (47).
4. Central thrust race (41).
5. Central distance piece (48).
6. Thrust ball cage (42).
7. Rear distance piece (long) (44).
8. Back distance thrust race (43).

To release the rear bearings unscrew the main driving wheel (46 left-hand thread) and take out the leather oil retaining washer (50) and the distance washer (49). The ball bearing can then be pressed out of the thrust case.

FIG. 42.



Section through thrust box.

(NOTE.—This sketch is purely diagrammatic. See below for true position of oil ways.)

Re-assembling the Thrust Box.

Proceed in the reverse order, attending carefully to the following IMPORTANT details.

The back distance piece (44) is LONGER than the front (39).

The small oil grooves in the front (39) and central (48) distance pieces must come AT THE TOP and on the side AWAY FROM THE CRANK. See that the leather oil-retaining washer is in perfect condition. See that the distance washer (49) has its FLAT side against the leather oil-retaining washer.

SEQUENCE OF OPERATIONS (RE-ASSEMBLING).

1. Replace thrust box on crankshaft.
2. Replace crankshaft, carrying thrust box, in crankcase, and bolt up.
3. Replace cylinders.
4. Attach induction pipes and sparking plug wires.
5. Lift engine from stool, and insert crankshaft in supports.
6. Fix crankshaft in supports, and screw on carburettor.
7. Replace magnetos and pumps.
8. Replace pistons and connecting rods.
9. Replace cam gear box.
10. Engage push rods with valve rockers.
11. Replace nose piece.

DETAILED INSTRUCTIONS FOR COMPLETE OVERHAUL (RE-ASSEMBLING).

N.B.—Clean and lubricate with castor oil all internal parts before replacement.

Part numbers refer to Fig. 48.

1. The thrust box, having been reassembled as per p. 51, is slipped on to the crankshaft; the rear nut (37, right hand thread) is tightened up.

2. The crankcase, complete with the cylinders, is lying front downward on the stool. Insert the crankshaft, complete with fittings, and bolt the thrust box to the crankcase, being careful not to omit the Grover washers. (See that the thrust box is well oiled before replacement.)

3. See p. 44.

4. Is self-explanatory.

5. Slide the crankshaft into the coned sleeve of the central support, and enter the rear extremity of the long end in the rear support, being careful not to burr the fine threads by clumsy entering.

6. Screw the coupling sleeve (32) home, when it will draw the crankshaft home in the central support. IMPORTANT WARNING: Do not remount the magnetos and pumps on the support until the crankshaft is right home. As the coupling draws the crankshaft home, it draws the gear wheel towards the central support; if the driven pinions of the magnetos and pumps are already in place, the wheel may be tightened hard up against then with no teeth registering for mesh, when damage will inevitably occur. This can be guarded against by gently rocking the engine as the crankshaft is drawn home, so that the wheel and pinions may mesh; but it is far safer to postpone mounting the driven pinions until after the crankshaft is fixed.

7. The pump drives can, of course, be meshed in any position. The timing of the magnetos may be left until the cam gear box has been replaced, if so desired. If the valves are timed first, the operator must be careful in timing his ignition to place No. 1 cylinder on that dead centre when it has both valves shut. Conversely, if the magneto is timed first, he must not time the valves without reference to the previously-set ignition timing. On the whole, it is simpler to time the valves first, when No. 1 cylinder can readily be put on the correct dead centre (both valves shut) for ignition timiug purposes. The timing procedure is as follows :—

Place No. 1 cylinder on the top dead centre of its compression stroke. Set the protractor against a holding down bolt of No. 1 cylinder. with its pointer swinging on the side next the operator. Turn the engine CLOCKWISE until the pointer registers $22\frac{1}{2}^\circ$, exactly. Leaving the engine in the above position, take either magneto, and turn its armature in the direction indicated by the arrow stamped on its baseplate, until the platinum points are just about to break (as the ignition point is fixed, there is no advance lever to trouble about).

Push the driven pinion of the magneto through the orifice in the central support, and mesh the pinion with the wheel, without disturbing the setting either of the engine or of the armature.

Bolt the magneto into position.

Time the other magneto in similar fashion.

To check the timing, see that :—

(*a*) The platinum points of both magnetos break simultaneously.

(*b*) The break occurs at $22\frac{1}{2}^\circ$ before top dead centre.

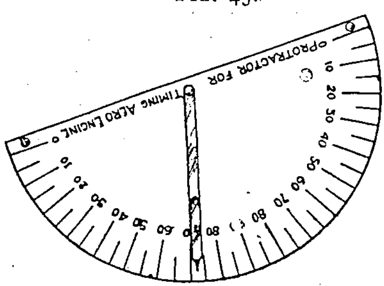
Should any small error be made in meshing the wheel and pinion, it may amount to either 5° or $2\frac{1}{2}^\circ$ either way. A 5° error means that the timing is one tooth out on the wheel and pinion ; a $2\frac{1}{2}^\circ$ error means that the timing is one serration out on the serrated hub which keys the driven pinion to the armature.

8–11. These operations have already been dealt with on pp. 45, 46 and 47, and are exactly similar in the case of a complete overhaul, unless the operator prefers to delay the timing of the magnetos until he has replaced the cam gear box.

Adjusting the Valve Push Rods.

This operation is not included under the above overhauls, as the valve setting should be checked after every 20 hours'

FIG. 43.



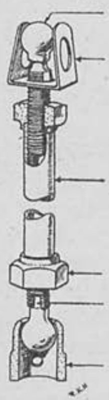
Timing protractor.

flying. Before using the protractor, make sure that the engine is supported with its crank TRULY VERTICAL. This necessitates :—

(*a*) The aeroplane standing level ; prop it up, if necessary.

(*b*) The crankshaft being properly entered in the central support, and the central support being accurately registered in the bearer plate, so that the crankshaft key comes at the bottom.

FIG. 44.

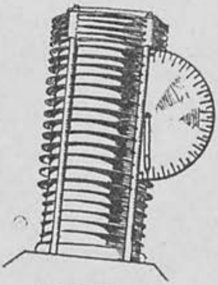


Details of Valve Push Rod.

The procedure for setting the adjustments is as follow :—
Undo the locknuts on the push rods.

Place the protractor against a holding down bolt of the cylinder under attention.

FIG. 45.



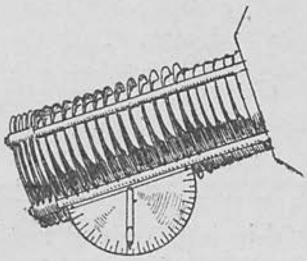
Inlet Opens.
Method of using protractor to check inlet valve opening.

Turn the engine till the protractor registers the correct valve setting angle ; these angles are :—

Inlet opens 5° before top centre.
Inlet closes 58° after bottom centre.
Exhaust opens 72° before bottom centre.
Exhaust closes 7° after top centre.

Of these angles, the closing of the inlet and the opening of the exhaust are the most important : these two angles should be carefully verified.

FIG. 46.



Exhaust Opens.

Method of using protractor to set exhaust valve opening.

Maintain the engine steady at the angle under test, and see that :—

(i) The valve rocker and stem are only just in contact.

(ii) A slight movement of the engine frees the rocker.

(iii) The rocker can be still further depressed by hand, when the tappet is exerting its maximum lift. If it cannot, there is an obvious danger of the tappet becoming jammed, and the fault is due to one of two causes. Either the push rod is too long, and its adjustment must be shortened ; or else the valve includes a faulty part, such as too long a spring, a spring with thick coils, or a spring cap which fouls the head of the valve guide when the valve is fully open.

(iv) The corresponding valve of the next cylinder in an anti-clockwise direction is not open simultaneously.

The rocking lever bearer cap bolt should be slack enough to be turned by the thumb and finger.

These directions look complicated in print ; but a little familiarity with the engine will enable a mechanic to check the settings rapidly.

REMOVING AND REPLACING VALVE GUIDES.

Push the special tool (No. 28 in Fig. 47) through the guide until its shoulder rests against the guide. Then place the sleeve on the other side of the guide, and screw up the nut, when the guide will press out of its housing.

To insert a new guide, place the tool and the sleeve together on the top side of the head, and screw up the nut.

REMOVING AND REPLACING ROCKER FULCRUM PINS.

Remove the bolts and caps. Push the special tool (No. 32 in Fig. 47) through the pin with the sleeve on, and screw up the nut. Separate distance pieces are attached to allow the pin to be drawn right out.

RUNNING THE ENGINE.

The engine should be run slowly at first starting, to allow the oil to thin down a little ; at least one minute should be allowed, when service exigencies permit, before accelerating to a high rate of revolutions. Half a pint of pure castor oil should be poured into the carburettor air pipes on first starting up, after which the throttle may be opened momentarily, so that the oil is drawn into the engine.

Owing to the centrifugal force generated by running the engine fast, it should never be switched off and on when running, nor should the throttle be shut suddenly. When the pilot desires to stop the engine, he should close the throttle gradually.

To prevent the engine from firing if it is turned during adjustments, it is wise to detach the two high tension leads from the terminals on the central support. A similar result is obtained by a special mode of stopping the engine at the end of a flight or run. After slowing the engine down on the throttle, shut off the petrol completely by means of the fine adjustment valve ; and just before the engine ceases to turn, open the throttle wide again, so that any petrol remaining in the induction system may be drawn out.

The following periodic attentions are advised :—

Frequently lubricate the valve rocker pins with thin oil (*e.g.*, paraffin).

After 20 hours' flying—

Adjust the push rods with the engine cold.
Clean the high tension distributor.
Clean the carbon brushes on the central support.

Clean and reset the sparking plugs.
Examine the contact breakers of the magnetos.
See that all unions in the petrol system are tight.
Clean the oil filter.

After 40 hours' flying—

Perform the partial overhaul described on p. 41, etc.

After 100 hours' flying—

Perform the complete overhaul described on p. 47, etc.

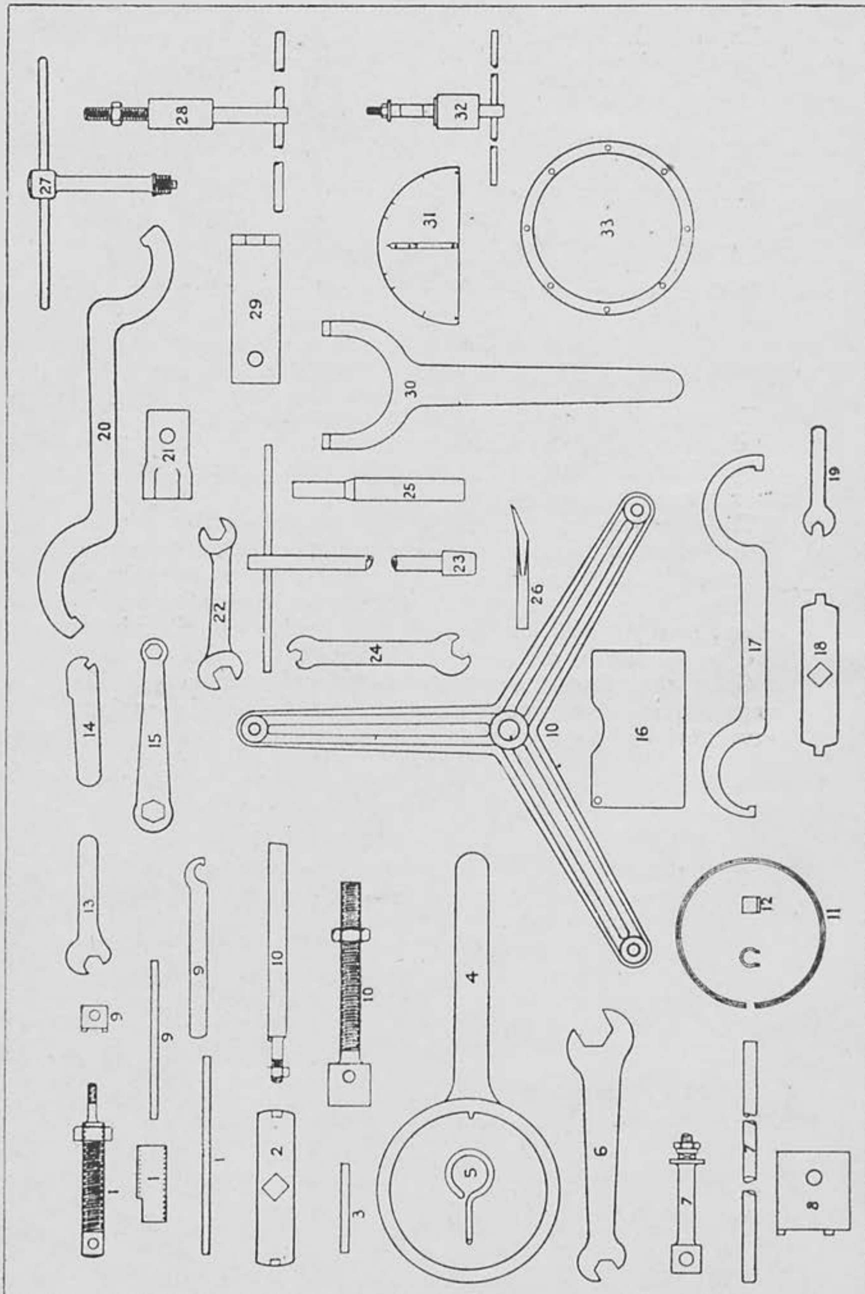
VARIOUS ADJUSTMENTS.

The valves wear well, and seldom require grinding in. When need arises, they should be ground in with the finest paste only. Unnecessary grinding in, or the use of a coarse abrasive, is extremely harmful.

The distributor disc should be cleaned periodically, and the high tension brushes on the central support should receive attention at the same time. If a new carbon brush is fitted, see that its tip is flush with its socket when the spring is fully compressed ; if it is long enough to protrude, the distributor and brush may be damaged.

Great care should be taken in fitting piston rings. The rings require about ·005″ more clearance than the makers' gauge (original pattern) allows.

FIG. 47.



B.R.1 Tool Kit.

TOOL KIT.

Tool Marked	
1	Used for extracting wrist pin.
2	,, ,, removing cam gear bearing nut (rear).
3	,, when grinding in valves.
4	,, ,, removing magneto gear wheel (large).
5	,, for extracting the cams.
6	,, ,, nuts on tripod extractor legs and ring nut holder.
7	,, in conjunction with Nos. 2 and 18.
8	,, for removing cam gear box bearing nut.
9	,, ,, removing cylinder bolt nuts.
10	,, ,, removing cam gear box.
11	,, ,, replacing piston in cylinder.
12	,, ,, holding tappets clear of cam gear when extracting the latter.
13	,, ,, nuts on valve push rods.
14	,, ,, adjusting ball joint on push rods.
15	,, ,, nuts on propeller bolts.
16	,, ,, checking distance between crankshaft and ball bearing in main connecting rod.

Tool Marked	
17	Used for removing nut and cap on oil pump.
18	,, ,, removing thrust bearing nut.
19	,, ,, rocker lever bolt nut.
20	,, ,, removing crankshaft securing and nosepiece nut.
21	,, ,, removing sparking plugs.
22	,, ,, spare spanner.
23	,, ,, induction pipe flange nut.
24	,, ,, nose piece nut, magneto nut and valve push rod nut.
25	,, ,, drift (large).
26	,, ,, ,, (small).
27	,, ,, extracting gudgeon pin and gudgeon pin lock pin.
28	,, ,, inserting and extracting valve guides in cylinder head.
29	,, ,, short crank and cam gear shaft nuts.
30	,, ,, removing thrust box bearing lock nut.
31	Protractor for timing engine.
32	Used for inserting and extracting rocking lever fulcrum pin.
33	Piston ring gauge.

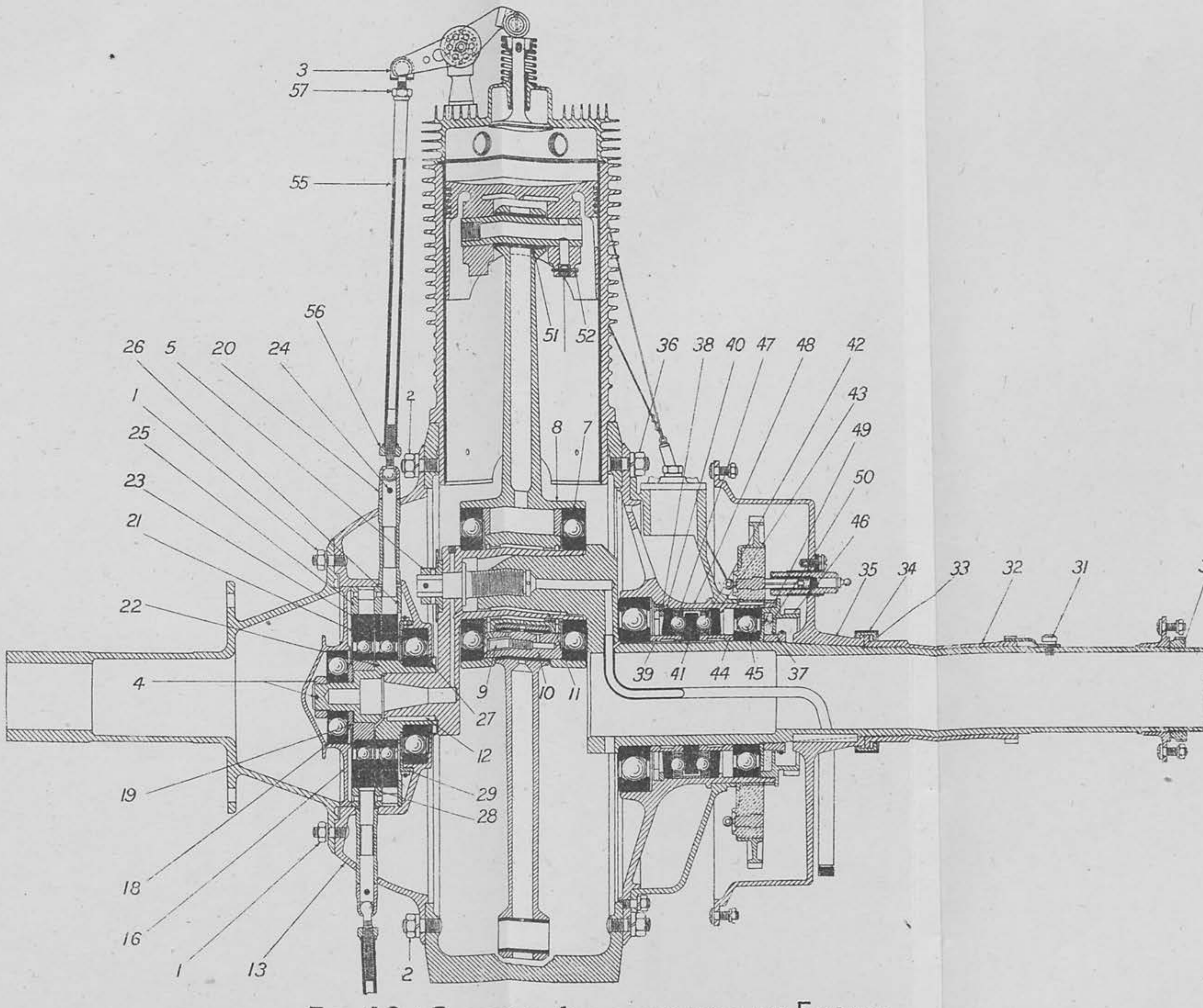


Fig. 48. General Arrangement of Engine.

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