Aug. 4, 1953 H. J. HICKEY 2,647,498

INTERNAL-COMBUSTION ENGINE

Filed June 17, 1947 4 Sheets-Sheet 1

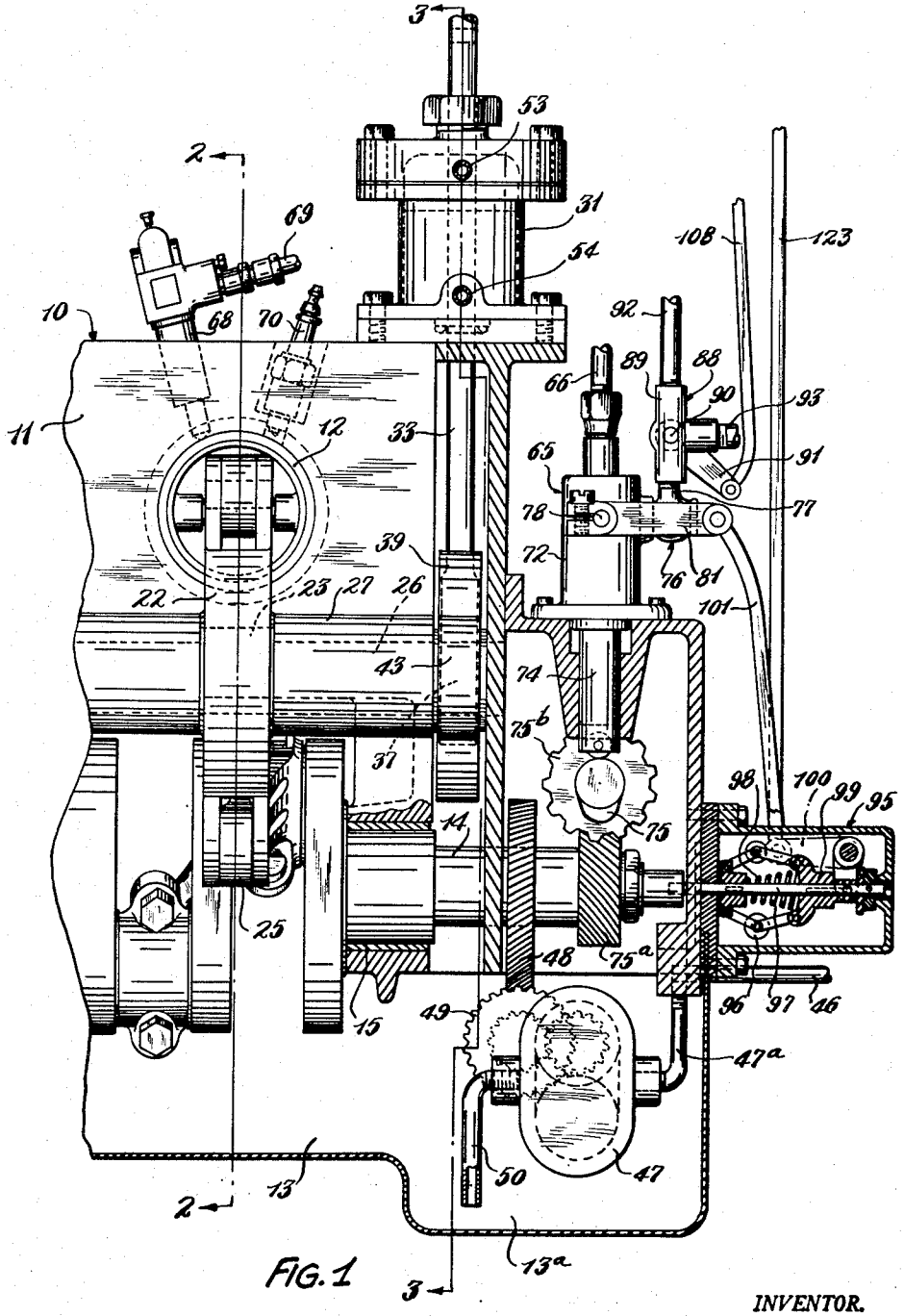


FIG. 1

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Aug. 4, 1953 H. J. HICKEY 2,647,498

INTERNAL-COMBUSTION ENGINE

Filed June 17, 1947 4 Sheets-Sheet 2

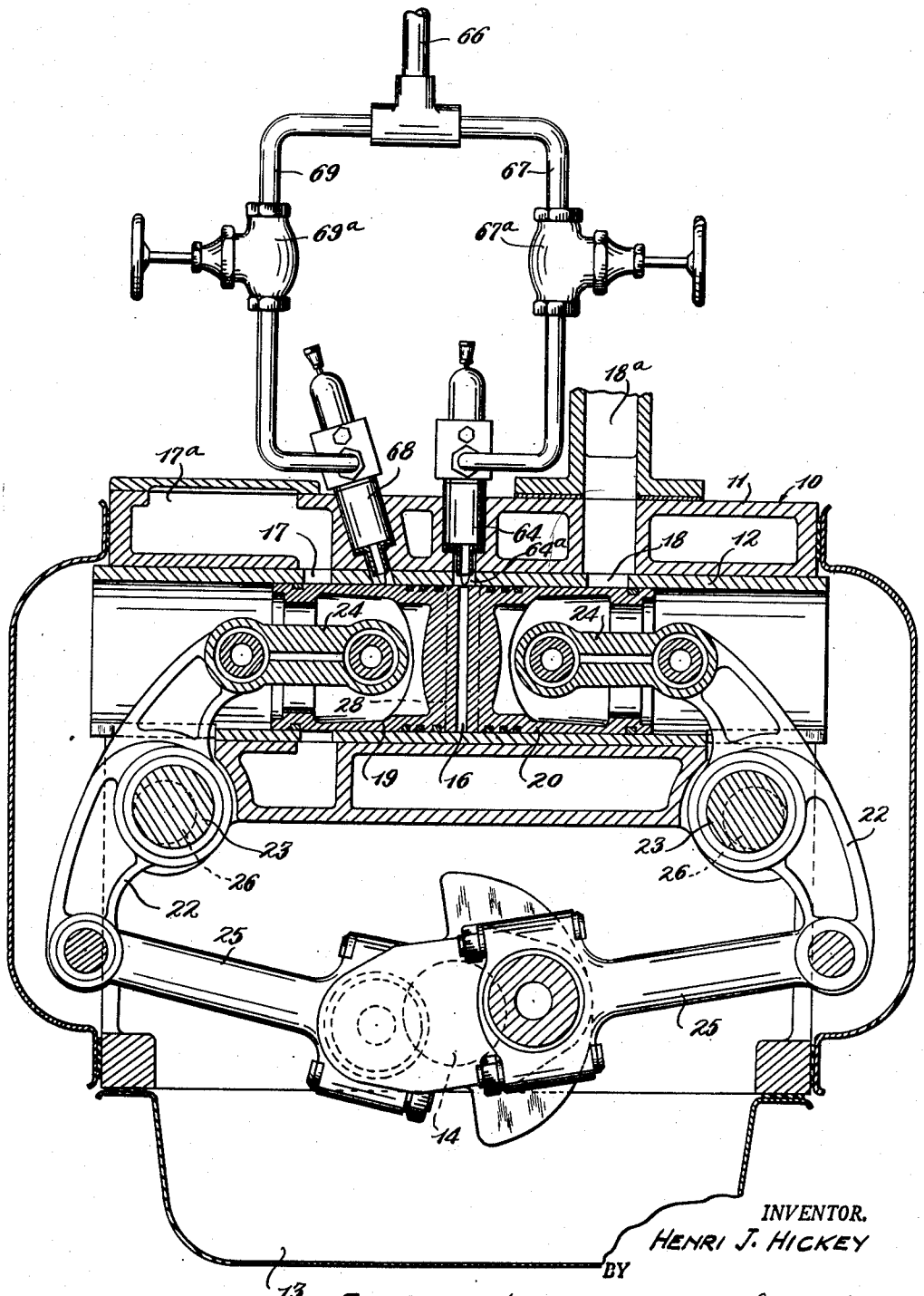


FIG. 2

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Filed June 17, 1947 4 Sheets-Sheet 3

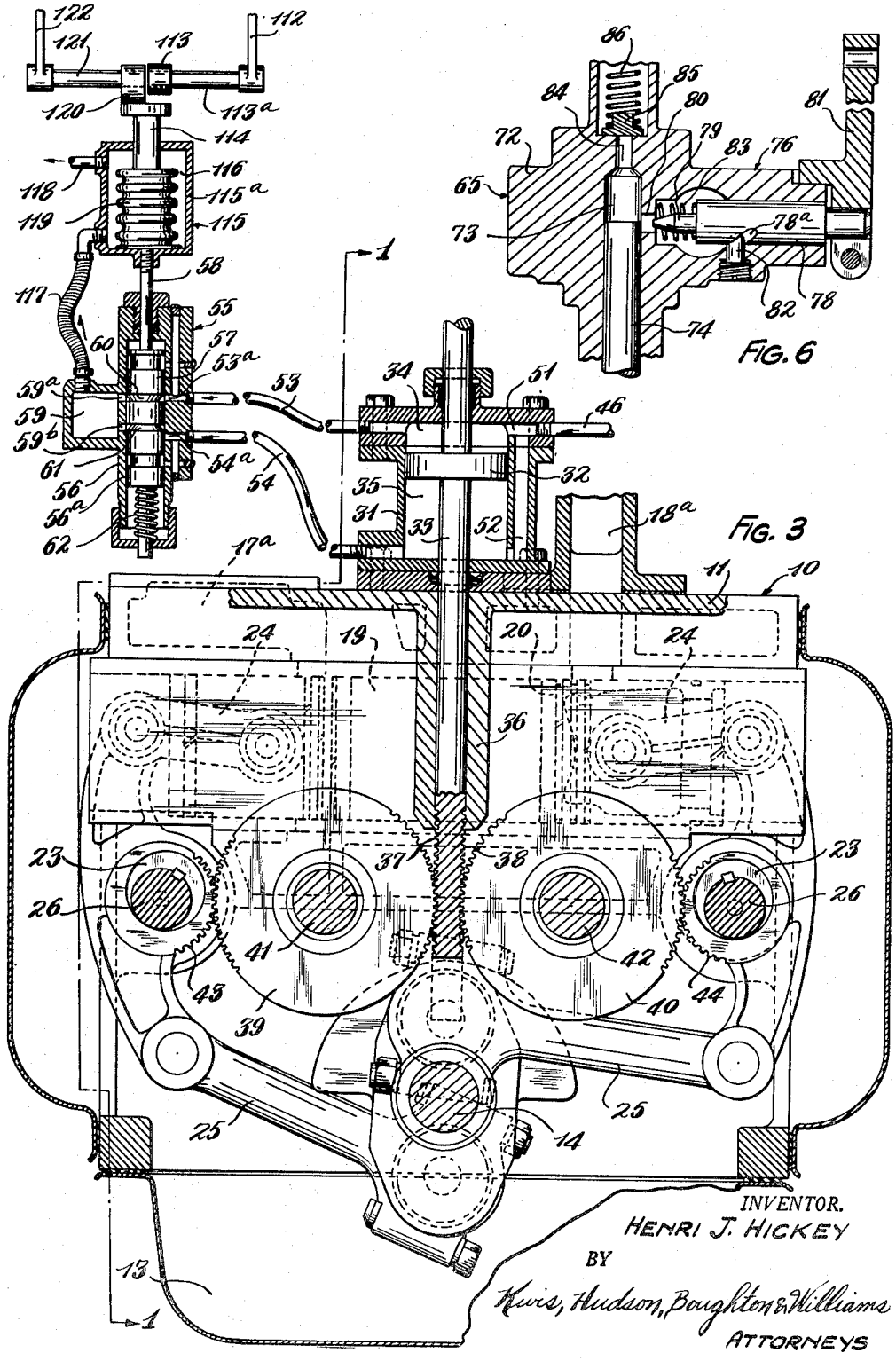


FIG. 3

FIG. 6

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Aug. 4, 1953 H. J. HICKEY 2,647,498

INTERNAL-COMBUSTION ENGINE

Filed June 17, 1947 4 Sheets-Sheet 4

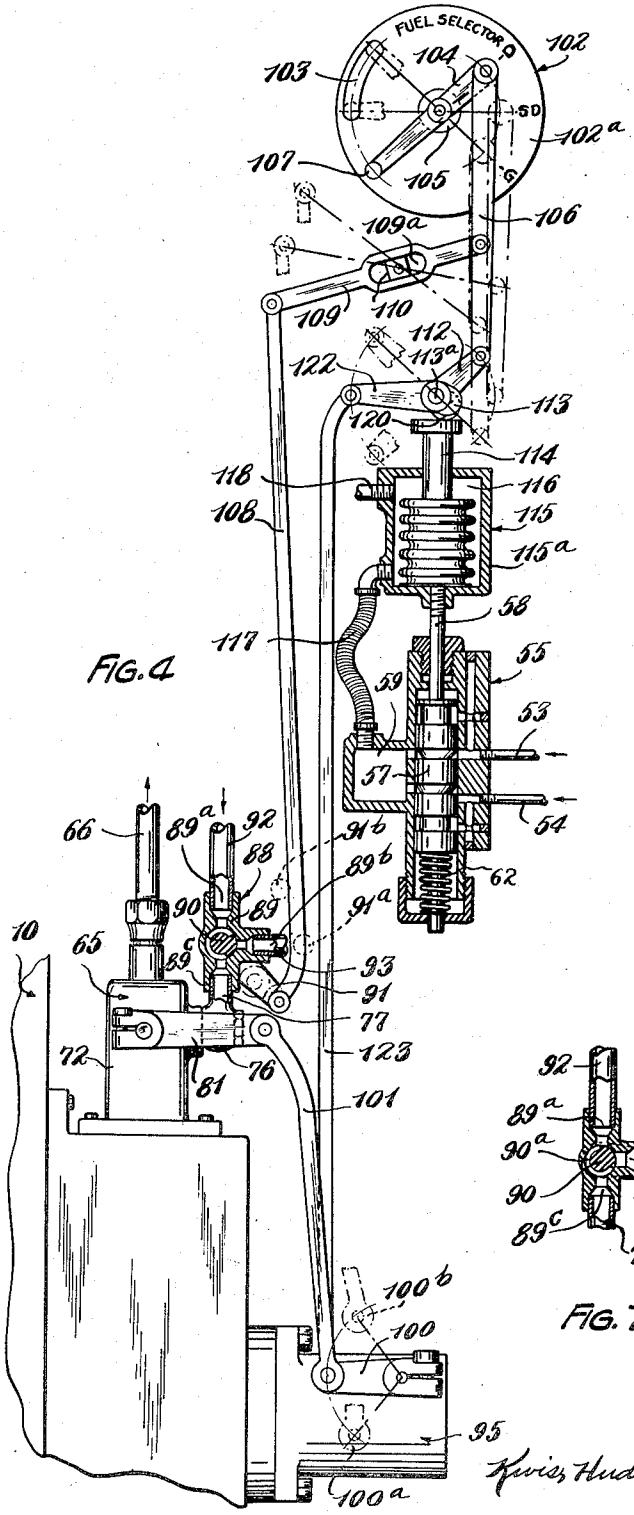


FIG. 4

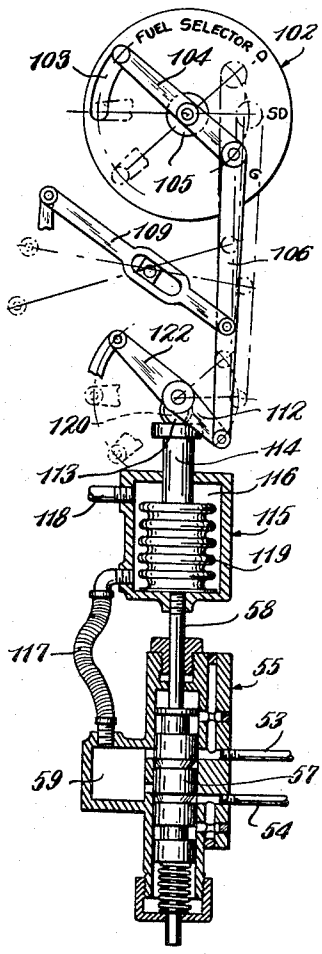


FIG. 5

FIG. 7

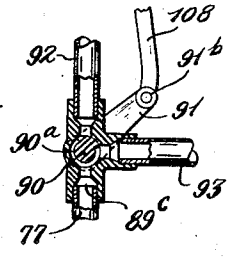


FIG. 8

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INTERNAL-COMBUSTION ENGINE

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Application June 17, 1947, Serial No. 755,166

9 Claims. (Cl. 123—48)

1

This invention relates to internal combustion engines of the variable compression type.

As is generally known by those skilled in this art, a diesel engine is a compression ignition engine, that is, an engine in which the heat of compression is used in igniting the fuel charge. In starting engines of this type, a relatively high compression ratio is needed in order to obtain the required ignition temperature but after the engine has been started any compression effected above that needed for ignition purposes represents wasted energy. In the improved engine herein disclosed the variable compression means permits the compression ratio to be varied while the engine is in operation, such that the compression ratio can be reduced after the engine has been started and a higher operating efficiency thus obtained.

When an engine of this type is started by using ordinary cranking methods and a high compression ratio, it places a heavy load on the starting equipment, and when this equipment is of the type embodying storage batteries, the results are frequently unsatisfactory, particularly in cold weather. In the improved engine herein disclosed, this difficulty is overcome by providing for the starting of the engine on a different type of fuel, such as gasoline, and the shifting to diesel fuel after the engine has been started.

Having in mind the above-mentioned general advantages, it can be said that one object of the present invention is to provide an improved variable compression engine in which novel means is employed for producing a desired variation in the compression ratio and in which the compression ratio can be varied while the engine is in operation so as to facilitate starting and also to improve the operating efficiency.

Another object is to provide an improved engine of this character in which the compression adjusting means is power actuated and in which novel control means is provided for the power actuated adjusting means.

A further object is to provide an improved engine having both a variable compression ratio means and a novel fuel supply means by which a shift can be made from one type of fuel to another such as from diesel fuel to gasoline and vice versa, whereby starting of the engine in cold weather conditions will be facilitated by the use of gasoline simultaneously with a low compression ratio.

Still another object of this invention is to provide an improved engine of this character in which the compression ratio adjusting means is

2

actuated by oil under pressure supplied from the crankcase of the engine.

Yet another object is to provide an improved engine of the character mentioned in which novel fuel selecting means is employed for effecting the above-mentioned shift from one type of fuel to another and in which the fuel selecting means controls the compression ratio varying means.

As another of its objects, this invention provides novel control means for the compression ratio varying means in which an operating condition of the engine, such as its temperature, is utilized for automatically producing a desired actuation of such control means.

Other objects and advantages of the invention are explained, or will become apparent, in the the following detailed specification and in the accompanying sheets of drawings in which:

Fig. 1 is a partial longitudinal sectional view taken through an internal combustion engine embodying the present invention, the view being taken substantially as indicated by line 1—1 of Fig. 3.

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

Fig. 3 is another transverse sectional view taken through the engine, substantially as indicated by line 3—3 of Fig. 1.

Fig. 4 is an elevational view, partly in section, showing the fuel selecting means and the control means for the compression ratio varying means.

Fig. 5 is an elongated view corresponding with a portion of Fig. 4 but showing the fuel selecting means and the control means in a different position.

Fig. 6 is a sectional detail view taken through the fuel pump and fuel inlet valve thereof, and Figs. 7 and 8 are sectional detail views showing other positions of the fuel selecting valve.

In the accompanying drawings the internal combustion engine 10 is shown as having a block or body 11 containing one or more main power cylinders 12 and also having a crankcase 13 which is adapted to contain lubricating oil. Although the engine may be constructed with any number of power cylinders, it is only necessary to refer to a single cylinder inasmuch as all of the cylinders are substantially identical and function in the same manner. The engine also includes a crankshaft 14 which is rotatably mounted in suitable bearings 15 and extends in a direction transverse to the longitudinal axis of the cylinder 12 and is offset from such axis. In

this instance the crankshaft 14 extends transversely to the cylinder at a point therebelow, as shown in the drawings.

The cylinder 12 is an open-ended cylinder having a combustion space or a chamber 16 in an intermediate portion thereof and also having inlet and exhaust ports 17 and 18 which extend through the cylinder wall and communicate with such combustion space. The ports 17 are air inlet ports leading from an air supply manifold 17a to which air under pressure is delivered by a suitable blower or air compressor (not shown). The exhaust ports lead into an exhaust manifold 18a. A pair of opposed power pistons 19 and 20 are operable in the cylinder and are connected with the crankshaft 14 by linkage which will now be described and which linkage is substantially identical for both pistons.

The power transmitting linkage for each of the pistons includes a rocking lever 22 which is journaled at an intermediate point thereof on a fulcrum member 23. The lever 22 has its upper end connected with the piston by means of a link 24 and its lower end connected with a crank of the crankshaft 14 by means of the connecting rod 25. The fulcrum member 23 is here shown as being an eccentric carried by a fulcrum adjusting shaft 26 which is rockably mounted in suitable bearings 27 of the engine block 11. By rocking of the shaft 26, the fulcrums 23 can be arcuately adjusted and when this is done the working travel of the pistons 19 and 20 is altered and this produces a change in the compression ratio of the engine. When the fulcrums 23 are in the position shown in Fig. 2, the pistons 19 and 20 have a working travel which brings them relatively close together thereby producing a relatively high compression ratio in the engine. When the fulcrums 23 are shifted arcuately in a direction away from each other, as seen in Fig. 2, the working travel of the pistons 19 and 20 will be such that the limit of their inward movement is represented by the broken lines 28, at which time the engine will have a relatively low compression ratio.

As indicated above, one of the features of this improved engine is that power means is provided for shifting the fulcrums 3 and thus producing the desired change in the compression ratio. This power means includes an auxiliary cylinder 31 which is mounted on the engine block 11 and an adjusting piston 32 operable in such cylinder. The piston 32 is mounted on a piston rod 33 which extends axially through the cylinder 31, and the piston divides the cylinder into upper and lower chambers 34 and 35. The piston rod 33 extends downwardly from the cylinder 31 through a hollow guide 36 of the engine block and the lower end of the piston rod has rack elements 37 and 38 on opposite sides thereof which are in meshing engagement with a pair of idler gears 39 and 40. These idler gears are mounted on pivot shafts 41 and 42 and mesh with pinions 43 and 44 which are carried by and secured to the fulcrum shafts 26.

With the construction just described above for the compression ratio adjusting means, it will be seen that if pressure fluid, such as oil, is supplied to the upper chamber 34 of the auxiliary cylinder 31 so as to produce an increase of pressure therein, it will cause a downward movement of the piston 32 and a corresponding downward movement of the racks 37 and 38. This will cause the gears 39 and 40 to rotate the fulcrum shafts 26 in an outward direction thereby shifting the fulcrums 23 away from each other and decreasing the compression ratio of the engine. Conversely, when the pressure in the lower chamber 35 of the auxiliary cylinder 31 is increased, it will cause an upward movement of the piston 32 and the racks 37 and 38 will thereupon rotate the gears 39 and 40 in a direction to shift the fulcrums 23 towards each other thereby increasing the compression ratio of the engine.

The pressure fluid for actuating the adjusting piston 32 of the auxiliary cylinder 31 may be oil which is supplied to this cylinder from the crankcase 13 of the engine through the conduit 46. A suitable pump 47 may be located in or adjacent the crankcase 13 and has its delivery outlet 47a connected with the conduit 46. The pump here shown is a pump of the gear type and is driven from the crankshaft 14 of the engine through a suitable gear train which includes the helical gears 48 and 49. The pump also has an intake or suction connection 50 extending into a sump or recess 13a of the crankcase. Although the pump 47 is here shown as being driven from the engine 10 it could, of course, be driven from a separate power device such as an electric motor.

The oil pressure supply conduit 46 communicates with the upper chamber 34 of the auxiliary cylinder 31 through a passage 51 and communicates with the lower chamber 35 through a passage 52. The passages 51 and 52 are in open communication with the cylinder 31 so that when the pump 47 is being driven, oil will be supplied continuously to the upper and lower chambers 34 and 35. Oil is discharged from the chambers 34 and 35 through the exhaust conduits 53 and 54 and actuation of the adjusting piston 32 in the cylinder 31 by the oil pressure is controlled by a control valve device 55 which will be described next.

The control valve device 55 comprises a housing 56 having a cylindrical valve chamber 56a therein and a piston valve 57 which is axially shiftable in the chamber 56a by means of the actuating rod 58. The wall of the valve chamber 56a has a pair of axially spaced inlet ports 53a and 54a by which the exhaust conduits 53 and 54 are connected with this chamber. At a point substantially opposite the ports 53a and 54a, the wall of the valve chamber 56a is provided with outlet ports 59a and 59b which communicate with an exhaust chamber 59. The outlet ports 59a and 59b are spaced somewhat closer together than the inlet ports 53a and 54a for a purpose which will be presently apparent. The valve member 57 has a pair of axially spaced metering grooves 60 and 61 thereon which have substantially the same axial spacing as the outlet ports 59a and 59b. A compression spring 62 located in the valve housing 56 below the valve member 57 acts on the latter tending to urge the valve member in an upward direction to the position in which it is shown in Fig. 3.

When the valve member 57 is in the position shown in Fig. 3, the metering groove 60 connects the ports 53a and 59a of the valve chamber and provides full communication therebetween. At this time the metering groove 61 is in communication with the outlet port 59b but is out of register with the port 54a, the latter being closed by the body of the valve member. When the valve member 57 is in the position just explained, a portion of the oil pressure supplied to the cylinder 31 through the conduit 46 passes freely through the upper chamber 34, but since the port

54a is closed, a working pressure will be built up in the lower chamber 35 for actuating the piston 32 in an upward direction. When the valve member 57 is moved downwardly so as to close the port 53a and open the port 54a, the pressure condition in the cylinder 31 is reversed, that is to say, pressure is built up in the upper chamber 34 while the lower chamber 35 is vented, thereby causing a downward movement of the piston 32.

When the valve member 57 is moved to a position in which the metering grooves 60 and 61 register partially with both pairs of ports 53a, 54a and 59a, 59b, oil pressure will be built up in both of the chambers 34 and 35 of the auxiliary cylinder 31 in such a manner that the piston 32 will be shifted and held in an intermediate position of the cylinder. The piston 32 can be made to move in either direction from this intermediate position by shifting of the valve member 57 in the proper direction. In connection with the actuation of the auxiliary cylinder 31 and the control valve device 55, as just described above, it will be understood of course that the oil delivered by the pump 47 will have adequate pressure and will be of sufficient volume to produce the desired actuation of the piston 32. It should also be mentioned at this point that the oil delivered by the pump 47 will have a temperature corresponding substantially with the operating temperature of the engine 10.

Attention will now be directed to the means for supplying fuel to the cylinder 12 of the engine 10. As shown in Fig. 2, the cylinder 12 is provided with a fuel injection device 64 which may be of any suitable construction and which is located in an opening 64a of the cylinder wall so as to be in communication with the combustion space 16 at all times regardless of whether the engine is adjusted for either a high or low compression ratio. Fuel is supplied to the injector 64 from a fuel pump 65 through a main fuel delivery conduit 66 and a branch conduit 67. The fuel thus supplied will be either diesel oil or gasoline, depending upon the conditions under which the engine is to be started and the fuel which has been selected by the operator.

The engine 10 is preferably also provided with a second fuel injection device 68 to which fuel can be supplied from the pump 65 through the main fuel delivery conduit 66 and the branch conduit 69. The injector 68 is intended for use during operation of the engine as a semi-diesel engine and the fuel supplied to this injector for this purpose is a diesel fuel. The branch conduits 67 and 69 are provided, respectively, with control valves 67a and 69a by which either of the injectors 64 and 68 can be selected for use. Instead of providing the valves 67a and 69a, the unused injector could be removed entirely from the engine and the cylinder opening closed by a suitable plug.

Ignition of the charge in the combustion space 16 is obtained either by the high compression heating effect which is produced during operation of the engine as a diesel engine or by means of a conventional spark plug 70, or the like, when the engine is being operated as a semi-diesel engine or when the fuel being used is gasoline. The spark plug 70 is located in a cylinder opening which is continuously in communication with the combustion space 16. A suitable ignition circuit (not shown) is provided for supplying high tension current to the spark plug 70.

In connection with the semi-diesel injector 68, it should be explained that this injector is located in spaced relation to the injector 64 and at a point such that the opening provided in the cylinder wall for the injector 68 will be intermittently covered and uncovered by the piston 19. When the engine is operated as a semi-diesel engine, combustion air under pressure is supplied to the cylinder through the air inlet ports 17 and a quantity of fuel is sprayed into the cylinder by the injector 68. The selection of this location for the injector produces the effect of changing the timing of the fuel injection so as to occur several degrees ahead of dead center. During the compression stroke of the pistons 19 and 20 great turbulence will be created in the cylinder and this will cause a thorough mixing of the fuel from the injector 68 with the combustion air. During the inward travel of the piston 19, this piston covers the cylinder opening for the injector 68 such that this injector will be protected by the piston during the time that combustion of the fuel mixture is taking place. In addition to the advantage of the increased turbulence and more thorough mixing of the fuel charge, this location for the injector 68 has the additional advantage that it will be protected during the combustion of the charge and is less likely to become clogged with carbon, or other such material resulting from the combustion of the fuel. This location also permits an injector of lower pressure characteristic to be used.

The fuel pump 65 can be of any conventional construction and as here shown includes a housing 72 having a pump cylinder 73 therein and a plunger 74 which is reciprocable in the cylinder and is actuated by a rotating cam 75. The cam 75 is carried by a shaft which is driven from the crankshaft by the helical gears 75a and 75b. The fuel pump 65 also includes an inlet valve device 76 to which liquid fuel is supplied through the inlet connection 77.

The inlet valve device 76 can also be referred to as a governor valve and, as shown in Fig. 6, includes a rotatable and axially movable stem 78 carrying a valve member or metering pin 79 for restricting or closing the fuel intake passage 80 of the pump cylinder 73. The stem 78 has an actuating lever 81 connected therewith such that swinging of the lever causes rotation of the stem.

Variation in the size of the intake passage 80 is produced by axial shifting of the valve member or metering pin 79 and this is produced by the action of an abutment pin 82 which engages in a helical slot 78a of the stem 78. When the lever 81 is swung in one direction the slot 78a cooperates with the abutment pin 82 to cause outward or opening movement of the metering pin 79 to increase the opening of the intake passage 80 and swinging of the lever in the opposite direction will cause the slot to cooperate with the abutment pin to cause inward or closing movement of the metering pin. A compression spring 83 acts on the stem 78 to urge the same in a direction corresponding with an opening movement of the metering pin 79. The delivery of fuel under pressure from the pump 65 takes place through the discharge opening 84 and past a check valve member 85 which is urged towards its closed position by the compression spring 86.

To provide for the shifting from diesel fuel to gasoline or vice versa, a fuel selecting valve 88 is provided and is here shown as being a three-way valve comprising a housing or body 89 and a plug or rotor 90 operable therein. The valve body 89 has two inlet connections 89a and 89b and a single outlet connection 89c. The valve plug

90 has a fluid passage 90a therein and is adapted to be shifted by means of the lever 91. A supply tank or other suitable source of diesel fuel is connected with the inlet 89a by the conduit 92. A tank or other source of gasoline is connected with the inlet 89b by means of the conduit 93. The outlet 89c of the selector valve 88 is connected directly with the inlet passage 77 of the fuel pump 65.

When the plug 90 of the fuel selector valve 88 is in the position shown in Fig. 4, the gasoline supply connection 89b is closed and the diesel fuel supply connection 89a is in open communication with the outlet 89c and diesel fuel will then be supplied to the intake of the pump 65. This is the setting of the selector valve 88 for the delivery of diesel fuel to the injector 64 by the fuel pump. When the lever 91 is shifted to the intermediate position 91a (see Fig. 7), the gasoline connection 89b will still be closed by the plug 90 but the diesel fuel supply connection 89a will be only partially closed and will therefore remain in communication with the outlet 89c. This is the setting of the fuel selector valve 88 which corresponds with the operation of the engine as a semi-diesel engine and provides for the supply of diesel fuel to the pump 65 and the injector 68 for the semi-diesel operation. When the lever 91 is shifted to the position indicated at 91b (see Fig. 8), the plug 90 of the fuel selector valve 88 will be in a position closing the diesel fuel supply connection 89a but the gasoline supply connection 89b will then be open so that gasoline will be supplied to the pump 65 for delivery to the injector 64. This is the setting of the fuel selector valve 88 for starting of the engine on gasoline.

The inlet valve 76 which controls the supply of fuel to the pump 65 is actuated automatically and for this purpose a governor device 95 of a conventional form may be provided. The governor 95 as here shown is of the type having centrifugally responsive fly-weights 96 and is driven from the crankshaft 14 of the engine by means of the auxiliary extension shaft 97. The governor device may also include a compression spring 98 and an axially movable head or yoke 99 which is shiftable in response to the actions of the fly-weights 96 and the compression spring and imparts swinging movement to an external lever 100. This lever is connected with the lever 81 of the fuel inlet valve 76 by means of the link 101. The lever 100 is movable from a position 100a representing a stopped condition of the engine to a position 100b which represents a normal running condition of the engine.

As indicated at the beginning of this specification, the fuel supply means includes selector means by which the operator can exercise a selecting or pre-selecting action with respect to the type of fuel to be supplied to the engine and with respect to the compression ratio at which the engine is to operate. For this purpose a fuel selecting device 102 is provided. This selecting device includes a stationary disk member 102a having an elongated arcuate electric contact 103 mounted thereon in insulated relation. This selecting device also includes a rockable lever 104 and a knob or handle 105 which is connected with this lever and adapted to be grasped by the operator for imparting swinging movement to the lever. One end of the lever 104 is pivotally connected with a link 106 and the other end carries an electric contact 107 which is insulated from the lever and is engageable with the stationary contact 103. The contacts 103 and 107 constitute an ignition switch by which the energizing circuit for the spark plug 70 can be closed.

As shown in Fig. 4, the link 106 is connected with the lever 91 of the fuel selector valve 88 by means of the link 108 and a rocking lever 109. The lever 109 can be fulcrumed in any suitable manner such as by being provided with a slot 109a which is slidable on a pivotally mounted block 110. With the arrangement just described it will be seen that when the lever 104 is swung to the position shown in Fig. 4 in which it points toward the diesel position D, the link 108 will be shifted downwardly so as to move the arm 91 of the fuel selector valve 88 to the position in which the diesel fuel supply connection 89a will be in communication with the inlet 77 of the fuel pump 65. On the other hand when the lever 104 is swung to the position pointing to the gasoline supply position G, the link 108 will lift the arm 91 of the fuel selector valve 88 to the position 91b in which gasoline will be supplied to the fuel pump 65. When the arm 104 is in the intermediate position pointing to the semi-diesel position SD, the arm 91 of the fuel selector valve will be in the position 91a at which time diesel fuel will be supplied to the pump 65.

The fuel selector device 102 is also operably connected with the valve member 57 of the control valve device 55 which controls the auxiliary cylinder 31 of the compression varying means. For this purpose the lower end of the link 106 is pivotally connected with a lever 112 which is connected with a rock shaft 113a carrying an abutment cam 113. The cam 113 cooperates with the head of a cam follower 114 which projects from a temperature responsive device 115.

The device 115 forms an operating connection between the cam 113 and the valve member 57 of the control valve device 55 and is connected with the valve member 57 by the above-mentioned rod 58. The device 115 comprises a casing 115a having a chamber 116 therein to which oil is supplied from the exhaust chamber 59 of the control valve device 55 through a flexible conduit 117. Suitable mounting means (not shown) is provided for the device 115 which permits this device to be shifted bodily in a substantially vertical direction relative to the control valve device 55. The oil which is supplied to the chamber 116 flows therethrough and is returned to the crankcase 13 of the engine by the conduit 118. The device 115 also includes a heat sensitive element 119 which is located in the chamber 116 and which expands when the temperature of the oil flowing through the chamber is such as to heat this element. The cam follower 114 is connected with the heat sensitive element 119 and is projected or retracted relative to the casing 115 in response to the expansion or contraction of this element. Such projecting and retracting of the cam follower 114 causes a corresponding increase or decrease in the overall length of the temperature responsive device 115.

The operating connection between the selector device 102 and the control valve device 55 is also formed, in part, by a second abutment cam 120 which is located in complemental adjacent relation to the cam 113. The cam 120 is carried by a rock shaft 121, as shown in Fig. 3, and a lever 122 mounted on this shaft is connected with the lever 100 of the governor 95 by means of the link 123.

To explain the operation of the improved engine, let it be assumed that the engine is stopped and in a cold condition and that the lever 104 of

the selector device 102 is in its full line position, as shown in Fig. 4. To facilitate the starting of the engine while in such cold condition, it is desirable to use gasoline as the starting fuel together with spark ignition afforded by the spark plug 70. To accomplish this the operator rotates the knob 105 to shift the lever 104 downwardly to the position pointing to the gasoline setting G. This causes the fuel selector valve 88 to be shifted to the gasoline setting, as explained above, and also causes the cam 113 to be shifted to its down position, as shown in Fig. 5. Since the engine is stopped, the lever 100 of the governor 95 is in the stop position 100a and the cam 120 at this time is in its elevated position. The movement of the cam 113 to the position shown in Fig. 5 causes this cam to push the cam follower 114 and the temperature responsive device 115 bodily downwardly thereby shifting the valve member 57 in the casing of the control valve device 55 to the position shown in Fig. 5 in which the outlet from the upper chamber 34 of the auxiliary cylinder 31 is closed.

The operator now causes the engine 10 to be cranked by operating the cranking device (not shown) which imparts rotation to the crankshaft 14. The rotation of the crankshaft causes the oil pump 47 to be driven and to supply oil under pressure to the auxiliary cylinder 31. Since the outlet of the upper chamber 34 of the auxiliary cylinder is now closed, the piston 32 will be moved downwardly to thereby adjust the engine to the low compression ratio. The shifting of the lever 104 of the selector device 102 to the gasoline position also causes the contact 107 to engage the contact 103 thereby closing the energizing circuit for the spark plug 70. The rotation of the crankshaft 14 by the cranking device also causes the governor 95 to be actuated sufficiently to transmit motion through the link 101 to the arm 81 of the fuel inlet valve 76 thereby opening this valve and enabling the fuel pump 65 to supply gasoline to the injector 64. The actuation of the governor 95 also causes motion to be transmitted through the link 123 to the lever 122 thereby moving the cam 120 toward its down position. The occurrence of the functions just described results in the engine being adjusted to the low compression ratio and in the engine being started on gasoline.

The engine is permitted to run on gasoline for a short period whereupon the operator shifts the lever 104 of the selector device 102 back to its full line position pointing to the diesel setting D, as shown in Fig. 4. This movement of the lever 104 dis-engages the contact 107 from the contact 103 to de-energize the ignition circuit and also causes the lever 112 to be swung in a direction to shift the cam 113 to its elevated position shown in Fig. 4. The movement of the lever 104 to its full line position of Fig. 4 also causes the lever 91 of the fuel selector valve 88 to be shifted to the position 91b in which diesel fuel will be supplied to the pump 65 instead of gasoline. Since the engine is at this time still running at a relatively low starting speed, the cam 120 will be held in a relatively elevated position by the governor 95, as shown in Fig. 4. Both of the cams 113 and 120 now being in the elevated position, the spring 62 of the control valve device 55 will shift the valve member 57 to its upper position shown in Fig. 4 and this will cause the auxiliary cylinder 31 to charge the engine setting to a high compression ratio. It should perhaps be mentioned at this point that when the cams 113 and 120 are shifted to the down position they are more effective as an abutment means against which the cam follower 114 reacts than when they are in the elevated position.

The shifting of the fuel selector valve 88 to the diesel setting, as just described, results in diesel fuel being supplied to the injector 64 by the pump 65 and the engine then continues to run on diesel fuel instead of gasoline and with a high compression ratio. As the temperature of the engine increases towards its normal running temperature, the temperature of the lubricating oil in the crankcase 13 will be increased correspondingly. The heated oil flowing through the control valve device 55 and the chamber 116 of the temperature responsive device 115 will cause heating of the element 119 and the resulting expansion of this element will react through the cam follower 114 against the cams 113 and 120 thereby pushing the valve member 57 downwardly and causing a corresponding downward movement of the adjusting piston 32 in the auxiliary cylinder 31. As explained above, such downward movement of the adjusting piston 32 causes the compression ratio of the engine to be decreased.

In this way the compression ratio of the engine will be decreased automatically after the engine has been started on gasoline and has been shifted to diesel fuel and has reached its normal operating temperature. This automatic shifting to the low compression ratio during the diesel operation is an important feature because it results in a much more economical operation of the engine. To fully appreciate the importance of this feature it is pointed out that during ordinary high compression operation of a diesel engine a substantial portion of the developed horsepower is used in producing the high compression, and since the compression effected after the initial starting of the engine is usually higher than is needed for ignition purposes, much of the horsepower thus used represents wasted energy. This invention therefore materially increases the horsepower output per cubic inch of piston displacement in comparison with engines of conventional types using diesel or gasoline fuels. This feature also provides the advantages of increased volume of the combustion chamber, creating better turbulence and burning, and increasing the thermal efficiency.

If an occasion arises for stopping the engine and the operator wishes to re-start it while still in a warmed up condition, the starting can be accomplished on diesel fuel and with the engine adjusted for the high compression ratio. Since the lever 104 of the selector device 102 would ordinarily be in the position pointing to the diesel setting D at this time, it will only be necessary for the operator to cause the necessary cranking of the engine to take place in order to cause the engine to be re-started on diesel fuel.

If the operator should wish to run the engine as a semi-diesel engine, that is to say on diesel fuel and with spark ignition afforded by the spark plug 70, he shifts the lever 104 of the selector device 102 to the position pointing to the semi-diesel setting SD. This causes diesel fuel to be supplied by the pump 65 and causes the contact 107 to engage the contact 103 for energizing the ignition circuit. At this time the valve 67a controlling the injector 64 is closed and the valve 69a controlling the injector 68 is opened. Assuming that the engine has previously been operating at the diesel setting, it will now change over to the semi-diesel operation and this will continue as

long as the lever 104 remains at the semi-diesel setting.

From the foregoing description and the accompanying drawings, it will now be understood that the present invention provides an improved internal combustion engine of the variable compression type and one in which the compression ratio can be varied by means of a power device and in accordance with different settings of a manually operable selector device. It will also be seen that the novel control apparatus which is provided for controlling the compression ratio adjusting means will cause the compression ratio to be decreased to a desired lower value after the engine has been started and has reached a warmed up condition. Furthermore, it will also be seen that the novel control and fuel supply apparatus provides for starting of the engine on gasoline fuel and with a low compression ratio that this materially reduces the load placed on the cranking device. Additionally, it will be seen that this invention provides for operation of the engine as a semi-diesel engine when this is desired by the operator.

Although the improved engine has been disclosed herein to a detailed extent, it should be understood that the invention is not intended to be limited correspondingly in scope 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 main 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 said main cylinder and offset therefrom, a pair of opposed power pistons reciprocable in said cylinder, fulcrums located adjacent said open ends, power transmitting linkage connecting said power pistons with said crankshaft including levers adapted to oscillate on said fulcrums, said fulcrums being arcuately shiftable for altering the travel of said power pistons in said main cylinder so as to vary the compression ratio of the engine, means for imparting such arcuate shifting to said fulcrums including a pair of gear members having toothed portions spaced apart, an auxiliary cylinder having an adjusting piston movable therein, means for supplying pressure fluid to said auxiliary cylinder, and a rack connected with said adjusting piston to be actuated thereby and having meshing engagement with the spaced apart toothed portions of said gear members.

2. In an internal combustion engine, a main 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 said main cylinder and offset therefrom, a pair of opposed power pistons reciprocable in said cylinder, fulcrums located adjacent said open ends, power transmitting linkage connecting said power pistons with said crankshaft including levers adapted to oscillate on said fulcrums, said fulcrums being arcuately shiftable for altering the travel of said power pistons in said main cylinder so as to vary the compression ratio of the engine, means for imparting such arcuate shifting to said fulcrums including a pair of gear members having toothed portions spaced apart, an auxiliary cylinder having an adjusting piston movable therein, means for supplying pressure fluid to said auxiliary cylinder, a rack connected with said adjusting piston to be actuated thereby and having meshing engagement with the spaced apart toothed portions of said gear members, and selector mechanism including a valve operable to control the actuation of said adjusting piston by the pressure fluid.

3. In an internal combustion engine, a main cylinder having open ends and a combustion space in an intermediate portion thereof, a crankcase adapted to contain oil, a crankshaft rotatable about an axis extending transversely to the axis of said main cylinder and offset therefrom, a pair of opposed power pistons reciprocable in said cylinder, fulcrums located adjacent said open ends, power transmitting linkage connecting said power pistons with said crankshaft including levers adapted to oscillate on said fulcrums, said fulcrums being arcuately shiftable for altering the travel of said power pistons in said main cylinder so as to vary the compression ratio of the engine, means for imparting such arcuate shifting to said fulcrums including a pair of gear members having toothed portions spaced apart, a double acting auxiliary cylinder having an adjusting piston reciprocable therein, a pump operable to supply oil under pressure to said auxiliary cylinder from said crankcase for producing working strokes of the adjusting piston in opposite directions, and a rack connected with said adjusting piston to be actuated thereby and having meshing engagement with the spaced apart toothed portions of said gear members.

4. In an internal combustion engine, a main cylinder, a crankcase adapted to contain lubricating oil, a power piston reciprocable in said main cylinder, power transmitting linkage connecting said power piston with said crankshaft, fulcrum means cooperating with said linkage and being arcuately adjustable for altering the piston travel in said main cylinder so as to vary the compression ratio of the engine, gear elements connected with said fulcrums, a pair of gear members meshing with said gear elements and rotatable about axes located intermediate said fulcrums, said gear members having toothed portions thereof disposed in spaced apart substantially opposed relation, an auxiliary cylinder having an adjusting piston movable therein, an oil pump operable to supply oil under pressure to said auxiliary cylinder from said crankcase, a rack connected with said adjusting piston to be actuated thereby and having meshing engagement with the spaced apart toothed portions of said gear members, a valve controlling the actuation of said adjusting piston by the oil from said pump and being shiftable from a position corresponding with a low compression ratio for the engine to a position corresponding with a high compression ratio, and manually operable selector means cooperating with said valve and being movable to positions corresponding with such low and high compression ratios.

5. In an internal combustion engine, a main cylinder, a crankcase adapted to contain lubricating oil, a power piston reciprocable in said main cylinder, means operable to vary the compression ratio of the engine including an auxiliary cylinder having an adjusting piston movable therein, an oil pump operable to supply oil under pressure to said auxiliary cylinder from said crankcase, an oil control valve controlling the actuation of said adjusting piston by the oil from said oil pump and having a control valve member which is shiftable from a position corresponding with a low compression ratio for the engine to a position corresponding with a high compression ratio, temperature responsive means

adapted to cause shifting of said control valve member in response to a predetermined change in the temperature of said oil, abutment means with which said control valve member cooperates and being movable to different positions for varying the effectiveness of said temperature responsive means, and manually operable selector means for moving said abutment means to said different positions.

6. In an internal combustion engine, a main cylinder, a power piston reciprocable therein, means operable to vary the compression ratio of the engine including an auxiliary cylinder having an adjusting piston operable therein, means for supplying liquid under pressure to said auxiliary cylinder for actuating said adjusting piston, a control valve for controlling the operation of said adjusting piston by the pressure liquid and including a movable valve member, cam means adapted to be selectively positioned, means cooperating with said cam means so as to react thereagainst and having operative connection with said valve member for automatically imparting movement to the latter, and means for causing the selective positioning of said cam means.

7. In an internal combustion engine, a main cylinder, a power piston reciprocable therein, means operable to vary the compression ratio of the engine including an auxiliary cylinder having an adjusting piston operable therein, means for supplying liquid under pressure to said auxiliary cylinder for actuating said adjusting piston, a control valve for controlling the operation of said adjusting piston by the pressure liquid and including a movable valve member, cam means adapted to be selectively positioned and comprising a pair of complemental cam elements, means cooperating with said cam means so as to react thereagainst and having operative connection with said valve means for automatically imparting movement to the latter, manually operable means connected with one of said cam elements for selectively positioning the same, and means responsive to a variable operating function of the engine for automatically selectively positioning the other of said cam elements.

8. In an internal combustion engine, a main 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 said main cylinder and offset therefrom, a pair of opposed power pistons reciprocable in said cylinder, fulcrums located adjacent said open ends, power transmitting linkage connecting said power pistons with said crankshaft including levers adapted to oscillate on said fulcrums, said fulcrums being arcuately shiftable for altering the travel of said power pistons in said main cylinder so as to vary the compression ratio of the engine, gear elements connected with said fulcrums, a pair of gear members meshing with said gear elements and rotatable about axes located intermediate said fulcrums, said gear members having toothed portions thereof disposed in spaced apart substantially opposed relation, an auxiliary cylinder having an adjusting piston movable therein, means for supplying pressure fluid to said auxiliary cylinder, and a rack connected with said adjusting piston to be actuated thereby and having meshing engagement with the spaced apart toothed portions of said gear members.

9. In an internal combustion engine, a main 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 said main cylinder and offset therefrom, a pair of opposed power pistons reciprocable in said cylinder, fulcrums located adjacent said open ends, power transmitting linkage connecting said power pistons with said crankshaft including levers adapted to oscillate on said fulcrums, said fulcrums being arcuately shiftable for altering the travel of said power pistons in said main cylinder so as to vary the compression ratio of the engine, gear elements connected with said fulcrums, a pair of gear members rotatable about axes located intermediate said fulcrums and lying substantially in a common plane which includes the axes of said fulcrums, said gear members having the toothed portion on the remote sides thereof in meshed engagement with the gear elements of said fulcrums and the toothed portion on their adjacent sides in spaced apart substantially opposed relation, an auxiliary cylinder having an adjusting piston movable therein, means for supplying pressure fluid to said auxiliary cylinder, and a rack connected with said adjusting piston to be actuated thereby and having meshing engagement with the spaced apart toothed portions of said gear members, the points of meshed engagement of said gear members with said gear elements and rack also lying substantially in said common plane.

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