March 14, 1950 H. J. HICKEY 2,500,823

INTERNAL-COMBUSTION ENGINE

Filed Nov. 10, 1945 3 Sheets-Sheet 1

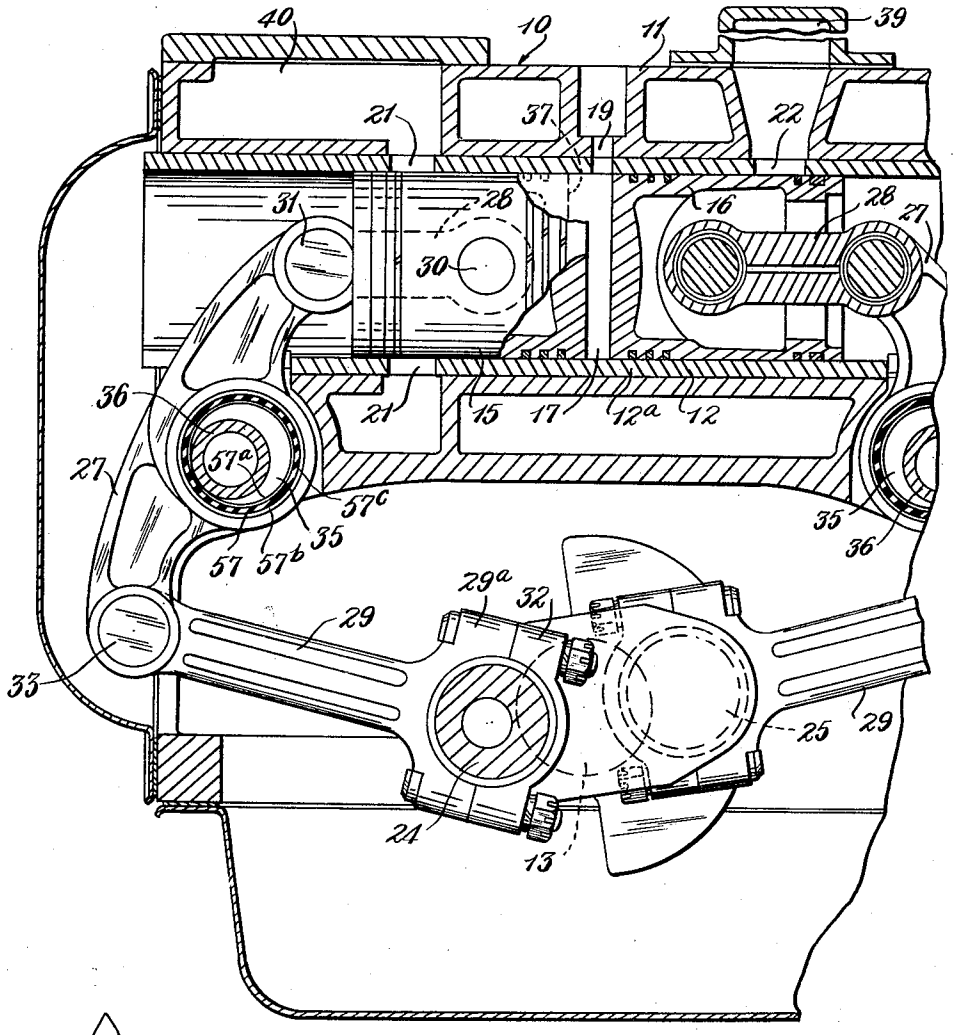


FIG. 1

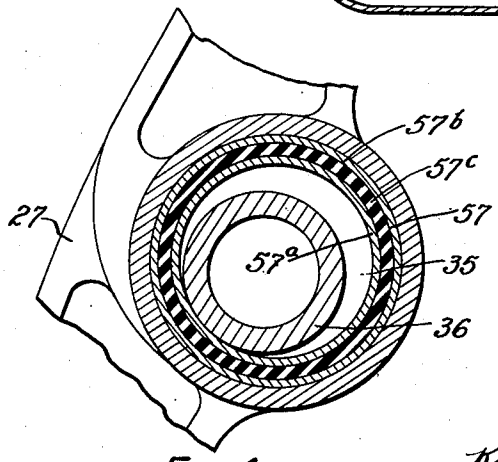


FIG. 4

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INTERNAL-COMBUSTION ENGINE

Filed Nov. 10, 1945 3 Sheets-Sheet 2

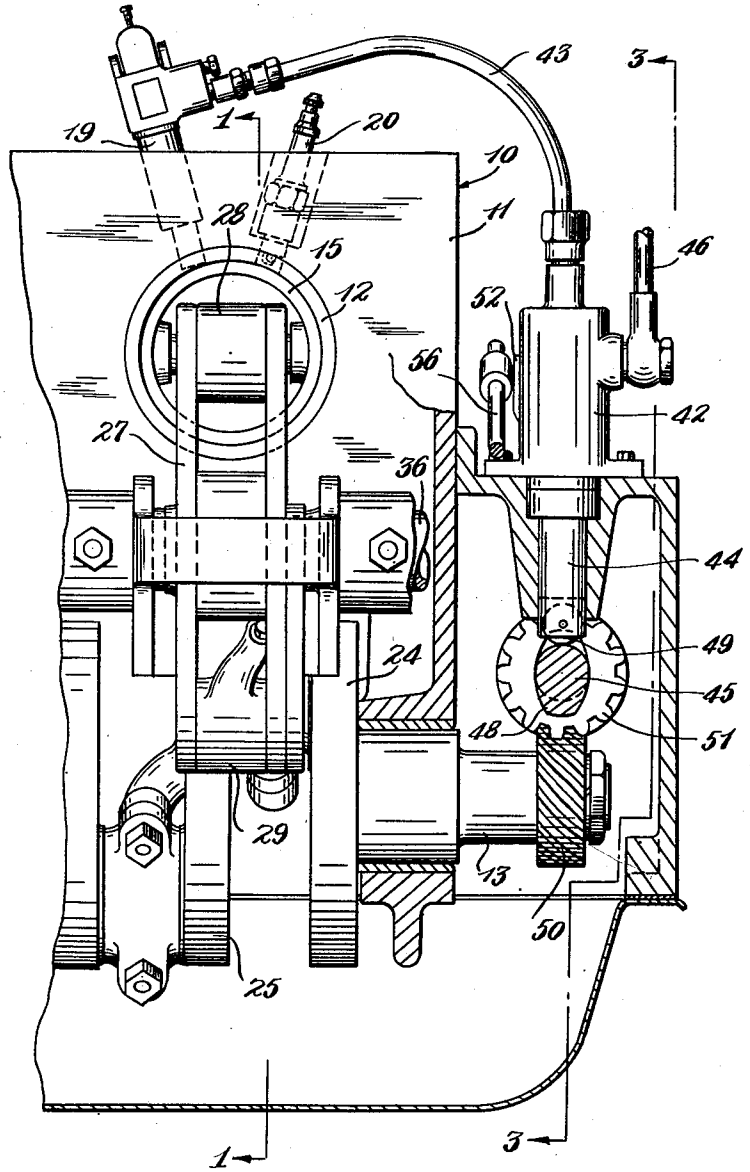


FIG. 2

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Filed Nov. 10, 1945 3 Sheets-Sheet 3

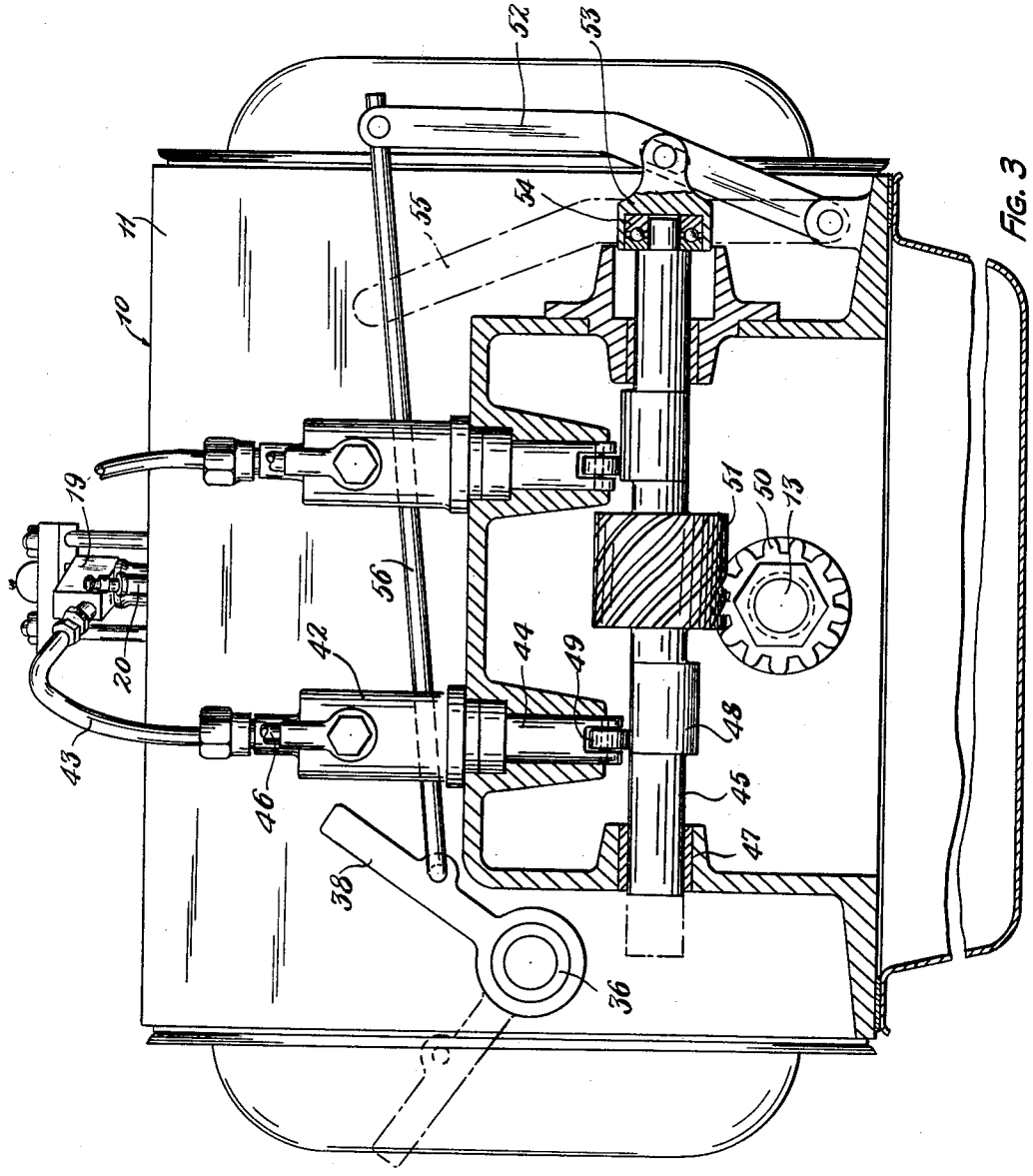


FIG. 3

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UNITED STATES PATENT OFFICE

2,500,823

INTERNAL-COMBUSTION ENGINE

Henri J. Hickey, Cleveland, Ohio

Application November 10, 1945, Serial No. 627,814

10 Claims. (Cl. 123—51)

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This invention relates to internal combustion engines and, as one of its objects, aims to provide an improved engine having a fuel injection means and embodying means by which the compression ratio and the fuel injection period can be varied while the engine is in operation.

Another object of the present invention is to provide an improved construction for a combustion engine having a fuel injection means and wherein novel means is employed for varying the injection period relative to the engine cycle.

A further object of this invention is to provide an improved internal combustion engine of the character mentioned, having means for substantially simultaneously varying the compression ratio and changing the fuel injection period relative to the engine cycle.

Still another object of the invention is to provide an improved combustion engine of the character referred to, in which the means for varying the compression ratio and the fuel injection period involves a relatively small number of parts and acts to accomplish the desired result in a simple and direct manner.

A further object of this invention is to provide an internal combustion engine of the type having a power piston operably connected with its crankshaft through a rockable lever and wherein the rockable lever is supported by bearing means embodying resilient rubber-like material capable of absorbing shocks and vibrations.

The invention can be further briefly summarized as consisting in certain novel combinations and arrangements of parts hereinafter described and particularly set out in the appended claims.

The invention herein disclosed is an improvement over the engine disclosed in my earlier Patent No. 2,316,790 granted April 20, 1943 and over copending application Serial No. 542,941 filed June 30, 1944, now Patent No. 2,398,640 granted April 16, 1946.

In the accompanying sheets of drawings,

Fig. 1 is a partial transverse sectional view taken through the engine transversely of the crankshaft and substantially as indicated by line 1—1 of Fig. 2.

Fig. 2 is an elevational view looking toward the open end of one of the cylinders and also showing certain portions of the engine in cross-section.

Fig. 3 is a transverse sectional view taken at a point adjacent one end of the engine and approximately as indicated by line 3—3 of Fig. 2, and

Fig. 4 is a sectional detail view on a larger scale taken transversely through the bearing means of one of the rocking levers.

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In the embodiment of the invention herein disclosed the accompanying drawings show an internal combustion engine 10 having a block or housing 11 containing one or more open-ended cylinders 12 and a crankcase in which a rotatable crankshaft 13 is located. The present invention is applicable to either a single cylinder engine or a multiple cylinder engine but since the principle is the same for both, the invention is hereinafter described by referring to a single cylinder. The crankshaft 13 is rotatable about an axis which extends transversely to the axis of the cylinder 12 and is offset from such cylinder axis. The engine 10 is also provided with a pair of opposed power pistons 15 and 16 which are reciprocable in the cylinder 12 and are operably connected with the crankshaft 13 by mechanism which will be presently described.

The cylinder 12 can be formed directly in the housing 11, or preferably as here shown, comprises a sleeve or barrel 12a suitably mounted in the housing. The intermediate portion of the cylinder 12 contains a combustion space or chamber 17 which is located between the inner ends of the pistons 15 and 16 and is of a variable size or volume depending upon the relative positions of the pistons in the cylinder. Gasoline or other suitable liquid fuel can be supplied to the combustion chamber 17 by a suitable fuel injection nozzle 19. The combustible mixture can be ignited in the combustion chamber by a suitable igniter such as the spark plug 20 or by compression ignition. At points spaced outwardly of the injection nozzle 19 the cylinder 12 is provided with air intake ports 21 and exhaust port or ports 22. These intake and exhaust ports are controlled by being intermittently covered and uncovered by the pistons 15 and 16.

The crankshaft 13 is provided with a pair of cranks 24 and 25 for the cylinder 12 and a similar pair of cranks for each of the other cylinders. The pistons 15 and 16 are connected respectively with the cranks 24 and 25 by similar linkages, each of which includes an oscillating or rockable lever 27 and upper and lower connecting rods 28 and 29 which have their outer ends pivotally connected to the opposite ends of the oscillating lever. Since the linkages for the pistons 15 and 16 are substantially the same, reference need be made to only one of these linkages, namely, the linkage connecting the piston 15 with the crank 24. The inner end of the upper connecting rod 28 is pivotally connected to the piston 15 by means of

the wrist pin 30. The pivotal connection of its outer end with the upper end of the oscillating lever 27 is made by means of the pivot pin 31. The inner end of the lower connecting rod 29 is connected with the crank 24 by means of a conventional forked end 29a and bearing cap 32. The pivotal connection between the outer end of the lower connecting rod 29 and the lower end of the oscillating lever 27 is made by means of a pivot pin 33.

The oscillating lever 27 is rockably mounted on a fulcrum 35 which is located adjacent the outer end of the cylinder 12 so that the axis of oscillation for the lever 27 extends substantially parallel to the axis of rotation of the crankshaft 13 and is located between coextending planes containing the axis of the cylinder and the axis of the crankshaft. The fulcrum 35 is here shown as being an eccentric which is carried by and connected with a fulcrum shaft 36. The fulcrum shaft 36 extends transversely to the axes of the cylinders and is of a length to serve the oscillating levers for the same end of all the cylinders.

To provide for varying the compression ratio of the engine so as to obtain an operating condition which will be best suited to a particular type of fuel or load value, the fulcrum shaft 36 is journalled for rocking or rotating movement in the housing 11 for causing an angular shifting of the eccentric 35 which will alter the travel of the piston 15 in the cylinder 12. When the eccentric 35 is shifted by rocking or rotating the fulcrum shaft 36 in a clockwise direction as seen in Fig. 1, the compression ratio will be increased and the piston 15 will then be movable during its inward or compression stroke to the extreme inward position in which it is shown in full lines in Fig. 1. When the fulcrum shaft 36 is rocked or rotated in a counter-clockwise direction for decreasing the compression ratio, the inward stroke of the piston 15 will extend to a point such as that represented by the broken line position 37, or any intermediate point. The means for rocking or rotating the fulcrum shaft 36 includes an actuating lever 38 which is suitably connected with one end thereof. This adjustment may be effected or controlled by any appropriate hydraulic, thermostatic or manual means.

It will be understood, of course, that the oscillating lever 27 adjacent the opposite end of the cylinder 12 will likewise be mounted on a fulcrum 35 and that, if desired, such fulcrum can be adjustable by means of a similar fulcrum shaft 36 for varying the compression stroke of the piston 16. If sufficient variation in the compression ratio can be effected by adjusting the fulcrum for only one of the pistons, then the fulcrum adjusting means can be omitted at the other end of the cylinder.

It will also be understood from the engine structure above described, that during the cycle of operation the pistons 15 and 16 will transmit torque to the crankshaft 13 through the oscillating levers 27 during the outward or power stroke of the pistons. When the outward travel of the pistons results in the exhaust and air intake ports 22 and 21 being uncovered, the products of combustion will be exhausted into the exhaust manifold 39 and a fresh supply of combustion air will be discharged into the cylinder from the manifold 40 through the ports 21. This incoming air will scavenge the cylinder and assist in the expulsion of the combustion gases through the exhaust port 22. During the inward or compression stroke of the pistons 15 and 16 the fresh air will be compressed in the combustion space 17 and when an appropriate degree of compression has occurred, the liquid fuel will be injected into and mixed with the compressed air by the injection nozzle 19. The compressed fuel mixture will then be ignited by the spark plug 20 or by compression ignition to produce the power stroke of the pistons. The fuel could, of course, be injected into the fresh air intake manifold or passage instead of directly into the combustion chamber.

The fuel delivered into the cylinders by the injection nozzles 19 is supplied to these nozzles under pressure by appropriate fuel injection pumps 42 which are connected with the respective nozzles by the conduits 43. The injection pumps 42 may be of any desirable construction and may embody a reciprocating plunger 44 which is adapted to be actuated by a rotatable camshaft 45. The liquid fuel can be supplied to the injector pumps 42 by conduits 46 leading thereto from a suitable source of fuel supply such as a tank or a conventional main fuel pump. The camshaft 45 is rotatably mounted in suitable bearings 47 provided in the engine housing 11 and has cams 48 thereon of an appropriate shape or contour which cooperate with the plungers 44 of the respective fuel pumps 42. The outer ends of the plungers 44 are preferably provided with rollers 49 which engage the cams 48.

One of the features of the improved engine 10 is the provision of means by which the fuel injection time or period can be varied relative to the engine cycle. For this purpose the camshaft 45 is axially shiftable in the bearings 47 and the cams 48 are made of a length such that they will remain in cooperating engagement with the plungers 44 for the different positions to which the camshaft is shifted. The camshaft is driven from the crankshaft 13 by cooperating helical gears 50 and 51 which are connected with these shafts.

The camshaft 45 can be shifted axially thereof by any suitable means such as the pivoted lever 52 and the yoke 53 which is connected with the lever and attached to one end of the camshaft by the anti-friction bearing 54. When the fuel injection period is to be advanced relative to the engine cycle the lever 52 is shifted from its full line position of Fig. 3 towards the broken line position 55. This movement of the lever shifts the camshaft 45 toward the left as seen in Fig. 3, and the corresponding movement of the gear 51 relative to the gear 50 causes angular or rotative movement to be imparted to the camshaft which changes the angular position of the camshaft relative to the crankshaft and the engine cycle. The angular movement thus imparted to the camshaft is in a direction to accelerate or advance the cams 48 and thus enable the camshaft to produce an earlier working stroke of the pump plungers 44 thereby causing the fuel to be injected into the combustion space 17 at an earlier point relative to the engine cycle. The movement of the lever 52 in the opposite direction will cause a corresponding retardation of the fuel injection period relative to the engine cycle.

Another feature of the improved engine is the provision of means by which the above described variation in the fuel injection period is accomplished substantially simultaneously with the variation in the compression ratio of the engine.

For this purpose the adjusting lever **52** for the fuel injection means is connected with the lever **38** of the fulcrum shaft **36**, as by means of the link **56**. When the fuel adjusting lever **52** is shifted toward the left to advance the fuel injection period, as explained above, the ratio adjusting lever **38** will simultaneously be shifted in a direction to decrease the compression ratio of the engine. Conversely, when the lever **52** is shifted in a direction to retard the fuel injection, the lever **38** will be shifted in a direction to increase the compression ratio. If conditions are such as to make it desirable to do so, the levers **52** and **38** can be connected so that an adjustment for retarding the fuel injection will be accompanied by a decrease in the compression ratio.

Another important feature of the improved engine **10** is the provision of means in the mountings for the oscillating levers **27** for absorbing shocks and vibrations, such as are transmitted to these levers as the result of the explosions occurring in the combustion space **17** or from other causes. This shock absorbing feature consists in the use of novel bearing means **57** between the oscillating lever **27** and its fulcrum **35**. The bearing **57** comprises a pair of coaxial inner and outer metal sleeves or races **57***a* and **57***b* and an intervening resilient sleeve or bushing **57***c* formed of a rubber-like material capable of withstanding the operating temperatures of the engine, such as a synthetic rubber. The resilient sleeve **57***c* is confined or retained between the metal sleeves or races **57***a* and **57***b* and if desired can be bonded thereto. The sleeves **57***a* and **57***b* form the bearing surfaces which permit rocking or oscillation of the lever **27** on the fulcrum **35** while the resilient bushing **57***c* serves to absorb and dampen various shocks and vibrations to which the lever is subject during the operation of the engine. It will be understood that the vibration absorbing bearing means **57** can be used at both ends of the cylinder **12** regardless of whether or not the fulcrums at both ends of the cylinder are adjustable for varying the compression ratio.

From the foregoing description and the accompanying drawings, it will now be readily understood that the present invention provides an improved internal combustion engine in which the compression ratio and the fuel injection period can be varied substantially simultaneously. Moreover, it will be seen that the invention provides simple and efficient means by which the fuel injection period of an internal combustion engine can be varied relative to the engine cycle. It will now also be understood that the present invention provides a shock absorbing mounting for the oscillating lever of an internal combustion engine of the type in which the power piston is connected with the crankshaft through such an oscillating lever.

Although the improved engine has been illustrated and described herein in considerable detail, it will be understood, of course, that the invention is not to be regarded as correspondingly limited but includes all changes and modifications coming within the scope of the appended claims.

Having thus described my invention, I claim:

1. In an internal combustion engine, a cylinder, a crankshaft, a power piston reciprocable in said cylinder, linkage connecting said power piston with said crankshaft, means cooperating with said linkage and being adjustable for varying the compression ratio of the engine, fuel injection means adapted to supply liquid fuel to the engine including a fuel injection pump, means operably connecting said pump with said engine to be driven therefrom and being adjustable for varying the fuel injection period relative to the engine cycle, and means for effecting said adjustment of the compression ratio and the fuel injection period substantially simultaneously.

2. In an internal combustion engine, a cylinder having an open end and a combustion space inwardly of said open end, a crankshaft rotatable about an axis extending transversely to the axis of the cylinder and offset therefrom, a power piston reciprocable in said cylinder, a fulcrum adjacent said open end, means connecting said power piston with said crankshaft including a lever adapted to oscillate on said fulcrum, said fulcrum being adjustable so as to vary the compression ratio of the engine, fuel injection means adapted to supply liquid fuel to the engine including a fuel injection pump, means driven from said crankshaft for operating said pump and being adjustable so as to vary the fuel injection period relative to the engine cycle, and means for effecting such adjustment of said fulcrum and said pump operating means substantially simultaneously.

3. In an internal combustion engine, a cylinder having an open end and a combustion space inwardly of said open end, a crankshaft rotatable about an axis extending transversely to the axis of the cylinder and offset therefrom, a power piston reciprocable in said cylinder, a fulcrum shaft adjacent said open end and extending transversely to the axis of the cylinder, an eccentric connected with said fulcrum shaft and providing a fulcrum, means connecting said power piston with said crankshaft including a lever adapted to oscillate on said fulcrum, said fulcrum shaft being rockable for changing the position of said fulcrum so as to vary the compression ratio of the engine, fuel injection means adapted to supply liquid fuel to the engine and including a fuel injection pump, means driven from said crankshaft for operating said pump and being adjustable so as to vary the fuel injection period relative to the engine cycle, and means operable to substantially simultaneously shift said fulcrum shaft and adjust the pump operating means.

4. In an internal combustion engine, a cylinder, a crankshaft, a power piston reciprocable in said cylinder, linkage connecting said power piston with said crankshaft, means cooperating with said linkage and being adjustable for varying the compression ratio of the engine, fuel injection means adapted to supply liquid fuel to the engine including a fuel injection pump, a rotatable camshaft for operating said pump, cooperating helical gears connecting said camshaft with said crankshaft, said camshaft being shiftable axially thereof for causing its angular position to be changed by said helical gears so as to vary the fuel injection period relative to the engine cycle, and means for effecting such adjustment of the compression ratio and such axial shifting of the camshaft substantially simultaneously.

5. In an internal combustion engine of the character described, a cylinder having open ends and a combustion space in an intermediate portion thereof, a crankshaft rotatable about an axis extending transversely to the axis of the cylinder and offset therefrom, a pair of opposed power pistons reciprocable in said cylinder, means operably connecting said pistons with said crankshaft and embodying means which is adjustable

for varying the compression ratio of the engine, fuel injection means adapted to supply liquid fuel to said combustion space and including a fuel injection pump, a rotatable camshaft for operating said pump, cooperating helical gears connecting said camshaft with said crankshaft, said camshaft being shiftable axially thereof for causing its angular position to be changed by said helical gears so as to vary the fuel injection period relative to the engine cycle, and means for effecting such adjustment of the compression ratio and such axial shifting of the camshaft substantially simultaneously.

6. In an internal combustion engine, a cylinder having an open end and a combustion space inwardly of said open end, a crankshaft rotatable about an axis extending transversely to the axis of the cylinder and offset therefrom, a power piston reciprocable in said cylinder, a fulcrum adjacent said open end, means connecting said power piston with said crankshaft including a lever adapted to oscillate on said fulcrum, said fulcrum being adjustable so as to vary the compression ratio of the engine, fuel injection means adapted to supply liquid fuel to the engine including a fuel injection pump, a rotatable camshaft for operating said pump, cooperating helical gears connecting said camshaft with said crankshaft, said camshaft being shiftable axially thereof for causing its angular position to be changed by said helical gears so as to vary the fuel injection period relative to the engine cycle, and means for effecting such adjustment of said fulcrum and such axial shifting of the camshaft substantially simultaneously.

7. In an internal combustion engine, a cylinder having open ends and a combustion space in an intermediate portion thereof, a crankshaft rotatable about an axis extending transversely to the axis of the cylinder and offset therefrom, a pair of opposed power pistons reciprocable in said cylinder, fulcrums located adjacent said open ends, means connecting said power pistons with said crankshaft including levers adapted to oscillate on said fulcrums, a fulcrum shaft connected with one of said fulcrums and being rockable for altering the position of said one fulcrum so as to vary the compression ratio of the engine, fuel injection means for supplying fuel to the engine including a fuel injection pump, a rotatable camshaft for operating said pump, cooperating helical gears connecting said camshaft with said crankshaft, said camshaft being shiftable axially thereof for causing its angular position to be changed by said helical gears so as to vary the fuel injection period relative to the engine cycle, and means operable to cause substantially simultaneous rocking of said fulcrum shaft and axial shifting of said camshaft.

8. In an internal combustion engine, a crankcase, a cylinder having an open end communicating with said crankcase and a combustion space inwardly of said open end, a crankshaft in said crankcase and rotatable about an axis extending transversely to the axis of the cylinder and offset therefrom, a power piston reciprocable in said cylinder, a fulcrum adjacent said open end, means connecting said power piston with said crankshaft including a lever in said crankcase and adapted to oscillate about said fulcrum, and bearing means in said crankcase and interposed between said lever and fulcrum and embodying resilient vibration absorbing material.

9. In an internal combustion engine, a crankcase, a cylinder having an open end communicating with said crankcase and a combustion space inwardly of said open end, a crankshaft in said crankcase and rotatable about an axis extending transversely to the axis of the cylinder and offset therefrom, a power piston reciprocable in said cylinder, a fulcrum shaft adjacent said open end and extending transversely to the axis of the cylinder, an eccentric connected with said fulcrum shaft and providing a fulcrum, means connecting said power piston with said crankshaft including a lever in said crankcase and adapted to oscillate about said fulcrum, said fulcrum shaft being rockable for changing the relative angular position of said fulcrum so as to vary the compression ratio of the engine, and bearing means in said crankcase and interposed between said lever and fulcrum and embodying a resilient bushing of rubber-like material.

10. In an internal combustion engine, a crankcase, a cylinder having open ends communicating with said crankcase and a combustion space in an intermediate portion of the cylinder, a crankshaft in said crankcase and rotatable about an axis extending transversely to the axis of the cylinder and offset therefrom, a pair of opposed power pistons reciprocable in said cylinder, fulcrums located adjacent said open ends, means connecting said power pistons with said crankshaft including levers in said crankcase and adapted to oscillate about said fulcrums, a fulcrum shaft connected with one of said fulcrums and being rockable for altering the relative angular position of said one fulcrum so as to vary the compression ratio of the engine, and bearings in said crankcase and disposed between said fulcrums and their oscillatable levers and embodying resilient bushings of rubber-like material.

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