July 6, 1948. E. GRIESHABER ET AL 2,444,440

INTERNAL-COMBUSTION ENGINE

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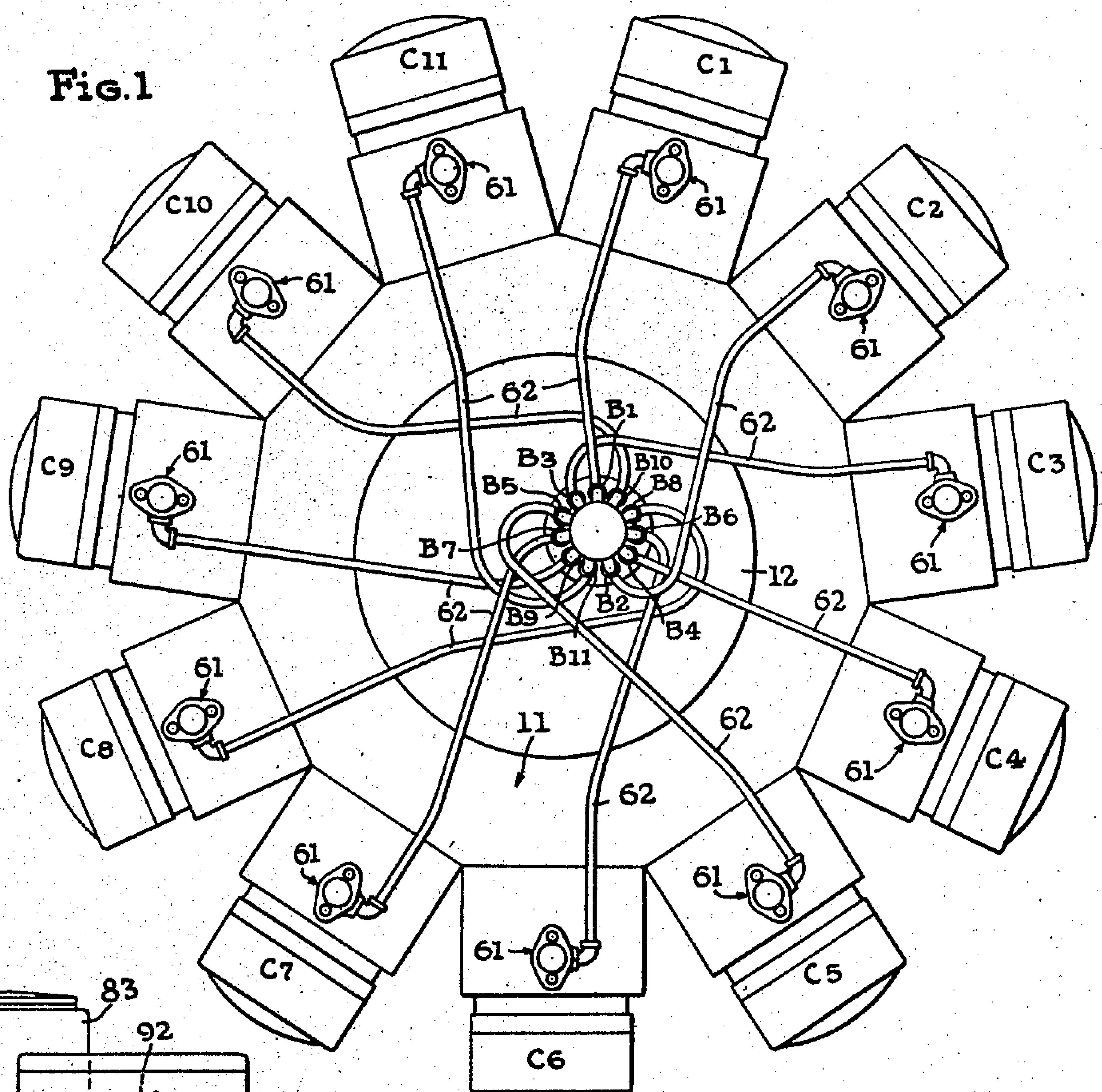
Fig.1



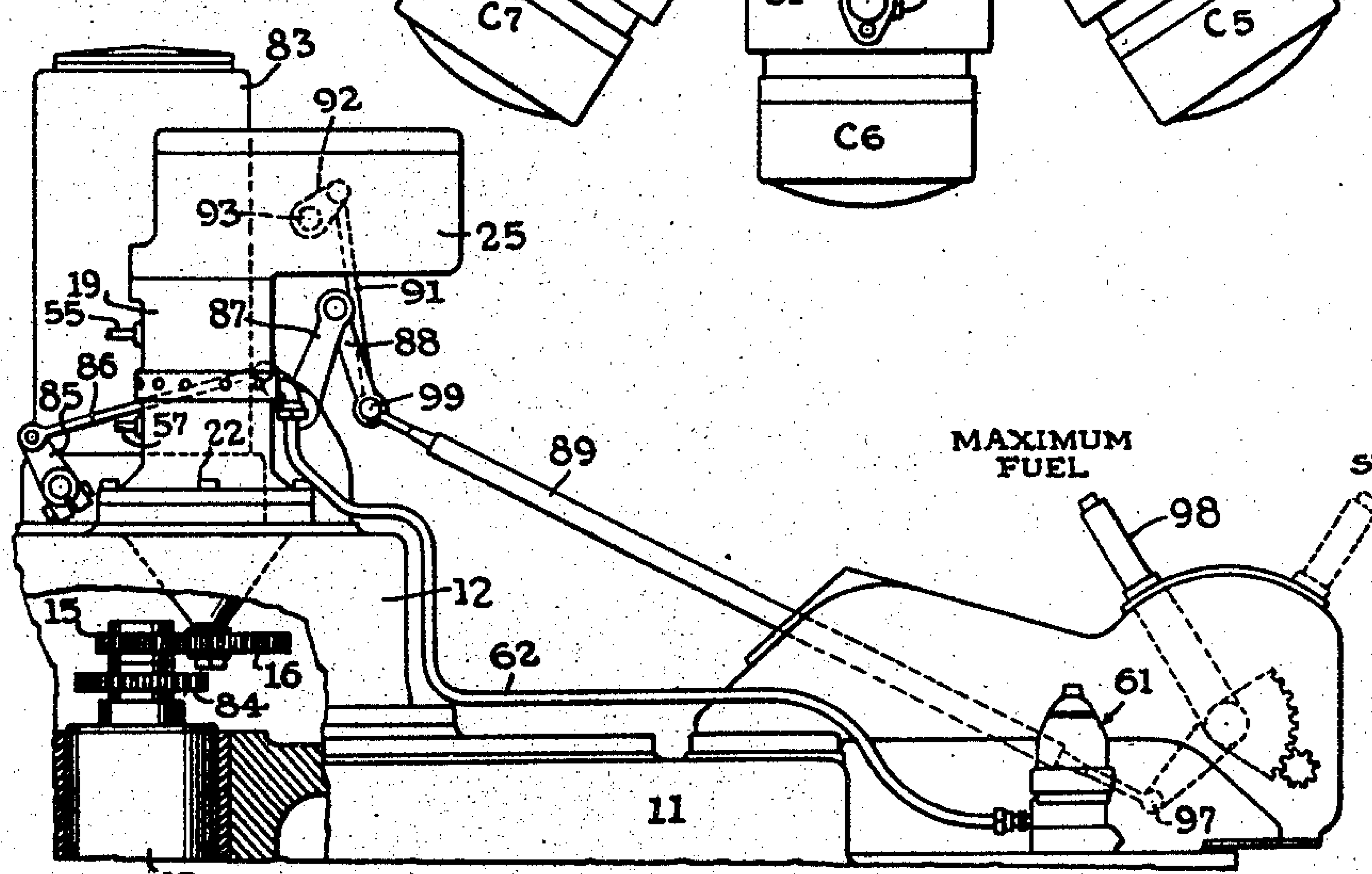


Fig.2

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INTERNAL-COMBUSTION ENGINE

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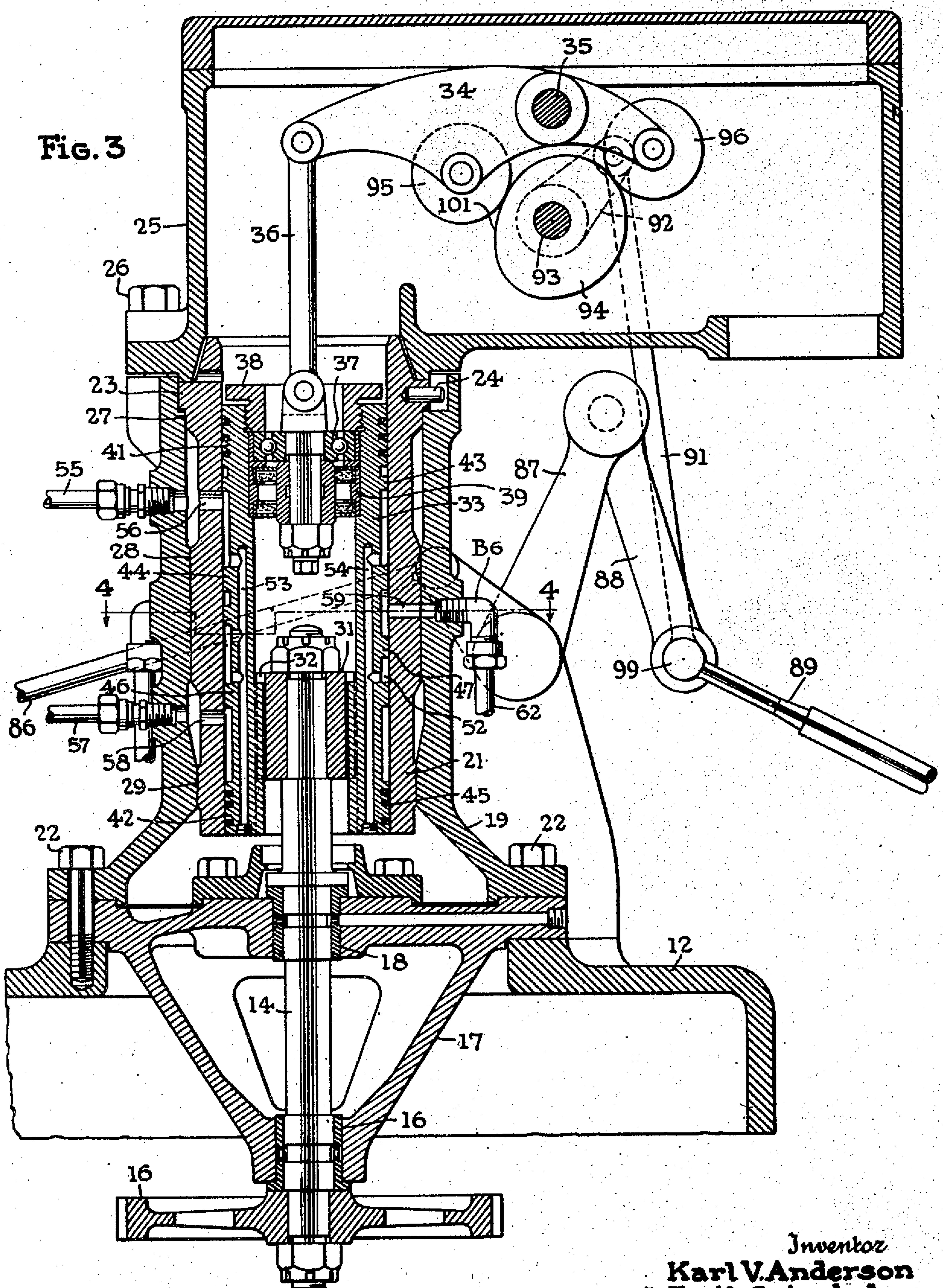
Fig. 3



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INTERNAL-COMBUSTION ENGINE

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Fig. 5

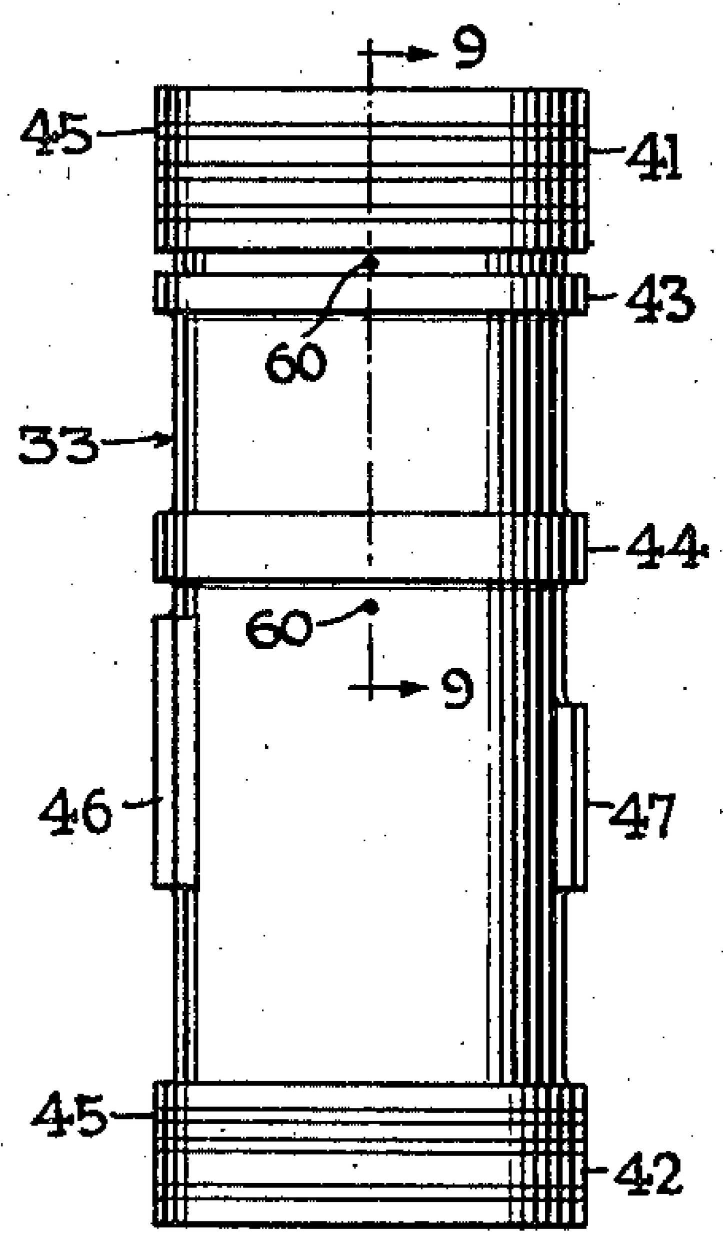


Fig. 6

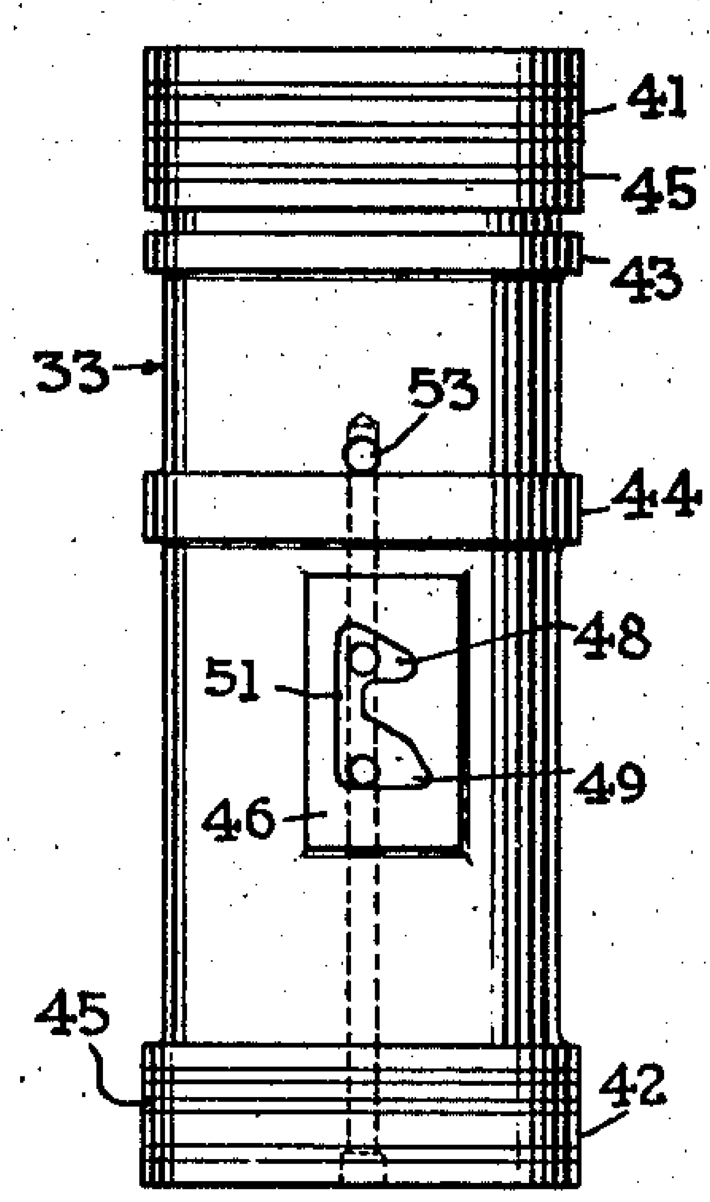
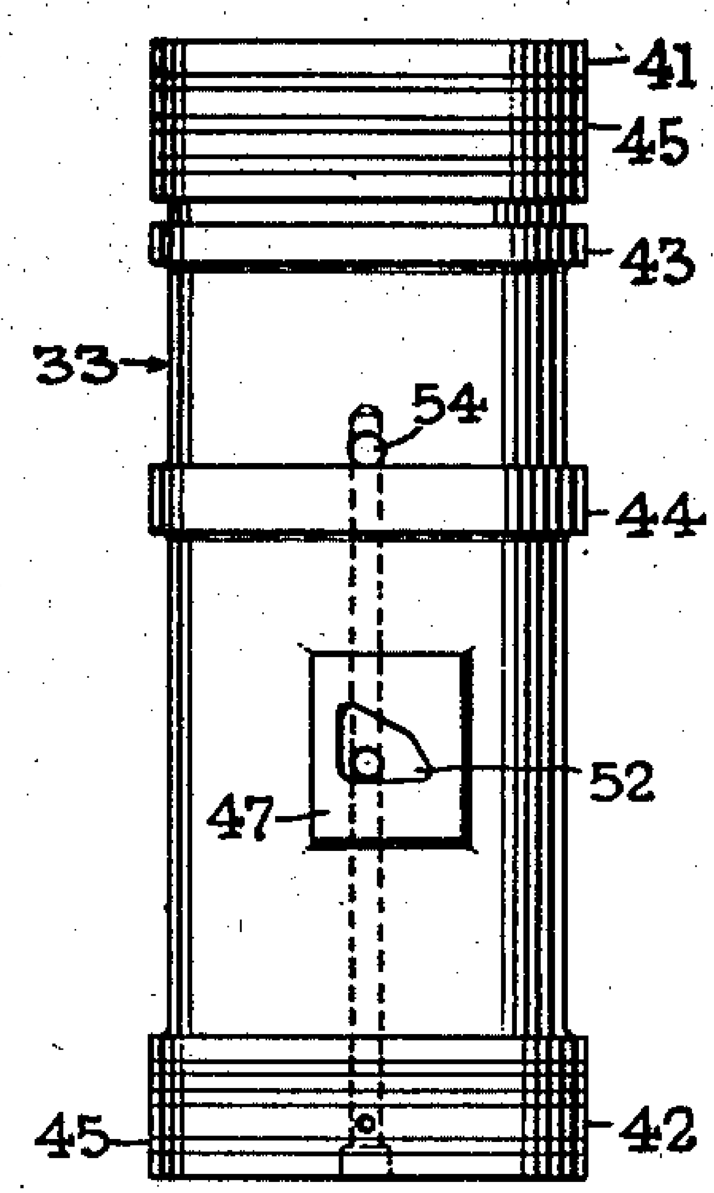


Fig. 7



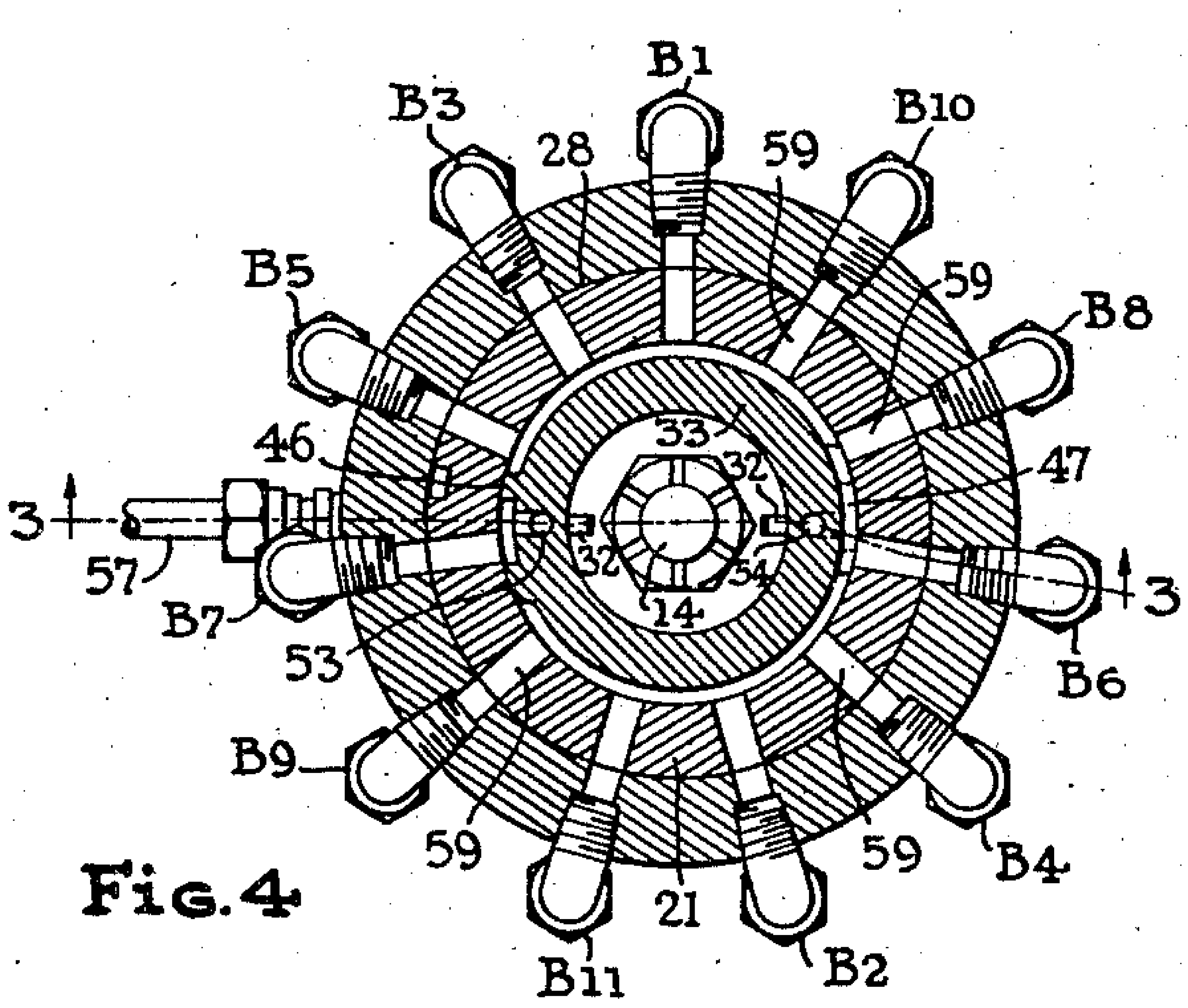


Fig. 4

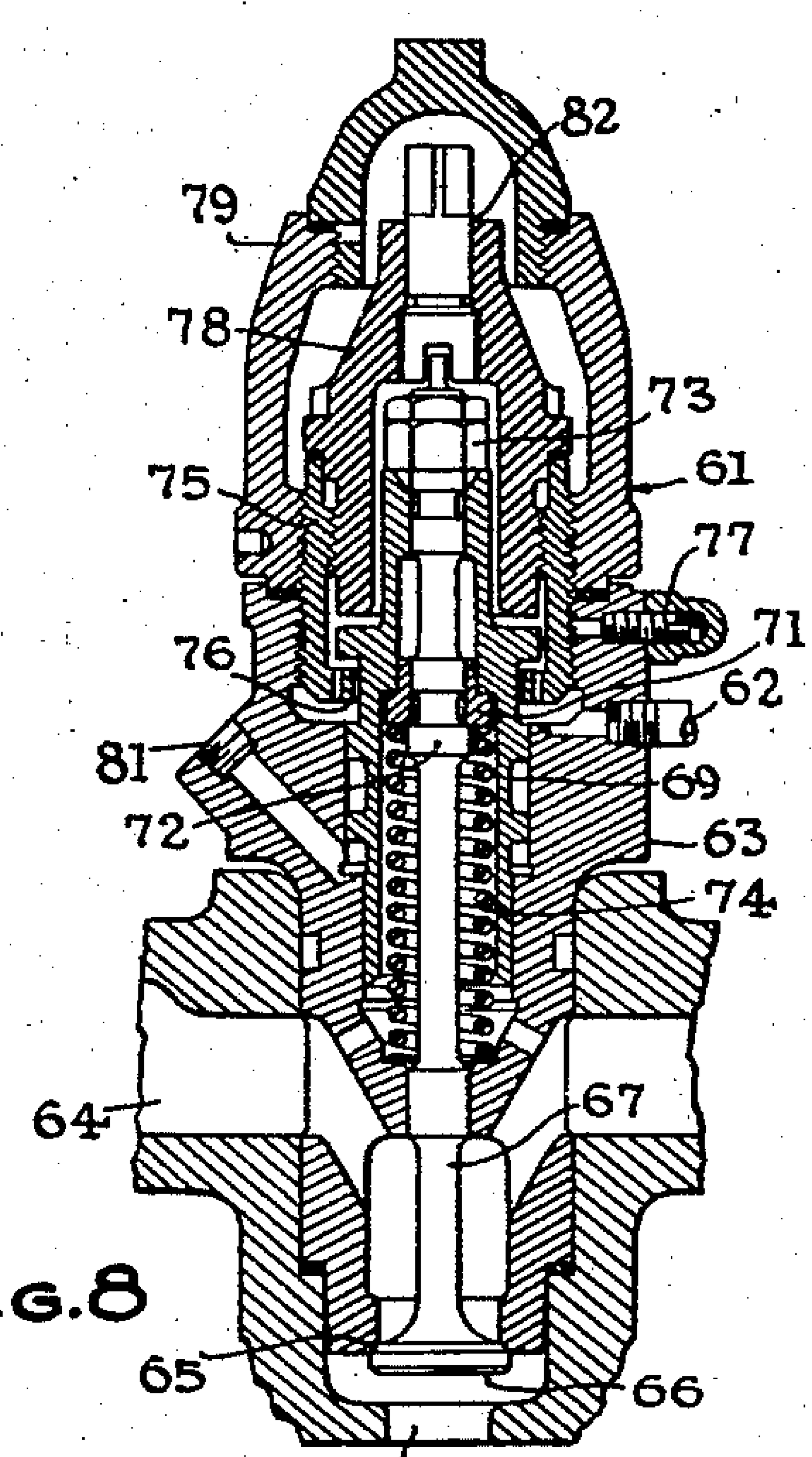


Fig. 8

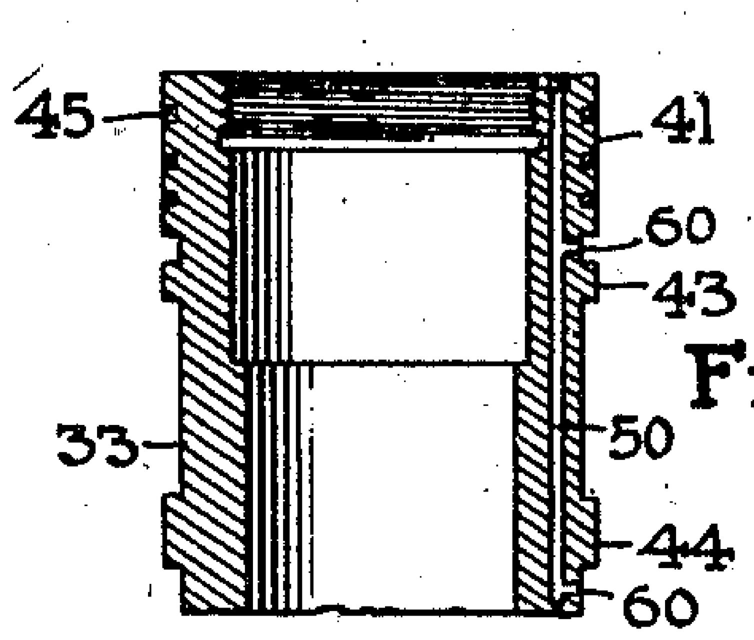


Fig. 9

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UNITED STATES PATENT OFFICE

2,444,440

INTERNAL-COMBUSTION ENGINE

Emil Grieshaber and Karl V. Anderson, Milwaukee, Wis., assignors to Nordberg Manufacturing Company, Milwaukee, Wis., a corporation of Wisconsin

Application September 27, 1946, Serial No. 699,697

9 Claims. (Cl. 123—90)

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This invention relates to the control of two cycle engines in which the cylinders fire serially.

The best example of such an engine is the radial single crank type which will be used as the basis of explanation of the principles involved. An eleven cylinder engine is illustrated but the scheme can be used with an engine having any odd number of cylinders per crank from three cylinders up.

Control is effected by variation of the fuel supply in two ranges one above, and the other below an intermediate value which will be loosely called "half load." In the upper range all cylinders fire serially in each revolution of the crank so that the firing order is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11. In the lower range the engine operates on the two cycle principle, but alternate cycles for each cylinder are suppressed. Thus, in two revolutions of the crank, the firing order is 1, 3, 5, 7, 9, 11, 2, 4, 6, 8, 10. This will be recognized as a typical 4-cycle firing order for single crank radial engines.

The result is had by arranging the fluid distribution ports uniformly around a fixed sleeve in the order 1, 3, 5, 7, 9, 11, 2, 4, 6, 8, 10, i. e. all the odd numbers in order, then all the even numbers in order. Turning in the sleeve at half crankshaft speed is a rotor which is shiftable axially to cause one or the other of two director ports to coact with the distribution ports. One director port has one outlet, but the other has two which are diametrically opposed. The latter engages all the distribution ports serially in one half turn of the rotor (i. e. in one turn of the crank), but the former requires a full turn of the rotor (i. e. two turns of the crank) and so gives the firing order described above as a typical four stroke firing order.

Theoretically such a distributor could be used to deliver fuel directly to the various cylinders, but since the connection to the cylinders would ordinarily be objectionably long, each cylinder is fed by a corresponding normally closed pressure opened valve, and the distributor admits motive fluid serially to the pressure motors of the valves and then exhausts it therefrom.

A further refinement involves the use of gas as a fuel and as the motive fluid for actuating the valves. The gas is delivered at high pressure say 100 p. s. i. and is supplied to the pressure actuated valves for admission to the engine cylinders at a reduced pressure say 50 p. s. i. The distributor directs high pressure gas to the motor units of the valves and exhausts the motor units into the low pressure gas line. This scheme offers the advantage that if any valve actuating motor should

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leak, the leaking gas will flow to the low pressure line and thus be fed to the engine.

The forms of the director ports and distribution ports are so coordinated that axial shifting of the rotor changes the duration of intercommunication and hence the duration of opening of the gas inlet valves. The engine governor is connected to shift the rotor axially.

From idling speed to half load the engine operates on the described 4 cycle firing order (i. e. omits alternate 2 stroke cycles for each cylinder) the duration of opening of the gas valves progressing from minimum to maximum. At half load the sleeve shifts rapidly sufficiently to establish the normal two stroke firing order, but with minimum duration of opening. From here on to full load, the duration of opening of the gas valves progresses to maximum.

In the following discussion no attempt will be made to describe the details of the crank-connecting rod arrangement which is preferably that described and claimed in the application of Karl V. Anderson, Serial No. 692,982, filed August 26, 1946. It should be understood that any crank arrangement suited to a single crank radial engine can be used.

The gas inlet valve in Figure 8 of the present application is not claimed per se in the present application, but forms the subject matter of applicants' pending application Serial No. 699,698, filed September 27, 1946.

In the accompanying drawings,

Fig. 1 is a general plan view of the engine intended chiefly to indicate the distributor, the cylinders and the connections from the distributor to the inlet valve motors of the various cylinders. Secondary details are omitted.

Fig. 2 is a view, principally in elevation, of the distributor and the control connection from the governor and from a manually adjustable controller. The latter is set in full operating position. In this view parts are broken away to show the drive from the crank-shaft to the distributor.

Fig. 3 is a vertical section through the distributor on a relatively large scale. The line of section is indicated at 3—3 on Fig. 4. The rotary valve is in its lowermost position assumed when the engine is stopped.

Fig. 4 is a horizontal section through the distributor on the line 4—4 of Fig. 3.

Fig. 5 is an elevation of the rotary distributor valve.

Figs. 6 and 7 are elevations of the rotary distributor valve looking respectively at the left side and at the right side of the distributor as positioned in Fig. 5.

Fig. 8 is an axial section of one of the pressure operated fuel gas inlet valves.

Fig. 9 is a fragmentary section on the line 9—9 of Fig. 5.

As best indicated in Figs. 1 and 2, the engine has a crank-case 11 with cover 12. On the crank-case are mounted eleven cylinders designated as C1, C2, C3 and so on to C11. In each of these cylinders is an ordinary trunk piston (not shown) each operatively connected by a connecting rod to a single crank on the vertical crank shaft 13. The shaft 13 turns clockwise when viewed in plan and the normal firing order is C1, C2, C3 . . . C11.

The crank and rod arrangement is preferably that shown in the copending application identified above.

The distributor which is the distinctive feature of the present invention is driven by a shaft 14 which turns at half crank shaft speed in the opposite direction to that of the crank shaft 13 (i. e., counter-clockwise when viewed in plan). Shaft 14 is driven by pinion 15 on the upper end of shaft 13, the pinion meshing with gear 16 fixed on shaft 14 and forming a two to one reduction train.

Shaft 14 is mounted in a spider 17 which carries two bearings 18. A bonnet 19 is mounted on the rim of spider 17 and supports a fixed cylindrically bored bushing which serves as the distributor valve seat 21. This is ported in a manner to be described in detail. Bolts 22 hold the bonnet and spider to the crank-case cover 12 (see Figs. 2 and 3). Valve seat bushing 21 seats on flange 23 and is positioned by stake 24. Housing 25 held by bolts 26 engages its upper end and holds it fixed in bonnet 19. The valve seat bushing 21 makes a gas-tight fit with bonnet 19 at the circumferential zones 27, 28 and 29 and is relieved in the intermediate spaces to afford gas passages.

Shaft 14 is coaxial with the bore of valve seat 21 and carries at its upper end a hub 31 splined at 32 to a hollow cylindrical distributor valve 33, so that the valve 33 may be shifted axially but always turns with hub 31 and shaft 14.

The valve is shifted axially by a governor-controlled rocker 34 fulcrumed at 35 in housing 25. A link 36 connects rocker 34 with the inner race of an annular ball bearing 37, whose outer race is clamped in the upper end of valve 33 by the annular plug 38 threaded into the upper end of valve 33. A spacer 39 holds oil guards as shown in Fig. 3.

The valve 33 has end portions 41 and 42 which fit the bore of seat 21 and between these are two circumferential lands 43 and 44 (see Figs. 5–7). Sealing rings 45 are mounted in grooves in the end portions 41 and 42. The lands 43 and 44 fit the bore of valve seat 21 but have no sealing rings. Intermediate portions of the exterior of valve 33 are reduced in diameter, except for two diametrically opposed rectangular bosses 46 and 47 which fit the valve seat.

Boss 46 has two triangular recesses 48 and 49 connected by groove 51 at the trailing edge. Boss 47 has a single triangular recess 52 diametrically opposed to 49 and at the same distance from the lower end of valve 33. All recesses 48, 49 and 52 are connected by passages 53 and 54 with the space between lands 43 and 44, which as will be explained is supplied with fuel gas at high pressure (say 100 lbs.). The space between land 44

and the lower end 42 is at a lower gas pressure (say 50 lbs.)

To supply gas at high pressure to the interval between lands 43 and 44 a connection 55 leads from the high pressure gas supply line through bonnet 19 to port 56 in bushing 21. A connection 57 leads from port 58 in bushing 21 to a point in the low pressure gas line which feeds the inlet valves, later described.

The groove between land 43 and end portion 41 is a leakage collecting groove, which is connected by passage 50 and ports 60 with the low pressure gas space below land 44. Thus leakage is recovered and fed to the fuel valves.

Throughout this specification and in the drawings the numeral 55 will be used to signify a connection to the high pressure gas line and 57 a connection to the low pressure gas line.

A circumferential series of eleven ports 59 are uniformly spaced around bushing 21 in position to be engaged by recess 48 or by recesses 49 and 52 depending on the axial displacement of valve 33. In the position shown in Fig. 3 there is no engagement. If the valve 33 is raised slightly recess 48 alone would engage ports 59 and at the upper narrow end thereof causing the cylinders to fire serially once in two revolutions of the crankshaft. As the valve is raised further, the lower wider end would engage. Further raising will cause the upper narrow ends of 49 and 52 to engage causing the cylinders to fire serially once in each revolution of the crank shaft, and the period of engagement will increase if the valve is raised further.

The ports 59 correspond to the various cylinders C1 to C11 respectively, to which they are connected by connections B1 to B11. The arrangement of these is shown in Figs. 1 and 4. They do not run serially but run through odd and then even ordinals successively in a closed circular series. It should be observed that since the crank-shaft and the distributor rotate in opposite directions, the fact is reflected in a reverse order arrangement clearly indicated in Figs. 1 and 4.

The connections B1 to B11 do not supply fuel gas to the cylinders. Instead they deliver motive pressure fluid (fuel gas at 100 lbs.) to pressure motors which operate the inlet valves of the various cylinders. These motor operated valves are generally indicated by the numeral 61 and the construction of the valves is shown in Fig. 8. The actuating connecting lines which lead from B1, B2, etc., as the case may be, are numbered 62 for all cylinders, and lead as diagrammed in Fig. 1.

Each motor operated valve 61 has a body 63 which fits into a recess formed in the corresponding cylinder casting and extends across a gas passage 64 connected to the low pressure gas line. Body 63 has a seat 65 for the inlet valve 66 which has a stem 67 and controls flow of fuel gas from passage 64 to and through an aperture 68 which communicates with the working space of the cylinder. A piston 69 encircles stem 67 and works in a cylinder in body 63. A spring seat bushing 71 is confined between a shoulder 72 in stem 67 and the piston 69. A nut 73 with check-nut, both threaded on the end of valve stem 67, hold the parts in assembled relation. The valve is biased closed by a coil compression spring 74.

To limit the opening movement of the valve an adjustable stop bushing 75 is threaded into the upper end of body 63 and has an inturned flange 76 which is engaged at the limit of opening movement by an encircling flange formed on piston 69 for that purpose. The assembly at 77 is a clamp to lock bushing 75 in its adjusted position. An internal seal cap 78 is threaded into the interior of bushing 75 and an external seal cap 79 is threaded onto the exterior thereof.

The connection 62 leads to the enclosed space above piston 69. The connection 81 receives another branch of the low pressure gas line and is simply a convenient way of venting gas if it leaks downward past piston 69. The swiveled part 82 is not concerned with the normal functioning of the valve, and need not be here described.

A speed responsive governor 83 (see Fig. 2) is driven by crank-shaft 13 through gear 84. Its construction is known. It includes a swinging arm 85 which turns clockwise on rise of speed, and is connected by link 86 with the short arm of a bellcrank lever 87 whose long arm is hinged to link 88. Link 88 and the long arm of bellcrank 87 are equal in length. The other end of link 88 is hinged to radius rod 89 and to one end of a link 91 whose other end is hinged to arm 92 fast on a shaft 93 journaled in housing 25.

Fast on shaft 93 is a cam 94 which has two complementary portions respectively engaging rollers 95 and 96 on rocker 34. The form of cam 94 is such that as cam 94 is turned counter-clockwise rocker 34 is tilted clockwise, lifting sleeve 33.

Guide link 89 swings about a pivot 97 adjustable by moving handle 98 (Fig. 2) between the maximum fuel position shown in Fig. 2, and a "stop" position in which the hinge 99 between links 88 and 91 is coaxial with the fulcrum of bellcrank 87. In the stop position the governor exercises no control and the valve 33 is in its lowermost position as shown in Fig. 3.

The greater slope in cam 94 at 101 is provided to accelerate the tilt of rocker 34 at the so-called half load position.

It should be observed that since the space between end rim 42 and land 44 is at the lower gas pressure any port 59 and its connected motor is exhausted except when the port is lapped by one of the bosses 46 or 47. Thus the timing of the commencement of venting of lines 62 is not affected by the governor, but the pressure built up in the line, and hence in the related valve motor is affected by the duration of engagement of the recess 48, 49 or 52 as the case may be with each port 59. This is controlled by the governor, and does affect the opening of each valve 66 in extent and duration of opening, since flow out through any line 62 cannot be instantaneous.

Consideration of Figs. 3 to 7 will show that when only cavity 48 engages ports 59 it will take one turn of the valve 33, or two turns of the crank-shaft for all cylinders to receive charges. The order of feeding the branches is B1, B3, B5, B7, B9, B11, B2, B4, B6, B8, B10 (see Fig. 4, remembering that 33 turns counter-clockwise). If the two cavities 49 and 52 engage ports 59 all cylinders will fire in one half turn of the distributor or one turn of the crank-shaft. To demonstrate, if 49 charges B1, 52 will next charge B2, 49 charges B3, 52 charges B4, and so on to charge all cylinders in one-half turn of the distributor; after which 52 charges B1, 49 charges B2 and so on for the next half turn of the distributor.

In consequence, above "half load" all the cylinders fire serially each turn of the crank, while below half load each cylinder omits alternate cycles.

The described arrangement is simple and gives uniform firing characteristics below as well as above half load. It greatly extends the range of satisfactory control.

Obviously the simplest and most practical arrangement is to use a fixed valve seat and locate the valve within the seat. Hence this arrangement is described for illustrative purposes. It should be remembered, however, that so far as the broad principle of the invention is concerned the essentials are a valve and a seat with provision for relative rotation and relative axial displacement between the two for the purposes set forth. Hence, the description of a fixed valve seat and a valve which may rotate and shift axially is intended to be illustrative and not limiting. Alternative arrangements within the scope of the claims are possible and are contemplated.

What is claimed is:

1. The combination of an internal combustion engine having a crankshaft and an odd number of cylinders arranged to fire serially on a two stroke cycle; means for supplying fuel to said cylinders; a cylindrical distributor valve seat having an annular series of ports related to said fuel supply means to control the operation thereof; a distributor valve coacting with said seat and rotatable relatively thereto, said valve being shiftable relatively to the seat in an axial direction and having two sets of director ports which are caused selectively to coact with the annular series of seat ports by said relative axial shifting of the valve, one set comprising a single director port, and the other two director ports which are diametrically opposed to each other in said valve; means for driving said valve at half the rotary speed of the crankshaft; and control means for shifting said valve in an axial direction relatively to the seat sufficiently to cause one or the other set of director ports to coact with the seat ports.

2. The combination defined in claim 1 in which the engine is of the radial, single-crank type.

3. The combination defined in claim 1 in which the ports in said seat and distributor are so coordinated as to form, that axial shifting of the valve relatively to the seat varies the duration of communication of the director ports with the seat ports, in the same sense and in two ranges, in one of which the single director port and in the other of which the two diametrically opposed director ports coact with the seat ports, and the control means is arranged to accelerate the axial motion of the valve at the point of transition between the two ranges.

4. The combination defined in claim 1 in which the engine is of the radial, single-crank type, the ports in said seat and distributor are so coordinated as to form, that axial shifting of the valve relatively to the seat varies the duration of communication of the director ports with the seat ports, in the same sense and in two ranges, in one of which the single director port and in the other of which the two diametrically opposed director ports coact with the seat ports, and the control means is arranged to accelerate the axial motion of the valve at the point of transition between the two ranges.

5. The combination defined in claim 1 in which the means for supplying fuel to the cylinders comprise pressure-motor operated inlet valves, one for each cylinder, the distributor valve seat ports are connected to respective motors, and the distributor valve acts to admit and exhaust motive fluid to and from said motors through said seat ports.

6. The combination defined in claim 1 in which fuel gas is supplied to the engine through two pressure lines, a high pressure line and a low pressure line, the means for supplying fuel to the cylinders comprise pressure-motor-operated inlet valves, one for each cylinder, each valve being yieldingly biased in a closing direction and arranged to control the flow of gas from the low pressure line to a corresponding cylinder, the distributor valve seat ports being connected with respective valve motors, and the distributor valve serving to connect the valve motors alternately to the high pressure line and the low pressure line.

7. The combination defined in claim 1 in which the ports in said seat and distributor are so coordinated as to form, that axial shifting of the valve relatively to the seat varies the duration of communication of the director ports with the seat ports, in the same sense and in two ranges, in one of which the single director port and in the other of which the two diametrically opposed director ports coact with the seat ports, and the control means comprises a governor responsive to engine speed and connected to shift said distributor valve through both said ranges.

8. The combination defined in claim 1 in which the ports in said seat and distributor are so coordinated as to form, that axial shifting of the valve relatively to the seat varies the duration of communication of the director ports with the seat ports, in the same sense and in two ranges, in one of which the single director port and in

the other of which the two diametrically opposed director ports coact with the seat ports, and the control means comprises a governor responsive to engine speed, a variable motion-ratio connection between said governor and said distributor valve whereby the governor acts to shift the valve axially, and manually adjustable means for determining the motion ratio between the governor and the distributor valve.

9. The combination defined in claim 1 in which the ports in said seat and distributor are so coordinated as to form, that axial shifting of the valve relatively to the seat varies the duration of communication of the director ports with the seat ports, in the same sense and in two ranges, in one of which the single director port and in the other of which the two diametrically opposed director ports coact with the seat ports, and the control means comprises a governor responsive to engine speed, a variable motion-ratio linkage forming the operative connection through which the governor shifts the distributor valve axially, said linkage being adjustable progressively between a stop position in which the valve is in a no load position regardless of the position of the governor, and a maximum fuel position in which the governor exercises complete control of the axial position of the valve, and manually operable means for adjusting said linkage while the engine is in operation.

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