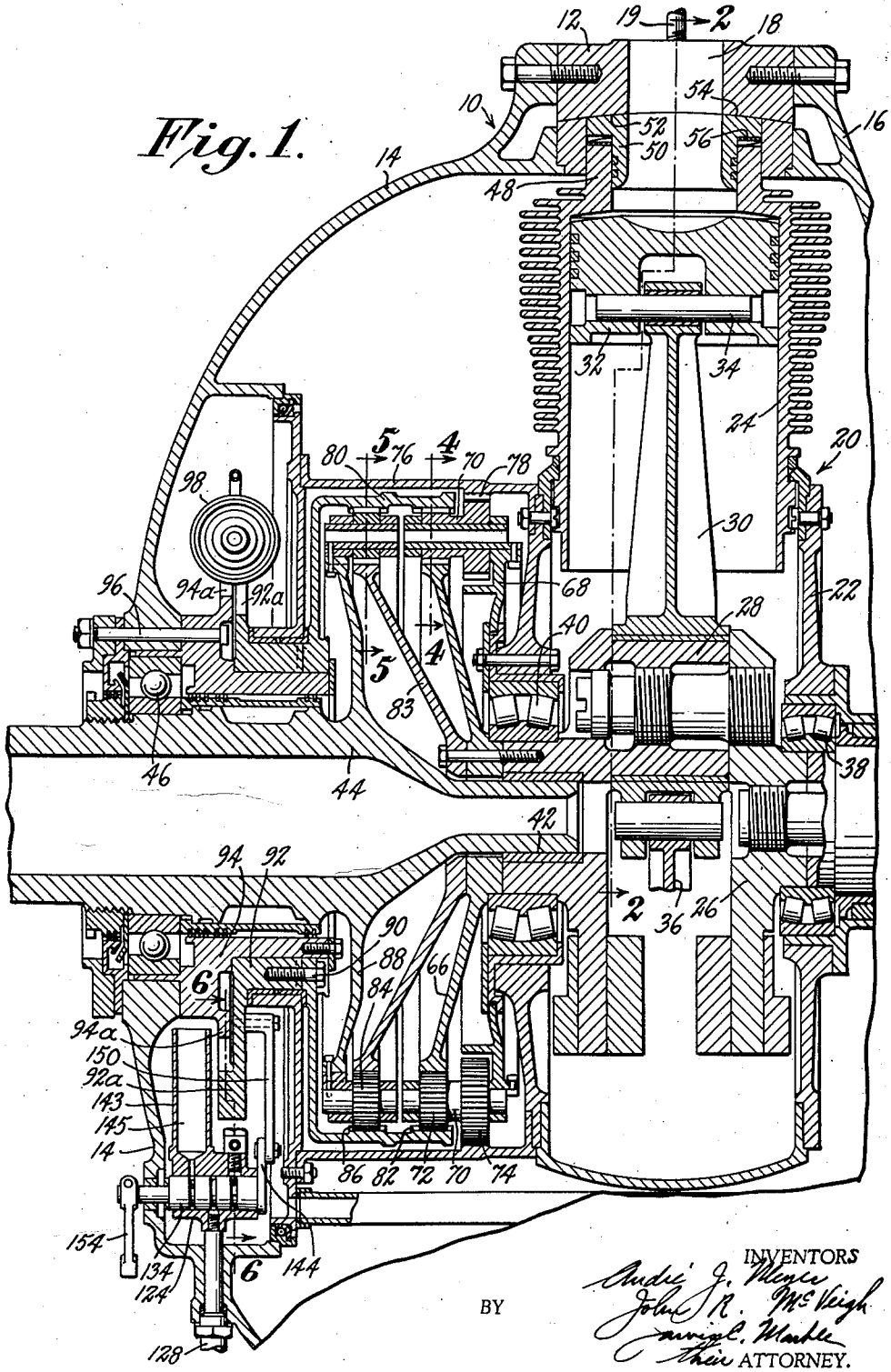
March 11, 1941. A. J. MEYER ET AL 2,234,187

ENGINE

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Fig. 1.



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ENGINE

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Fig. 2.

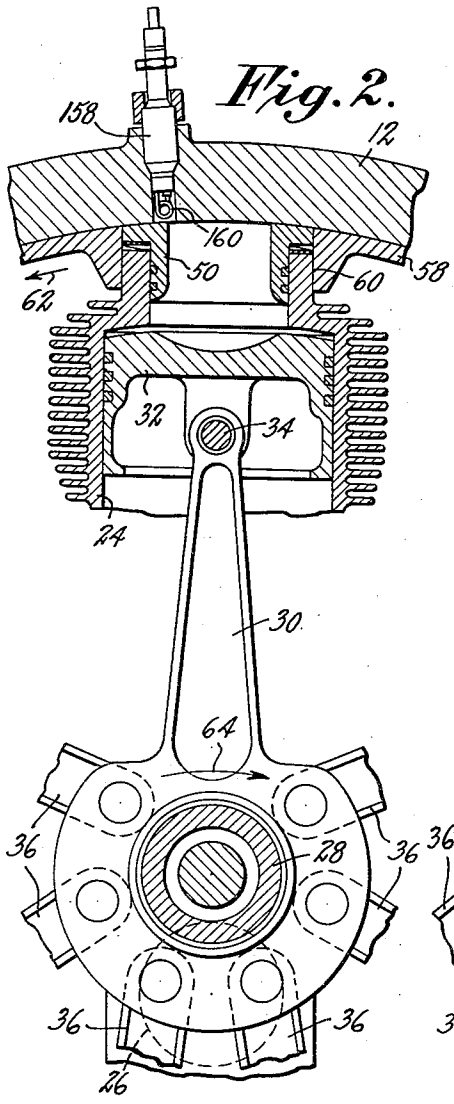


Fig. 3.

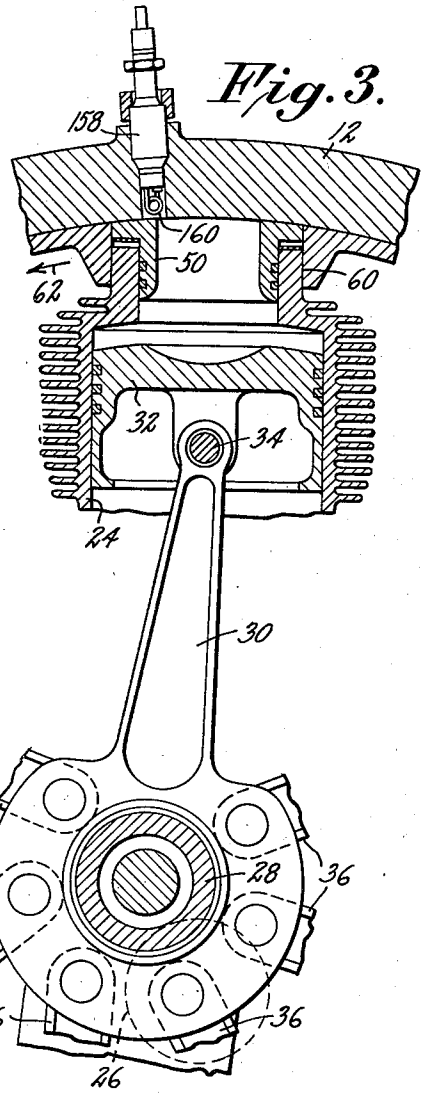


Fig. 4.

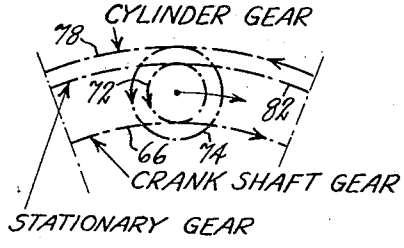
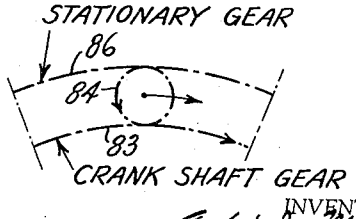


Fig. 5.



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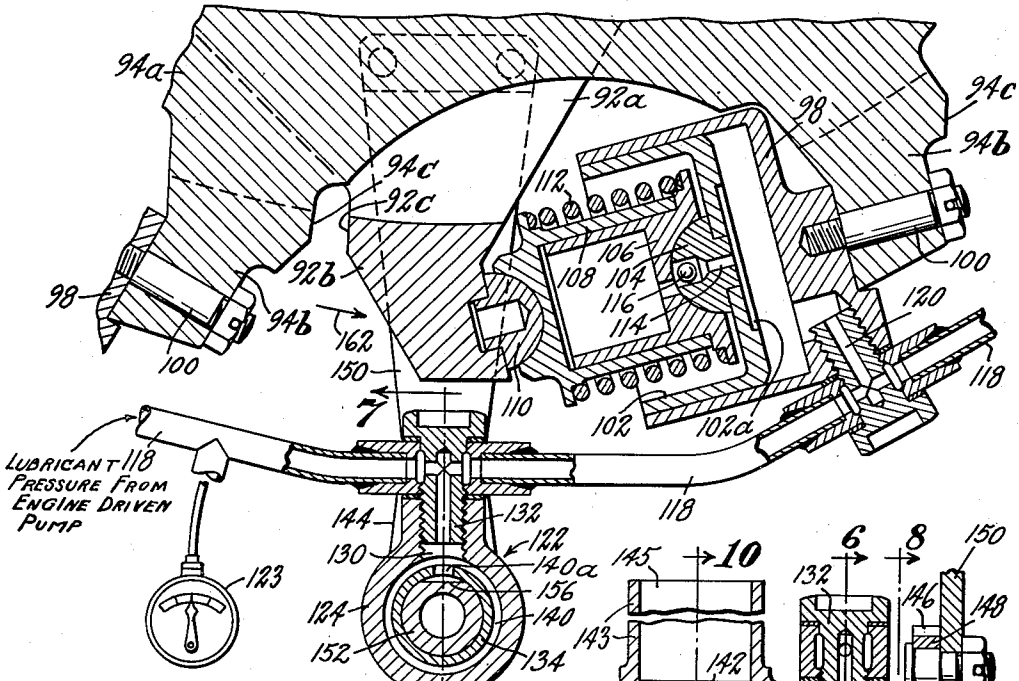


Fig. 6.

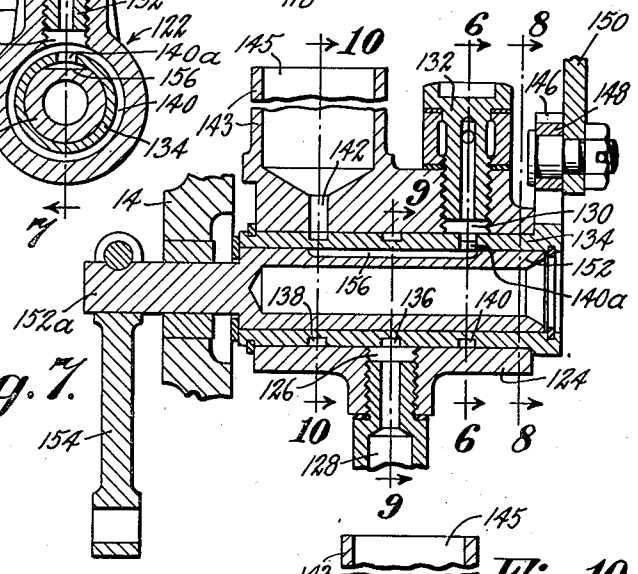


Fig. 7.

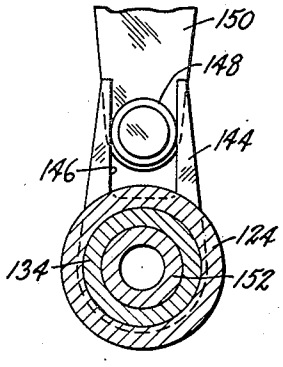


Fig. 8.

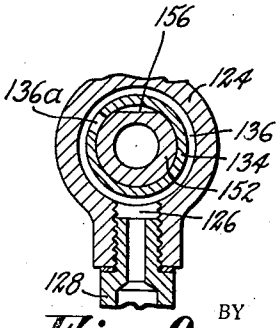


Fig. 9.

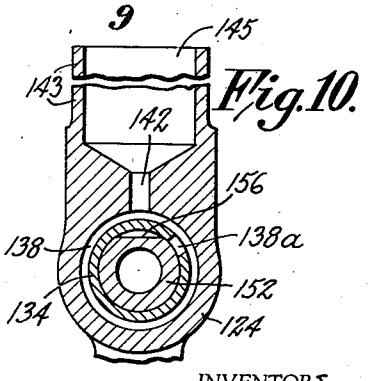


Fig. 10.

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UNITED STATES PATENT OFFICE

2,234,187

ENGINE

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Application December 29, 1938, Serial No. 248,202

31 Claims. (Cl. 123—44)

The present invention relates to engines and has particular reference to engines of what may conveniently be termed the bi-rotary type, in which there is relative rotary motion between a cylinder bank and a ported valve member associated therewith and having valve ports for controlling flow of cylinder gases. Still more particularly the invention relates to bi-rotary engines of the kind in which the cylinders are in radial or star arrangement and are encircled by an annular valve member.

In engines of this general type, the relative movement between cylinder bank and valve member may be obtained either by having either the cylinder bank or the valve member stationery, or by mounting both of these parts for rotation at different absolute speeds.

Because of the greater ease of mounting engine auxiliaries, manifolds, etc., the usual form of construction employs a stationary valve member forming a part of the housing and mounting structure of the engine and the present invention will be described in connection with such form of engine although it is to be understood that the invention is not limited to this specific form of the bi-rotary type.

One of the salient objects of the present invention is to provide an improved form of bi-rotary engine construction which will enable timed ignition to be employed without resorting to the usual forms of high tension spark ignition of the kind which utilizes high frequency currents which interfere with the transmission and reception of radio frequency signals.

A further important object of the invention is the provision of improved bi-rotary engine construction whereby the timing of an ignition system of a kind not interfering with radio frequency signals may be varied readily with respect to the engine cycle. Still another object of the invention is the provision of improved engine structure of the kind under consideration which in combination with means for varying the timing of ignition also provides means for readily measuring the torque being developed by the engine at any given time. Still another object of the invention is the provision of improved gearing for maintaining the several relatively rotating components of the engine in desired phase relation with respect to each other and which permits such phase relation as between certain of the relatively rotating parts to be varied at will within predetermined limits.

Other and more detailed objects of the invention and the manner in which the several objects are attained will best be understood from a consideration of the ensuing portion of this specification taken in conjunction with the accompanying drawings illustrating one suitable form of apparatus for carrying the invention into effect.

In the accompanying drawings:

Fig. 1 is a partial longitudinal central section of a bi-rotary engine embodying the features of the invention, showing one of the pistons at the end of its exhaust stroke;

Fig. 2 is a section taken on the line 2—2 of Fig. 1 showing the piston of Fig. 1 at the end of its compression stroke;

Fig. 3 is a section similar to Fig. 2, showing the piston somewhat ahead of top dead center on its compression stroke;

Figs. 4 and 5 are diagrammatic sections taken respectively on the lines 4—4 and 5—5 of Fig. 1;

Fig. 6 is a section on enlarged scale taken on lines 6—6 of Figs. 1 and 7;

Fig. 7 is a section taken on the line 7—7 of Fig. 6; and

Figs. 8, 9, and 10 are sections taken respectively on the lines 8—8, 9—9, and 10—10 of Fig. 7.

Referring now to Fig. 1, the engine comprises a stationary mounting structure indicated generally at 10 and comprising an annular ported valve ring 12 supported between a forward casing member 14 and a rear casing member 16, the latter being provided with suitable mounting brackets or the like (not shown) for holding the engine. The valve member 12 is provided with a plurality of peripherally spaced ports for controlling cylinder gases, one of the exhaust ports 18 being shown in Fig. 1, the port being adapted to communicate with an exhaust manifold secured to the valve member by means of suitable studs, one of which is shown at 19.

Mounted for rotation within the valve ring is a cylinder bank indicated generally at 20 and comprising a crank case structure 22 and a plurality of radially arranged cylinders 24 secured to the crank case structure. In the present embodiment only a single cylinder bank is illustrated, but it will be understood that in so far as the present invention is concerned, the engine may comprise a plurality of cylinder banks axially arranged.

Mounted for rotation at the axis of the engine is the crankshaft 26, provided with crank pin 28 upon which is journaled the large end of a master connecting rod 30, the small end of which is connected to piston 32 by means of the usual wrist pin 34. In the engine illustrated the cylin-

der bank comprises seven cylinders, the pistons of the cylinders not shown being connected to the master connecting rod by means of rods 36, shown in Fig. 2.

The crankshaft is mounted for rotation relative to the crank case structure by means of bearings 38 and 40, and at its forward end provides a socket bearing 42 for the reception of the rear end of a power shaft 44, the forward end of which is supported by a bearing 46 mounted in the stationary housing member 14. The forward end of the power shaft 44 is adapted to transmit the power developed by the engine to a propeller or power utilizing means.

Each of the cylinders 24 terminates at its outer end in a cylindrical neck 48 in which is telescoped an annular sealing element or cuff 50, the outer surface 52 of which is in sliding bearing contact with a complementary inner sealing surface or valve track 54, forming the inner face of the valve member 12. Preferably surfaces 52 and 54 are spherically curved and the sealing elements are advantageously held in contact with the sealing surface of the valve member by means of springs 56 interposed between the flanges at the outer ends of the elements and the ends of the cylindrical necks 48.

In addition to the sealing elements 50, a ring-like sealing member 58 is provided which may be integral or in the form of a number of segmental shoes. The outer surface of the sealing member is curved to mate with the surface 54 of the valve member and the sealing member is provided with a series of peripherally spaced apertures 60 through which the sealing elements 50 project into sealing contact with the valve member. The function of the sealing member 58 is to close the valve ports in the valve member when they are not in registry with the cylinder ports provided by the annular sealing elements 50.

The engine illustrated is of the four stroke cycle explosion type and is constructed so that the cylinder bank rotates relative to the stationary structure including the valve member in the direction of the arrow 62, Fig. 2, while the crankshaft rotates in the direction of the arrow 64 (Fig. 2). These directions correspond respectively to counter-clockwise and clockwise as viewed from front to rear of the engine and in the following description the directions of relative movement of the various parts will be referred to from this point of view.

In order to secure the desired rates of relative rotation between the several major components of the engine, of which the mounting structure may be considered as one, the cylinder bank and associated structure as the second, the crankshaft as the third, and the power shaft as the fourth, gearing is provided which will now be described.

This gearing comprises what may be termed a compound planetary gear divided into two sections. The first section comprises a crankshaft gear 66, secured to the forward end of the crankshaft, and a planet carrier 68 carrying a plurality of peripherally spaced compound planets 70. Each of the compound planets 70 comprises two planet pinions 72 and 74, the latter being of larger diameter than the former. The planets are mounted outside the crankshaft gear 66 which meshes with the smaller pinions 72. A gear case member 76 is secured to the crank case structure and has formed thereon or attached thereto an internal ring gear 78 which encircles and meshes with the outer portions of the pinions 74.

An annular drum-like member 80 is mounted to have limited turning movement with respect to the casing structure by means hereinafter to be described, this member, for the purposes of this description, being conveniently termed an adjustable stationary member. Member 80 is provided with an internal ring gear 82 encircling the planet pinions 72 and meshing with the outer portions thereof.

The second section of the planetary gearing comprises a crankshaft gear 83 also fixed to the crankshaft and meshing with the inner portions of a set of planet pinions 84. The outer portions of these planet pinions mesh with a second internal ring gear 86 carried by the adjustable stationary member 80. The several planet pinions 84 are carried by a planet carrier constructed to rotate with the power shaft 44 and in the present instance formed by an integral radially extending flange 88 formed on said shaft.

The operation of the above described gearing is as follows, it being assumed for purposes of explanation that the member 80 is stationary with respect to the housing structure. Considering first the section of the gear first described and with reference to Fig. 4, it will be evident that if the crankshaft gear 66 rotates in clockwise direction as indicated by the arrow in the figure, the planet pinions 72 rolling on the stationary gear 82, will cause the planet carrier 68 to rotate in clockwise direction and will also cause both the planet pinions 72 and the planet pinions 74 to rotate together about the axes of the respective compound planets in counter clockwise direction as indicated in Fig. 4. Because of the greater diameter of pinion 74 as compared with pinion 72, and the movement of rotation about the axis of the gearing and about its own axis imposed on the former pinion by the action of the latter pinion, it will be evident that pinion 74 meshing at its outer part with the cylinder gear 78 will cause the latter gear, and with it the cylinder bank, to rotate in counter-clockwise direction. It will be evident that the desired ratio of absolute speeds of the crankshaft and cylinder bank may be secured by proper proportioning of the pitch diameters of the several gears. By way of example, it may be noted that for a four-cycle engine having seven cylinders per bank and with the cylinder bank and crankshaft rotating in opposite directions, the absolute speed of rotation of the cylinder bank is one-seventh that of the absolute speed of the crankshaft.

Referring now more particularly to Fig. 5, it will be evident that if the crankshaft gear 83 of the second section of the gearing rotates in clockwise direction, the pinions 84, meshing with the stationary gear 86, will be caused to rotate in counter-clockwise direction about the axes of the pinions and that the planet carrier will be caused to rotate in clockwise direction, as indicated, but at a speed less than the speed of the crankshaft, thus providing for a gear reduction between the crankshaft and the power shaft. This gear reduction is particularly advantageous in the case of aviation engines on the power shafts of which propellers are directly mounted, in order to secure relatively low propeller speeds with high crankshaft speeds. It will be evident that the desired ratio of gear reduction can be procured by properly relating the diameters of the several gears in the second gear section.

It will further be evident that in so far as the principle of the gearing is concerned, the two crankshaft gears 66 and 83 of the present embodiment may be of the same pitch diameter and arranged to mesh with planet pinions 72 and 84 of like diameter, which in turn mesh with stationary gears 82 and 86 of like diameter. In such case a single crankshaft gear, stationary gear and planet carrier is sufficient, but the construction described, with the gearing divided into two sections, provides the advantage of permitting different reduction gear ratios for the power shaft to be provided readily for use with the same engine, by merely substituting crankshaft gears 83 and planets 84 of different size, without disturbing the remainder of the gearing.

Referring now to the adjustable stationary member 80, and the manner of mounting this member and providing for its controlled adjustment to different positions within its range of turning movement relative to the casing, it will be seen from Fig. 1 that the drum-like member 80 is secured as by means of bolts 90 to a member 92 journaled on a hub part 94 secured by means of bolts 96 to the stationary housing member 14. Member 92 is provided with a radially extending flange portion 92*a* and member 94 is provided with a radially extending flange portion 94*a* axially adjacent to the flange portion 92*a* of member 92. The flange 94*a* (see Fig. 6) is cut away to provide a series of peripherally spaced recesses with intervening projections 94*b*. The flange 92*a* is likewise cut away to provide a series of peripherally spaced projections 92*b*. The projections on the respective flanges are staggered peripherally and the outer portions thereof overlap axially to provide stops 92*c* and 94*c*. Between each adjacent pair of projections, tangentially arranged control cylinders are interposed. In the embodiment illustrated, eight of such cylinders are employed but the number of cylinders used may be varied as desired.

In Fig. 6 the construction of one of said cylinders is shown and it will be sufficient to describe one such cylinder since all are alike. Referring now to Fig. 6, the control cylinder 98 is secured to the projection 94*b* by means of a suitable stud 100 and has mounted for reciprocation therein the piston 102. Piston 102 is provided with a hemispherically faced ball member 104 providing one of the elements of a ball and socket joint, the other element of which is formed by a dash pot piston 106 arranged to slide in a dash pot cylinder 108. The base of the latter cylinder is recessed to form one part of a ball and socket connection, the other part of which is provided by a hemispherically curved abutment element 110 mounted in a suitable recess in the projection 92*b*.

A coil spring 112 around the dash pot cylinder 108 and compressed between suitable flanges on the dash pot cylinder and piston, tends to force the dash pot elements apart. The interior of the dash pot and the interior of the main cylinder are placed in communication by means of a passage 114 controlled by a check valve 116 opening toward the dash pot cylinder.

A manifold 118 for liquid under pressure, preferably lubricating oil from a suitable high pressure oil pump driven by the engine, is provided, this manifold being provided with a suitable number of branch connections 120 each affording communication between the manifold and one of the pressure cylinders.

Flow of oil under pressure to this manifold is controlled by means of a control valve indicated generally at 122 and a pressure gauge 123 is provided, this gauge being connected to the manifold 118 for the purpose of indicating the pressure of the fluid therein.

The control valve 122 comprises an outer casing 124 providing an inlet 126 to which pressure fluid is admitted. In the embodiment shown, the source of fluid under pressure is pipe 128 leading from the pressure pump driven by the engine. Casing 124 also provides an outlet 130 which by means of a suitable connection 132 provides communication between the interior of the valve and the manifold 118. An annular valve member or sleeve 134 is mounted for turning movement in the bore of the casing 124. Sleeve 134 is provided with three circumferentially extending and axially displaced grooves 136, 138, and 140. Groove 136 is axially in alignment with the inlet 126 in the housing; groove 140 is axially in alignment with the outlet; and groove 138 is axially in alignment with a relief or overflow port 142.

An open standpipe 143 providing a reservoir 145 communicating with port 142 is provided above this port. This standpipe may be cast as a part of the valve housing 124 or may be a suitable length of pipe screwed into the housing.

The sleeve 134 is provided at one end with an external actuating arm 144 slotted at 146 to receive a sliding lock 148 carried at the end of an arm 150 rigidly fixed to the member 92.

A second valve member or sleeve 152 is mounted to rotate inside sleeve 134 and at one end is provided with a shaft extension 152*a* passing through a bearing in the casing member 14, which serves to support the valve assembly. Externally of the casing a control lever 154 is secured to the projecting end of the valve part 152*a*.

The outer surface of sleeve 152 is flattened at one part to provide a groove 156 extending axially along that part of the sleeve corresponding to the portion of sleeve 134 in which the grooves 136, 138, and 140 in the latter are located.

The grooves 136, 138, and 140 in sleeve 134 are provided respectively with ports 136*a*, 138*a*, and 140*a* (see Figs. 9, 10, and 6), these ports passing through the wall of the sleeve and being peripherally displaced from each other so as to communicate respectively with the groove 156 in different positions of sleeves 134 and 152 with respect to each other.

By reference to Fig. 1 it will be apparent that the phase relation of the crankshaft with respect to the engine cylinders and consequently the phase relation between the pistons and the engine cylinders is fixed by the connection through the crankshaft gear 66, the compound planets 70, and the cylinder gear 78. The phase relation between these rotating parts and the stationary valve member is evidently determined by the connection between the compound planets 70 and the gear 82. As long as the gear 82 remains fixed with respect to the casing structure, the position of any given piston in its cylinder will be the same for any given position of the cylinder relative to the valve member.

If, however, the position of the gear 82 is shifted rotationally with respect to the casing structure, the given position of the piston in its cylinder will occur with the cylinder in a different position of relative rotation with respect to the valve ring.

The adjustably mounted parts 80 and 92 con-

stitute what may conveniently be considered a timing member, the position of which determines the phase relation of the relatively rotating engine components and also, as will hereinafter be explained more fully, the timing of ignition with respect to the cycle of engine operation.

By making the timing member rotationally adjustable with respect to the casing, certain advantages constituting important objects of the present invention are attainable and the control cylinder and valve structure just described are provided for the purpose of effecting desired rotational adjustment of the adjustable stationary member and gear **82** with respect to the engine casing and valve member.

In engines of the kind under consideration it is highly advantageous for many reasons to place the ignition means in the valve member, where such means is exposed to cylinder temperatures and pressures only for very short periods of time, rather than to mount such means in the cylinder walls.

In accordance with the present invention, the ignition means is placed in the valve member and further, in order to secure full advantage of the invention, ignition is provided by glow plugs of the kind to which continuous direct current may be supplied for heating the plug elements. A preferred arrangement is indicated in Fig. 2 wherein a glow plug **158** is shown mounted in a suitable opening passing through the valve member **12** and having an igniting element **160** adapted to be heated to incandescence by current supplied to the plug from any suitable source. It will be understood that in an engine of the kind illustrated, a suitable number of such plugs are mounted in peripherally spaced relation around the valve member in order to provide ignition at the proper time in the engine cycle for all of the cylinders. For the specific kind of engine with seven cylinders herein illustrated by way of example, the number of such plugs required is equal to the number of cylinders plus one, divided by two. Thus for the present engine, four such plugs would be required at equally spaced intervals around the valve member, provided single ignition is employed. Obviously, ignition systems of the so-called dual type may be used, with twin plugs at each ignition point.

By reference to Fig. 2 it will be apparent that tthe time when ignition occurs, even if the ignition plug is maintained continuously at igniting temperature, will be determined by registration of the leading edge of the cylinder port with the ignition cavity, and in Fig. 2 ignition has been shown as occurring in fully retarded position with the leading edge of the cylinder port coming into communication with the ignition cavity just as the piston reaches top dead center on its compression stroke. If it is assumed that this timing of ignition occurs with the adjustable stationary member of the gearing in a given position with respect to the valve casing, it will be evident that if the adjustable member is permitted to turn in counter-clockwise direction (as viewed from the front of the engine) with respect to the casing, the cylinder port will arrive in registry with the ignition cavity at an earlier time in the cycle of operation of the cylinder. In Fig. 3 the condition is shown representing a counter-clockwise shift in position of the adjustable stationary member of the gearing as compared with the position of this member for the condition obtaining in Fig. 2. As shown in Fig. 3, the cylinder port is in registry with the ignition cavity while the piston is in advance of top dead center on its compression stroke by some 25° of crank travel. This position represents normal fully advanced timing of ignition while the position shown in Fig. 2 represents normally fully retarded timing of ignition. Obviously, any intermediate degree of ignition timing may be secured by intermediate positions of adjustment of the adjustable stationary member of the gearing relative to the casing structure.

By this means it is possible to utilize substantially any desired form of continuously operating ignition means heated either electrically or by other means while at the same time obtaining the desired adjustably timed ignition which is ordinarily accomplished through the use of intermittently operated high frequency, high tension circuits. Consequently, with the present construction it is possible to employ an ignition system which will in no way interfere with radio frequency signals and it is further possible to use a relatively very simple ignition system since the necessity for the usual timing and distributor mechanism is eliminated.

In order to obtain the desired control of the position of adjustment of the adjustable member **80**, the structure described with reference to Figs. 6 to 10 is employed. This apparatus operates as follows, it being assumed that the fluid system is filled with operating liquid under high pressure as shown by gauge **123**.

The torque imposed on the adjustable stationary part (**80**, **92**) by operation of the engine tends to cause this part to move in the direction of the arrow **162** (Fig. 6), which direction of movement corresponds to advance of ignition timing. Movement in this direction is resisted by the fluid under pressure in the control cylinder, this fluid being trapped in the pressure system by the control valve. The pressure maintained in the supply conduit **128** is such that if the control cylinders are placed in communication with the source of supply, the pressure of the liquid will be sufficient to overcome the torque on the member **92**, and turn this member, together with the gear **82**, in clockwise direction to effect retardation of the timing of ignition. In the present instance the limit of turning movement in this direction is determined by the stop provided by the surfaces **92***c* and **94***c*, which are located to come together in relative positions of the parts corresponding to the timing shown in Fig. 2.

In order to admit pressure fluid to the control cylinders to retard ignition, the control lever **154** is turned to rotate the inner valve sleeve **152** in counter-clockwise direction from the position shown in the figures, thereby placing ports **136***a* and **140***a* in communication with each other by way of the groove **156**. Likewise, if it is desired to advance the timing of ignition from any given setting, pressure liquid is released from the control cylinders by moving the valve sleeve **152** in clockwise direction from the position shown in the figures, to thereby place ports **138***a* and **140***a* in communication by way of the groove **156**. With these latter ports in communication, pressure liquid can flow to the groove **138** and escape through the relief port **132**.

In order that there shall be a definite position of adjustment of the member **92** for each position of adjustment of the control lever **154**, compensating mechanism comprising the valve sleeve **134** and the actuating arm **150**, is provided.

This compensating mechanism operates as follows: Let it be assumed that as previously described, ignition is retarded from a given initial timing by turning the valve sleeve **152** counter-clockwise to place ports **136***a* and **140***a* in communication. Without the compensating mechanism, any movement of the control lever **154** sufficient to establish this connection would result in continuous movement of the parts until the positive stop position corresponding to fully retarded ignition was reached. The retarding movement, however, causes the arm **150**, attached to the adjustable part, to turn the valve sleeve **134** in counter-clockwise direction, thus moving the ports **136***a* and **140***a* away from their initial positions in the same direction as the direction of adjustment of the valve sleeve containing the groove **156**. It will be evident that continued movement of the parts, initiated by an adjustment of the control lever **154**, will result in a compensating action which will move the valve ports out of communication with the control groove in the valve.

Likewise, if the control lever is moved clockwise to advance the ignition timing, the resulting movement of the adjustable member will turn the compensating sleeve likewise in clockwise direction to shift the position of ports **138***a* and **140***a* to a new position out of communication with the groove **156**.

Thus it will be seen that for every position of adjustment of the control lever there is a corresponding definite position of adjustment of the adjustable member of the gearing relative to the casing.

The above described control arrangement also automatically takes care of leakage which may occur in the system. If, because of leakage from the control cylinders or through the control valve, the adjustable member tends to turn under the influence of engine torque to advance the ignition, this turning movement will cause the compensating sleeve of the control valve to turn in clockwise direction, thereby bringing the inlet port **136***a* into communication with the port **140***a* through the groove **156**, to admit pressure fluid in replacement of that which has leaked from the system. The pressure fluid admitted will, of course, operate to turn the adjustable member toward retarded position and this movement will cause the compensating sleeve of the control valve to move in counter-clockwise direction until the inlet port **136***a* is again out of communication with the groove **156**.

From the above it will be thus seen that the mechanism is not only self-compensating to provide a fixed relation between the position of the control lever and the adjustable gear part, but also is self-compensating with respect to leakage.

The position of the parts shown in Fig. 6 corresponds approximately to fully advanced timing of the ignition, and movement of the parts toward further advanced position may readily be prevented by means of any suitable stop (not shown) for limiting movement of the control lever **154** in the direction corresponding to advance of timing.

When the engine stops, the adjusting gear member is automatically shifted to retard the ignition to fully retarded position, by the action of the springs **112**. As soon as engine operation ceases, the torque acting on the adjustable member ceases and springs **112** can then separate the dash pot cylinder and piston merely by overcoming the friction of the engine parts. In order for the springs **112** to separate these parts, the reaction of the springs must be taken by the pistons **102** but this is readily accomplished since operating liquid is trapped in the control cylinders.

When the springs **112** commence to expand to effect retardation, oil from the control cylinders flows past the check valve **116** into the dash pot cylinders to compensate for the increase in volume of the latter. This flow of oil from control cylinders permits the control pistons **102** to move further toward advanced position because of the loss of the oil from the control cylinders, but due to the greater diameter of the control cylinders, the movement of the control pistons will be much less than the movement of the dash pot cylinders toward retarded position. As long as the oil remains trapped in the system there will obviously be sufficient oil in the control cylinders to fill the expanded dash pot cylinders.

After a certain amount of movement toward retarded position occurs, however, the compensating mechanism operates to open the control cylinders to the relief port **142**, and thereafter oil may be forced from the control cylinders by the action of the springs **112** without further movement toward retarded position of the adjustable member **92**. If this should occur, the pistons **102** will eventually provide a solid abutment against which the springs **112** may react, by coming in contact with the heads of the control cylinders. After this event occurs, continued expansion of the springs **112** will act to force the adjustable member to the fully retarded position determined by the stops **92***c* and **94***c*. During this continued movement, the further expansion of the dash pot cylinders creates a suction effect in the fluid system and in order to prevent air from being drawn into this system by this suction effect, the reservoir **145** is advantageously provided, from which reservoir oil is delivered to compensate for the increased volume of the fluid system after the pistons **102** seat against their respective cylinder heads. In order to provide for continued flow of oil to the dash pots after such seating, the heads of the pistons **102** are advantageously recessed as shown at **102***a* in order to provide channels for flow of oil from the inlets of the several control cylinders to the passages **114** through the pistons.

When the engine is started, ignition commences in fully retarded position and rapid movement to advanced position under the influence of engine torque and before operating pressure can be built up in the oil supply line, is prevented by the liquid trapped in the dash pot cylinders by the check valves **116**. This liquid is gradually forced from these cylinders under the influence of engine torque by leakage between the dash pot cylinders and the pistons, the clearance between which may readily be made such as to secure the desired rate of flow of the liquid from the dash pots.

The above described control arrangement also provides means whereby the torque being developed by the engine may readily be ascertained at any particular moment, which taken in conjunction with the speed of operation of the engine at the moment serves to give the power being developed.

By reference to Fig. 1 it will be evident that the torque reaction from all of the rotating components of the engine is transmitted through the gearing to the adjustable stationary member **80**. The net reactive torque of the crankshaft and power shaft system is taken by gear **86** through the pinions **84** while the net reactive torque as

between crankshaft and cylinder bank is taken by the gear 82 through the crankshaft gear 66, the cylinder gear 78, and the compound planets 70. This torque, as previously noted, tends to turn the adjustable stationary member in the direction of the arrow 162 of Fig. 6 and it will be appreciated that the value of this torque is reflected in the pressure of the liquid in the control cylinders required to balance it. The unit pressure of the liquid in the cylinders is readily determined by means of the pressure gauge 123 and with cylinders having a given total effective area it is readily possible to translate this unit pressure directly into terms of foot-pounds or other units of torque on the gauge.

In connection with this feature of the apparatus it is to be noted that the stop limiting the movement of the control valve toward advanced timing position should be adjusted so that the corresponding positions of adjustment of the control pistons 102 during normal operation of the engine, are with these pistons spaced from the heads of the control cylinders. Such spacing of the control pistons in fully advanced position is desirable for two reasons. The first is to have available, in case the engine is stopped with ignition fully advanced, a supply of oil in the control cylinders for keeping the dash pot cylinders filled during the initial part of the retarding movement that occurs when the engine is stopped, thus reducing the size of the reservoir required to prevent air from subsequently being drawn into the fluid system.

The second reason is that if the pistons 102 are permitted to come into direct contact with the heads of the control cylinders in the normal fully advanced position of timing, the torque load will no longer be carried by the fluid in the control cylinders and consequently the pressure of this fluid will not operate to indicate the torque being developed by the engine.

From the foregoing description it will be evident to those skilled in the art that many changes and variations in the structure hereinbefore described by way of example may be made without departing from the principles of the invention, the scope of which is to be understood as embracing all forms of apparatus coming within the purview of the appended claims when they are construed as broadly as is consistent with the state of the prior art.

What is claimed is:

1. In a bi-rotary engine, a plurality of engine components mounted for relative rotation with respect to each other, said components including a crackshaft, a cylinder bank and casing structure and one of said components being stationary, gearing interconnecting the crankshaft, cylinder bank and casing structure for maintaining the relatively rotating components in desired phase relation with respect to each other, said gearing including a gear adjustably mounted with respect to the stationary component, and means for adjusting the position of said gear relative to the stationary component to alter the phase relation between certain of said relatively rotating components.

2. In a bi-rotary engine, a plurality of engine components mounted for relative rotation with respect to each other, said components including a crankshaft, a cylinder bank and casing structure and one of said components being stationary, gearing interconnecting the crankshaft, cylinder bank and casing structure for maintaining the relatively rotating components in desired phase relation with respect to each other, said gearing including a gear adjustably mounted for limited turning movement about its own axis with respect to the stationary component, and means for adjusting the position of rotation of said gear about its own axis in order to alter the phase relation between certain of said relatively rotating components.

3. In a bi-rotary engine, stationary mounting structure, a cylinder bank mounted to rotate within said stationary structure, a crankshaft mounted for rotation relative to said cylinder bank and relative to said stationary structure, gearing interconnecting said cylinder bank, said crankshaft, and said mounting structure for maintaining the relatively rotating parts in desired phase relation with respect to each other, said gearing including a stationary gear turnably adjustable about its own axis and means for adjusting the position of rotation of said stationary gear about its own axis to alter the phase relation of the cylinder bank and crankshaft relative to the mounting structure.

4. In a bi-rotary internal combustion engine, a plurality of engine components comprising a casing structure providing a valve track, a cylinder bank having a plurality of open ended cylinders mounted for relative rotation with respect to said valve track, a crankshaft mounted for relative rotation with respect to said cylinder bank and with respect to said valve track, a plurality of ignition devices mounted in said casing structure in peripherally spaced relation along said valve track and adapted to be brought into communication with the open ends of said cylinders by the movement thereof past said devices due to the relative movement between the cylinder bank and the casing structure, gearing interconnecting said cylinder bank, said crankshaft and said casing structure for maintaining the relatively rotating components in desired phase relation with respect to each other, said gearing including an adjustably mounted gear, and means for adjusting the position of said gear to alter the phase relation between the relatively rotatable components and to thereby alter the timing of communication between said ignition devices and said cylinders.

5. In a bi-rotary internal combustion engine, a plurality of engine components comprising a casing structure providing a valve track, a cylinder bank having a plurality of open ended cylinders mounted for relative rotation with respect to said valve track, a crankshaft mounted for relative rotation with respect to said cylinder bank and with respect to said valve track, a plurality of untimed continuously operating ignition devices mounted in said casing structure in peripherally spaced relation along said valve track and adapted to be brought into communication with the open ends of said cylinders by the movement thereof past said devices due to the relative movement between the cylinder bank and the casing structure, gearing interconnecting said cylinder bank, said crankshaft and said casing structure for maintaining the relatively rotating components in desired phase relation with respect to each other, said gearing including an adjustably mounted gear, and means for adjusting the position of said gear to alter the phase relation between the relatively rotatable components and to thereby control the timing of ignition effected by said devices by controlling the timing of communication between the ignition devices and the cylinders.

6. In a bi-rotary internal combustion engine,

an annular valve member, a cylinder bank having a plurality of open ended cylinders mounted within said valve member for relative rotation with respect thereto, a crankshaft mounted for relative rotation with respect to said cylinder bank and with respect to said valve member, a plurality of peripherally spaced ignition devices located in said valve member and adapted to be brought into communication with said cylinders by the movement of the open ends of the cylinders past said devices, and gearing interconnecting said cylinder bank, said crankshaft and said valve member for maintaining the relatively rotating parts in desired phase relation with respect to each other, said gearing including a gear rotationally adjustable about its own axis to alter the phase relation of the crankshaft and cylinder bank with respect to the valve member to thereby alter the timing of communication between the cylinders and said ignition devices.

7. In a bi-rotary engine, a housing structure, a cylinder bank and a crankshaft, the aforesaid parts being mounted for relative rotation with respect to each other, gearing interconnecting the relatively rotating parts to maintain them in desired phase relation, said gearing including a gear to which force due to torque reaction is transmitted from the crankshaft and cylinder bank, and means including a body of liquid for transmitting said force from said gear to said housing structure.

8. In a bi-rotary engine, a housing structure, a cylinder bank and a crankshaft, the aforesaid parts being mounted for relative rotation with respect to each other, gearing interconnecting the relatively rotating parts to maintain them in desired phase relation, said gearing including an adjustably mounted gear to which force due to torque reaction is transmitted from the crankshaft and the cylinder bank, fluid pressure controlled means providing an adjustable force transmitting connection between said gear and said housing structure, and means for supplying pressure fluid to and permitting the escape of pressure fluid from the first mentioned means to adjust the position of rotation of said gear with respect to said housing structure.

9. In a bi-rotary engine, a housing structure, a cylinder bank and a crankshaft, the aforesaid parts being mounted for relative rotation with respect to each other, gearing interconnecting the relatively rotating parts to maintain them in desired phase relation, said gearing including a gear to which force due to torque reaction is transmitted from the crankshaft and the cylinder bank, fluid pressure controlled means providing an adjustable force transmitting connection between said gear and said housing structure, a control valve for controlling the supply and escape of pressure fluid to and from the first mentioned means to govern the position of rotation of said gear with respect to said housing structure, and compensating means actuated by movement of said gear relative to the housing structure for determining a given position of rotation of the gear with respect to the housing structure for each given position of adjustment of said control valve.

10. In an internal combustion engine, a valve member providing a circular valve track, a cylinder bank mounted for relative rotary movement with respect to said valve member, said cylinder bank including a plurality of cylinders having cylinder ports at their combustion chamber ends, a plurality of untimed ignition devices located in said valve member in peripherally spaced relation and positioned to be passed by said cylinder ports due to said relative rotary movement, whereby to effect ignition of the charges in said cylinders at times determined by communication of the cylinder ports with said ignition devices, and means associated with the engine for changing the times of communication of said ports with said devices in relation to the engine cycle to advance or retard the timing of ignition.

11. In an internal combustion engine, a valve member providing a circular valve track, a cylinder bank mounted for relative rotary movement with respect to said valve member, said cylinder bank including a plurality of cylinders having cylinder ports at their combustion chamber ends, ignition devices consisting of a plurality of glow plugs located in said valve member in peripherally spaced relation and positioned to be passed by said cylinder ports due to said relative rotary movement whereby to effect ignition of the charges in said cylinders at times determined by communication of the cylinder ports with said plugs, and means associated with the engine for changing the times of communication of said ports with said devices in relation to the engine cycle to advance or retard the timing of ignition.

12. A bi-rotary internal combustion engine having relatively rotatable components, an untimed ignition system having ignition producing devices mounted in one of said components and means operatively connecting said relatively rotatable components, said means being adjustable to vary the phase relation between said components to variably time with respect to the cycle of operation of the engine the ignition effected by said ignition system.

13. A bi-rotary internal combustion engine having relatively rotatable components, untimed glow plug ignition means including glow plugs mounted in one of said components and means operatively connecting said relatively rotatable components, said means being adjustable to vary the phase relation between said components to variably time with respect to the cycle of operation of the engine the ignition effected by said glow plugs.

14. In a bi-rotary internal combustion engine, a member having ignition pockets formed therein and located to be passed at timed intervals by cylinder ports, untimed ignition means located in said pockets, and means operatively connecting said member and the cylinders in which said ports are located, said means being adjustable to vary the timing of communication between said pockets and said ports with respect to the cycle of operation of the cylinders.

15. In a bi-rotary internal combustion engine, a member having ignition pockets formed therein and located to be passed at timed intervals by cylinder ports, glow plugs located in said pockets, and means operatively connecting said member and the cylinders in which said ports are located, said means being adjustable to vary the timing of communication between said pockets and said ports with respect to the cycle of operation of the cylinders.

16. In the operation of a bi-rotary engine of the kind having ignition means mounted outside the engine cylinders and located to be passed at intervals by cylinder ports, that improvement which consists in continuously operating said ignition means and timing the instants of ignition by varying the timing of communication between the cylinder ports and the ignition means.

17. In a bi-rotary internal combustion engine, untimed ignition devices, an adjustably mounted timing member movable to bring said devices into communication with the engine cylinders at different times in their cycle of operation to advance or retard the timing of ignition, said timing member being biased toward advanced position by force due to torque reaction from the engine, and fluid pressure actuated control means for maintaining said timing member in predetermined position of adjustment against said force.

18. In a bi-rotary internal combustion engine, untimed ignition devices, an adjustably mounted timing member movable to bring said devices into communication with the engine cylinders at different times in their cycle of operation to advance or retard the timing of ignition, said timing member being biased toward advanced position by force due to torque reaction from the engine, fluid pressure actuated control means for maintaining said timing member in predetermined position of adjustment against said force and spring actuated means for automatically moving said timing member to fully retarded position when the engine is stopped.

19. In a bi-rotary internal combustion engine, untimed ignition devices, an adjustably mounted timing member movable to bring said devices into communication with the engine cylinders at different times in their cycle of operation to advance or retard the timing of ignition, said timing member being biased toward advanced position by force due to torque reaction from the engine, fluid pressure actuated control means for maintaining said timing member in predetermined position of adjustment against said force, spring actuated means for automatically moving said timing member to fully retarded position when the engine is stopped, said spring actuated means being over-balanced by said force during normal operation of the engine and including dash pot means arranged to prevent sudden movement of said timing member under the influence of said force from its fully retarded position to its predetermined position of adjustment when the engine is started.

20. In an engine, a plurality of relatively rotatable engine components, gearing interconnecting said components to maintain them in desired phase relation, said gearing including an adjustably mounted timing member the movement of which varies the phase relation of said components, and means for controlling the position of said timing member comprising a control cylinder located between said member and said mounting structure, means for supplying liquid under pressure to said control cylinder, a control valve for controlling the flow of pressure liquid to and from said cylinder, said control valve comprising a first valve part movable at will to different positions to admit pressure fluid to or release pressure fluid from said control cylinder and a second valve part operatively connected to said adjustable member to be actuated by movement thereof to effect compensating control of pressure fluid in accordance with the movement of said adjustable member and to thereby cause said adjustable member to assume a given position of adjustment for each given position of adjustment of said first valve part.

21. In a bi-rotary internal combustion engine, an adjustable timing member for varying the timing of the engine, means providing an abutment, and fluid pressure actuated means for controlling the position of adjustment of said timing member including a control cylinder and a dash pot arranged in series between said timing member and said abutment, spring means associated with said dash pot, said spring means tending to expand said dash pot and to move said timing member to fully retarded position and said spring means being compressed by torque applied to said member when the engine is operating, means for supplying pressure liquid to said control cylinder to vary the position of said member during operation of the engine, a passage connecting the control cylinder and the dash pot for maintaining the latter filled with pressure fluid during operation of the engine and means for preventing return flow of pressure fluid from the dash pot to the control cylinder, said dash pot being constructed to permit leakage of the pressure fluid therefrom only at a relatively slow rate, whereby to prevent rapid movement of the timing member toward advanced position from its retarded position when the engine is started.

22. In a bi-rotary internal combustion engine, an adjustable timing member for varying the timing of the engine, a fluid pressure actuated system for determining the position of adjustment of said timing member, engine driven means for supplying pressure fluid to said system when the engine is operating, a control valve having a pressure fluid inlet and an overflow for determining the quantity of fluid in the system when the engine is operating, mechanical means automatically operable when the engine stops to move said timing member to fully retarded position and to enlarge the volume for fluid in said system, and means providing a reservoir of fluid in communication with the overflow of said valve for keeping said system filled with fluid when its volume is enlarged due to operation of said mechanical means.

23. In a bi-rotary engine, a plurality of relatively rotatable engine components, gearing interconnecting said components to maintain them in desired phase relation, said gearing including a member to which the force due to torque reaction developed by operation of the engine is transmitted, means providing an abutment, means for causing said force to be transmitted to said abutment through a confined body of fluid, and means for indicating the pressure of the fluid in said body.

24. In a bi-rotary engine, a plurality of relatively rotatable engine components including a mounting structure, a cylinder bank and a crankshaft, gearing interconnecting the cylinder bank and the crankshaft to maintain desired phase relation therebetween, said gearing including a gear for establishing the phase relation of the cylinder bank and the crankshaft with respect to said mounting structure and for transmitting the force due to torque reaction developed by operation of the engine, means for causing said force to be transmitted to said mounting structure through a confined body of fluid, and means for indicating the pressure of the fluid in said body.

25. In a bi-rotary engine, a plurality of relatively rotatable engine components consisting of a mounting structure, a cylinder bank, a crankshaft and a power shaft, gearing interconnecting said components for maintaining them in desired phase relation, said gearing including a gear member to which the force due to torque reaction developed by operation of the engine is transmitted, means for causing said force to be trans-

mitted from said gear member to said mounting structure through a body of fluid, and means for indicating the pressure of the fluid in said body.

26. In a bi-rotary engine, a plurality of relatively rotatable engine components consisting of a mounting structure, a cylinder bank, a crankshaft and a power shaft, planetary gearing interconnecting said components for maintaining them in desired phase relation and for effecting a gear reduction between the crankshaft and the power shaft, said gearing comprising two separate sections, a first section for interconnecting the crankshaft and the cylinder bank and a second section for interconnecting the crankshaft and the power shaft, a gear member common to both of said sections and to which the force due to torque reaction developed by operation of the engine is transmitted, and a connection between said gear member and said mounting structure for preventing rotation of the gear member and for transmitting said force to said mounting structure.

27. In a bi-rotary engine, a plurality of relatively rotatable engine components consisting of a mounting structure, a cylinder bank, a crankshaft and a power shaft, planetary gearing interconnecting said components for maintaining them in desired phase relation and for effecting a gear reduction between the crankshaft and the power shaft, said gearing comprising two separate sections, a first section for interconnecting the crankshaft and the cylinder bank and a second section for interconnecting the crankshaft and the power shaft, a gear member common to both of said sections and to which the force due to torque reaction developed by operation of the engine is transmitted, said gear member being turnably mounted with respect to said mounting structure, and means providing an adjustable connection between said gear member and said mounting structure for transmitting said force to the mounting structure.

28. In a bi-rotary engine, a plurality of relatively rotatable engine components consisting of a mounting structure, a cylinder bank, a crankshaft and a power shaft, planetary gearing interconnecting said components for maintaining them in desired phase relation and for effecting a gear reduction between the crankshaft and the power shaft, said gearing comprising two separate sections, a first section for interconnecting the crankshaft and the cylinder bank and a second section for interconnecting the crankshaft and the power shaft, a gear member common to both of said sections and to which the force due to torque reaction developed by operation of the engine is transmitted, said gear member being turnably mounted with respect to said mounting structure, and means providing an adjustable connection including a body of pressure fluid for transmitting said force from said gear member to said mounting structure.

29. In a bi-rotary engine, a plurality of relatively rotatable engine components consisting of a mounting structure, a cylinder bank, a crankshaft and a power shaft, planetary gearing interconnecting said components for maintaining them in desired phase relation and for effecting a gear reduction between the crankshaft and the power shaft, said gearing comprising two separate sections, a first section for interconnecting the crankshaft and the cylinder bank and a second section for interconnecting the crankshaft and the power shaft, said first section comprising a crankshaft sun gear, a cylinder ring gear and a plurality of compound planets the different pinions of which mesh respectively with the sun and ring gears of the section, said second section comprising a second crankshaft sun gear, a planet carrier mounted on said power shaft and a plurality of planet pinions on said carrier and meshing with said second sun gear, and a gear member common to both of said sections and having teeth meshing with one set of planet pinions of said first section and with the planet pinions of said second section, said gear member being connected to said mounting structure.

30. In a bi-rotary engine, a plurality of relatively rotatable engine components consisting of a mounting structure, a cylinder bank, a crankshaft and a power shaft, planetary gearing interconnecting said components for maintaining them in desired phase relation, and for effecting a gear reduction between the crankshaft and the power shaft, said gearing comprising two separate sections, a first section for interconnecting the crankshaft and the cylinder bank and a second section for interconnecting the crankshaft and the power shaft, said first section comprising a crankshaft sun gear, a cylinder ring gear and a plurality of compound planets the different pinions of which mesh respectively with the sun and ring gears of the section, said second section comprising a second crankshaft sun gear, a planet carrier mounted on said power shaft and a plurality of planet pinions on said carrier and meshing with said second sun gear, a gear member common to both of said sections and having teeth meshing with one set of planet pinions of said first section and with the planet pinions of said second section, said gear member being adjustably mounted to turn with respect to said mounting structure, and means for preventing rotation of said gear member including a pressure fluid connection for transmitting to the mounting structure the force transmitted to said gear member by the pinions with which it is in mesh.

31. In a bi-rotary engine, a plurality of engine components mounted for relative rotation with respect to each other, said components including a crankshaft, a cylinder bank and casing structure and one of said components being stationary, gearing interconnecting the crankshaft, cylinder bank and casing structure for maintaining the relatively rotating components in desired phase relation with respect to each other, said gearing including parts for transmitting torque reaction to said stationary component from said cylinder and crankshaft components, and indicating means for measuring the torque transmitted through said parts.

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