April 2, 1946. F. RUSTAD 2,397,752

INTERNAL-COMBUSTION ENGINE

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Fig. 1.

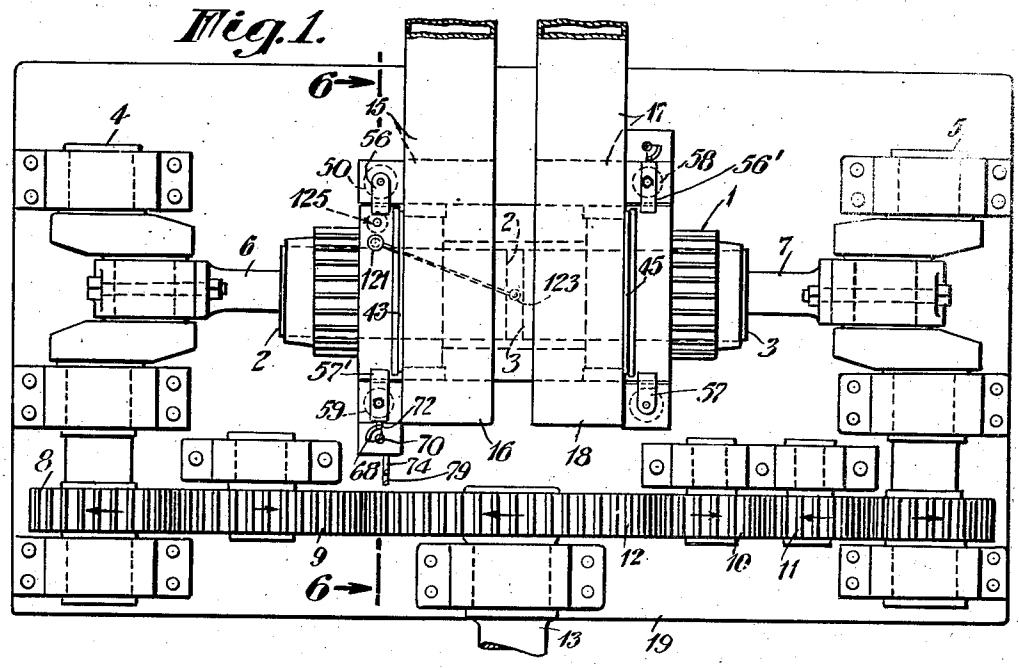

Fig. 2.

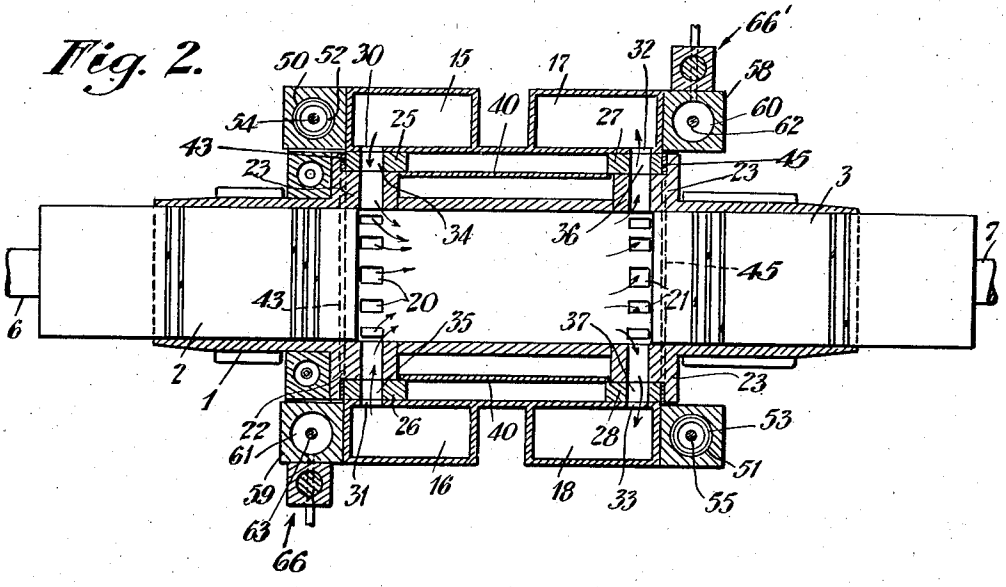

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Fig. 3

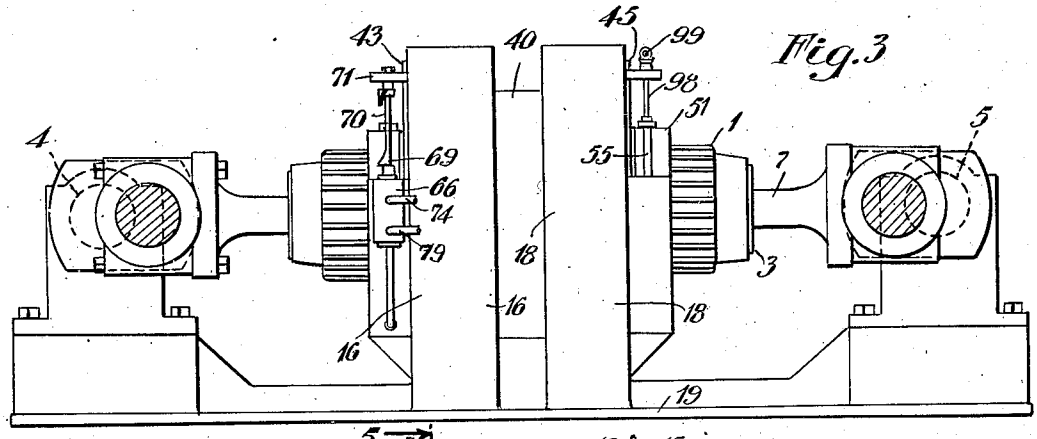


Fig. 4.

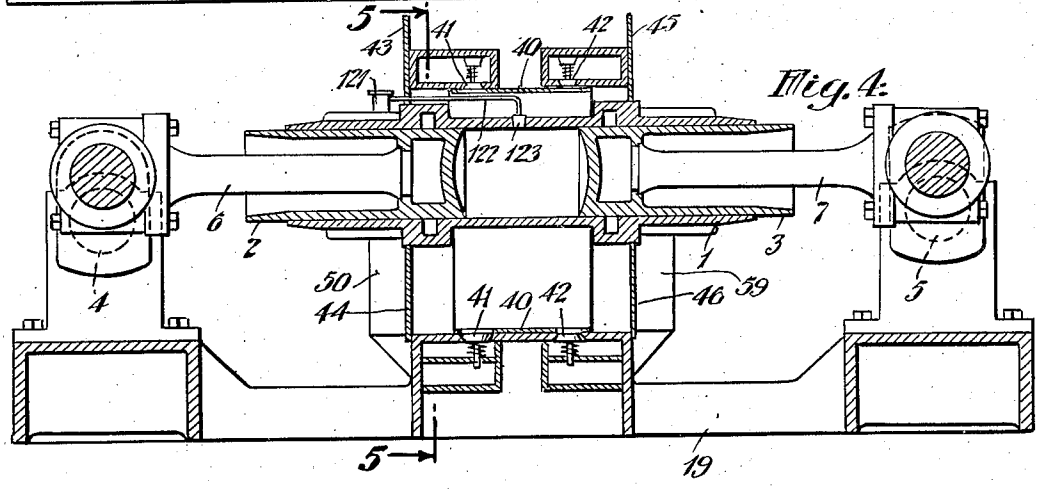
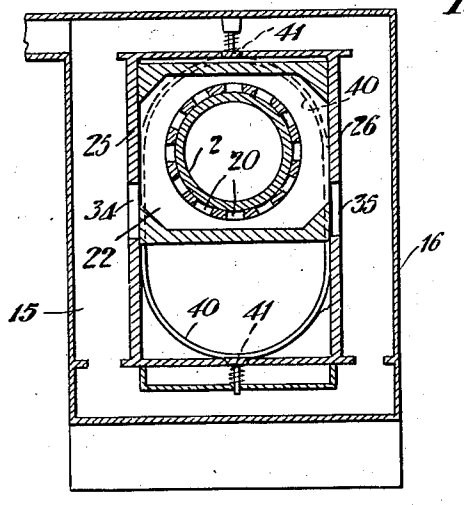


Fig. 5.



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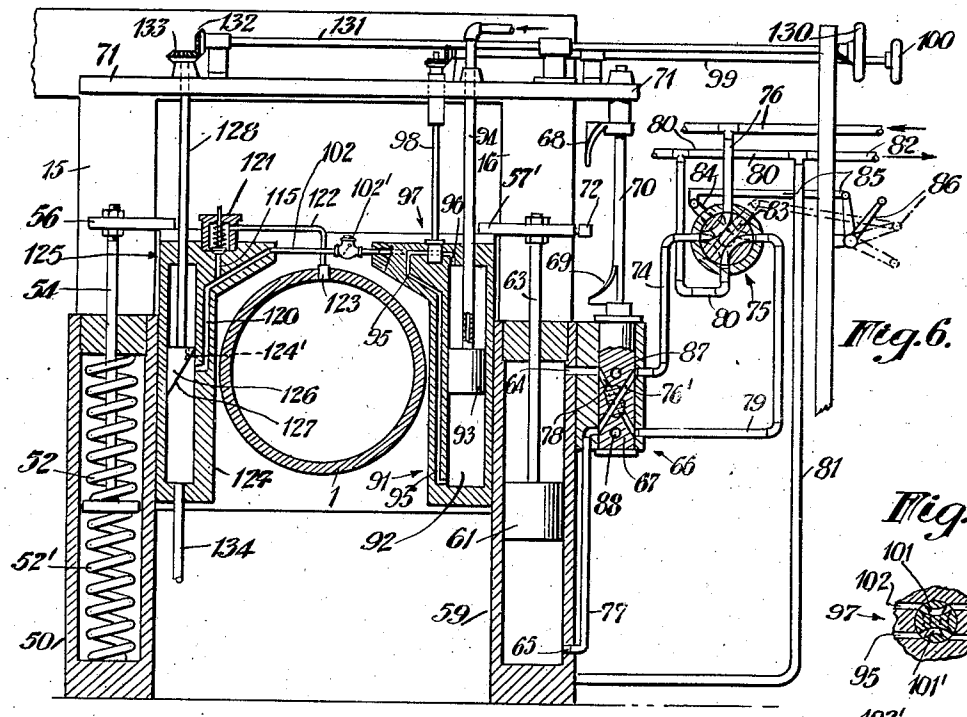

Fig. 6.

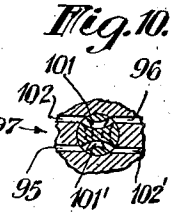

Fig. 10.

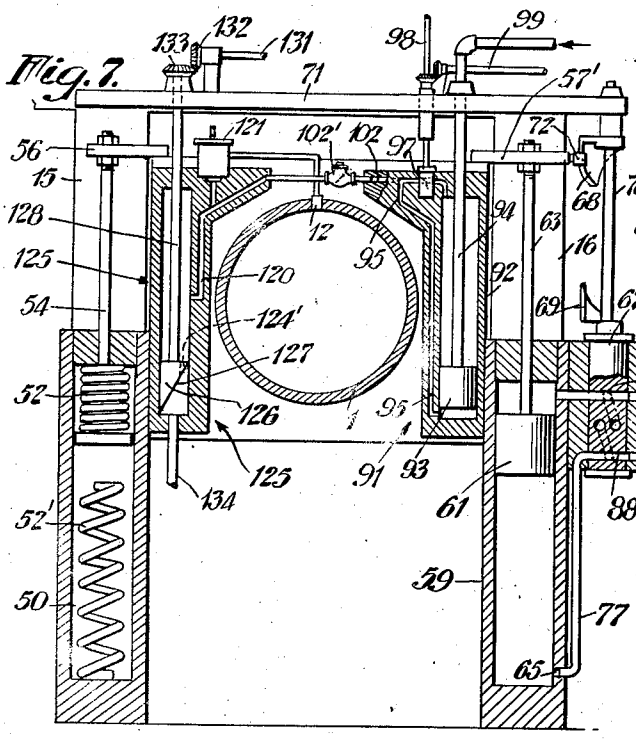

Fig. 7.

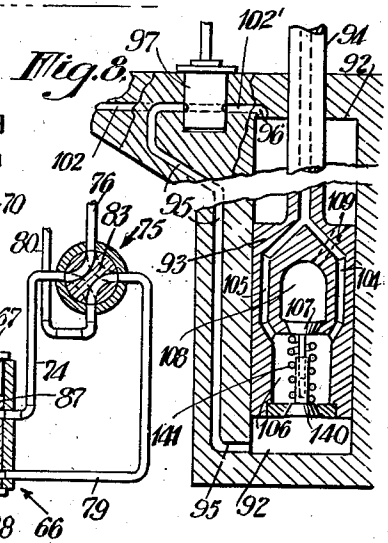

Fig. 8.

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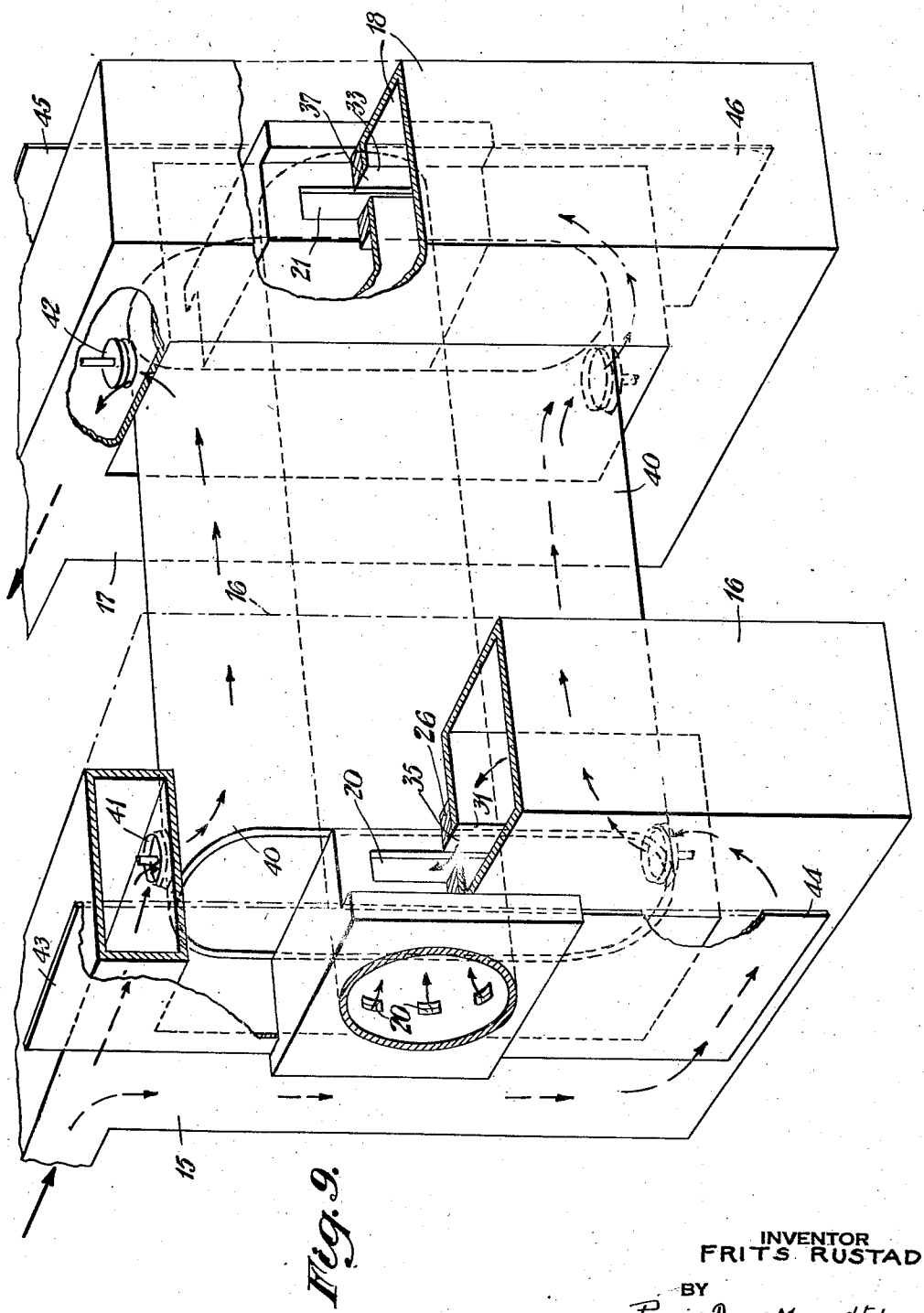

Fig. 9.

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INTERNAL-COMBUSTION ENGINE

Frits Rustad, Larchmont, N. Y.

Application September 23, 1944, Serial No. 555,417

14 Claims. (Cl. 123—42)

This invention relates to internal combustion engines and has for its object the provision of an improved engine of the opposed-piston type. The invention provides an engine having at least one cylinder with the opposed pistons reciprocable therein, a crankshaft for each piston and means for shifting the cylinder in a direction transverse to its longitudinal axis during each revolution of the crankshaft.

One of the characteristic features of the invention is the use of piston connecting rods which travel in the direction of the cylinder axes without swinging, and a component of the forces acting on the crankshafts imparts a motion to the engine cylinders which is transverse to the movement of the pistons. In one of its embodiments, the invention provides means acting in synchronism with the pistons for applying forces in a direction transverse to the cylinder axes to start the engine and to supplement, during the operation of the engine, the action of the crankshafts in imparting the transverse motion to the cylinders. I have found it advantageous to attach to the engine cylinders resilient means having an oscillatory effect on the cylinders which aids in supporting the cylinders and in starting and continuing the transverse motion.

The invention is especially applicable to Diesel engines containing any number of cylinders and is advantageously adapted to multi-cylinder engines, either upright or horizontal, and to engines with interconnected groups of cylinders in which the shafts are connected by gears to a common power shaft. The cylinders, including the immediately connected elements, such as fuel supply means, pistons, connecting rods and the like, are slidably supported on bearings which permit movement thereof on each side of the center position of the cylinders the length of the shaft crank.

One of the important features of the invention is the provision of a pump system, preferably operated by the lubricating oil, to start the engine and to apply forces aiding in the continuing transverse movement of the cylinder. This feature is especially important when the engine is a Diesel engine because it provides a simple and compact means of starting the engine. By means of one or more small pumps arranged to act against the slidable mass of the engine, the cylinders are moved transversely with a resulting movement of the pistons, fuel pump, etc., and the engine is started. The engine of the invention may, accordingly, be started without the use of the complicated and bulky equipment now necessary to provide air under pressure to start Diesel engines. I have found it advantageous to support the engine cylinder on one or more double acting springs which have an oscillatory effect on the movement of the cylinders and which cushions the movement of the cylinder at the extreme positions of motion.

Another important aspect of the invention is the provision of a very simple reversing system comprising valve means operated from a control station for controlling the action of the starting pumps. The invention provides manually operable valve means for controlling the admission of oil to the starting pumps to determine the movement of the cylinders and the direction of rotation of the crankshafts.

These and other novel features of the invention will be better understood after considering the following discussion taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a plan view of a single cylinder engine embodying the invention;

Fig. 2 is an enlarged horizontal sectional view of the cylinder portion of Fig. 1;

Fig. 3 is a side view of the engine of Fig. 1;

Fig. 4 is a sectional view along the line 4—4 of Fig. 1;

Fig. 5 is a sectional view along the line 5—5 of Fig. 4;

Fig. 6 is a view along the line 6—6 of Fig. 1 with control apparatus included;

Fig. 7 is a view similar to Fig. 6 illustrating the parts in different positions;

Fig. 8 is an enlarged view of the fuel pump;

Fig. 9 is a diagrammatic illustration of means for the intake and exhaust of gases; and

Fig. 10 is a cross sectional view through the valve and its ports.

The opposed piston engine illustrated in the drawings comprises but a single cylinder which is provided with suitable fins for air cooling, it being understood, of course, that any desired number of similar cylinders may be used and that the engine may be liquid cooled if desired. The engine is also a two-stroke Diesel engine and it is to be understood that the invention also applies to spark-ignition engines. The invention illustrated is arranged in a horizontal position and it is to be understood that the invention also applies to engines in which the cylinders are arranged in an upright position.

The Diesel engine illustrated in the drawings comprises an air cooled cylinder 1 having opposed pistons 2 and 3 reciprocable therein which are connected to crankshafts 4 and 5 by the connecting rods 6 and 7 respectively. It will be noted

that the piston rods do not have the usual cross head but travel in a straight line without the usual swinging. As the crankshafts rotate, a forced component imparts to the pistons, cylinder and all of the movable apparatus affixed thereto an upward and downward movement, as shown in Figs. 3 and 4. In other words, during each rotation of the crankshafts, the cylinder and its immediate assembly of connected elements moves upward and downward. This use of rigid connecting rods moving in a straight line resulting in or contributing to a movement of the cylinder in a direction transverse to the movement of the pistons is one of the characteristic features of the invention.

In order that the crankshafts will move in unison, they are connected together by means of the intermediate gears 8, 9, 10 and 11 to the master gear 12 which drives the power shaft 13 (Fig. 1).

The intake manifolds 15 and 16 and the exhaust manifolds 17 and 18 are permanently secured to the foundation structure 19 and do not participate in the upward and downward movement of the cylinder assembly. In the vicinity of the intake ports 20 and the exhaust ports 21 the cylinder has enlargements or projections 22 and 23 which, as shown in Fig. 5, are substantially square in cross section. The upright sides of these extensions are in engagement with the upright bearing guides 25, 26, 27 and 28 which are securely attached to the manifolds 15, 16, 17 and 18 respectively (Fig. 2). The intake manifolds 15 and 16 and the exhaust manifolds 17 and 18 have elongated slots 30, 31, 32 and 33, respectively, which are in coincident engagement with similar slots 34, 35, 36 and 37 in the bearing guides 25, 26, 27 and 28 respectively. As the cylinder moves upward and downward in sliding engagement with the guides, the intake ports 20 and exhaust ports 21 are always in direct communication, through said slots, with the interiors of their respective manifolds.

In order to facilitate the circulation of cooling air around the central portion of the cylinder between the intake and exhaust ports, a housing member 40 is mounted in spaced relation thereabout and in secure attachment to the guides 25, 26, 27 and 28, as best shown in Figs. 5 and 9. This housing is oblong in cross section to permit the upward and downward movement of the cylinder therein. By means of a suitable arrangement of valves, as best shown in Figs. 4 and 9, the air from the intake manifold which is provided under pressure for scavenging and combustion is introduced into the space inside the housing 40 through the valves 41 and is discharged through the valves 42 into the exhaust gas manifold.

In the schematic illustration of the invention in Fig. 9, it will be seen that the cylinder 1 slides upward and downward in bearing contact with the guides 25, 26, 27 and 28 with the inlet ports 20 and exhaust ports 21 always in coincident engagement with openings communicating with the interiors of the manifolds 15, 16, 17 and 18. The air for scavenging and combustion is supplied to the manifold 15 from such sources as are usually used for Diesel engines, and it flows through the engine passages in the directions indicated by the arrows. When the piston 2 is in a position clearing the inlet ports 20, the air blows therethrough and serves as scavenging air blowing the exhaust gases through the ports 21 and into the exhaust manifold. The air continues to flow, providing a residual quantity of air for combustion purposes. It will be noted that a part of the air entering the intake manifold forces the one-way valves 41 open and flows into the space between the housing 40 and the cylinder and thence through the one-way valves 42 from which it is discharged into the exhaust gas manifold. The end closures 43, 44, 45 and 46 are rigidly attached to the engine cylinder and move upward and downward therewith. They are in bearing contact with the sides of the inlet and exhaust manifolds and, accordingly, seal off the space inside the housing 40. It will be understood that Fig. 9 is somewhat exaggerated to facilitate illustration and that the housing 40 is much shorter, as shown in Figs. 1 to 5.

In order to facilitate the starting of the engine, and also to aid in the continuing transverse movement of the cylinder, suitable spring means are provided, and to this end, the two diagonally disposed cylinders 50 and 51 are mounted on the platform or engine bed 19 and are attached to the manifolds 15 and 18 respectively. As best shown in Figs. 6 and 7, the cylinders 50 and 51 contain double acting springs 52 and 52' and 53 and 53' with rods 54 and 55, respectively, in bearing engagement therewith. The rods 54 and 55 are attached at the top to brackets 56 and 57 which are rigidly and securely attached to the upper portion of the cylinder. These springs serve to cushion the upward and downward movement of the cylinder and aid in the upward and downward movement to the cylinder.

In order to start the engine, and preferably to aid in the continuing transverse movement of the cylinder, diagonally disposed cylinders 58 and 59 are mounted on the platform 19 and attached to the manifolds 16 and 18. The cylinders have pistons 60 and 61 slidably mounted therein with connecting rods 62 and 63 securely attached to brackets 56' and 57' respectively. The rods 54, 55, 62 and 63 move upward and downward with the cylinder of the engine. The upper part of the cylinder 59 has a port 64 and the lower part has a port 65, each in communication with a valve 66 having a rotatable control member 67 which is operated by cams 68 and 69 on the rod 70. The upper end of rod 70 is attached to the stationary platform 71 and, while it may turn, does not move upward or downward. The bracket 57 moves upward and downward with the cylinder and has a projecting roller 72 which engages the cams 68 and 69 to turn the member 67 first in one direction and then in the opposite direction repeatedly as the engine operates.

The valve 66 in the position of the valves shown in Fig. 6 is supplied with oil under high pressure through the pipe 74, reversing valve 75 and pipe 76 which connects to any suitable source of high pressure oil, for example, to the high pressure side of the lubricating oil system of the engine (not shown). The oil flows through the diagonal passage 76', pipe 77 and port 65 into the lower part of cylinder 59, forcing the piston 61 and the engine assembly upward. The oil is removed from the upper part of cylinder 59 through port 64, diagonal passage 78, pipe 79, reversing valve 75, and pipe 80 from which it flows to the sump through pipe 81 or to the low pressure side of a lubricating system through pipe 82. The oil for cylinders 58 and 59 may be from a source of sufficient pressure that the oil discharged from the cylinders may be under a sufficiently high pressure to be used as the lubricating oil and returned to the sump after passing through the

bearings. In such a construction the excess of oil over that required for lubrication may be returned directly to the sump through a pressure release valve.

The control portion 83 of the valve 75 is connected by lever 84 and rod 85 to the manually operated starting lever 86 which may be located at any desired place, for example, at a remote operating station. The lever 86 may be moved to a position, such as that shown in full lines which is for forward rotation of the engine, to set the member 83 in a position whereby there are communicating passages therethrough as shown in full lines, or it may be set in the position shown in broken lines for reverse running of the engine to connect the passageways in member 83 shown in broken lines. With the parts in the position shown in Fig. 6, the oil forces the piston 61 and the entire cylinder assembly in an upward direction to upper dead center, at which time cam 69 engages roller 72 and valve member 67 is turned sufficiently to connect the horizontal hole 87 with port 64 and pipe 74 and horizontal hole 88 with pipes 77 and 79, as shown in Fig. 7. The high pressure oil now enters the top of cylinder 59 forcing piston 61 and the engine cylinder downward and the oil in the lower part of cylinder 59 flows out through port 65, pipe 77, hole 88, pipe 79 and 89 to the low pressure side of the lubricating system or to the sump. When cylinder 1 reaches lower dead center, the cam 68 engages the roller 72 and turns member 67 back to the position shown in Fig. 6. The piston 60 of cylinder 58 has a similar arrangement of apparatus to that shown for operating and controlling piston 61 of cylinder 59.

The engine may be reversed by controlling the fuel supply, as will be described fully hereinafter, and by manipulating the lever 86 by throwing it to the stop position, thus turning the valve member 83 to close the passages therethrough and stop the engine. The lever 86 is then set in the reverse position to drive the pistons and cylinders in the opposite direction and fuel is again admitted to the engine.

The means for supplying the engine with fuel oil are best shown in Figs. 6, 7 and 8. The fuel oil pump 91 comprises a cylinder 92 that is rigidly connected to the engine cylinder 1 and is movable up and down therewith. The piston 93 is attached by the hollow rod 94 to the stationary platform 71. It is the movement of the cylinder 92 that gives relative movement to piston 93. Fuel oil from any suitable source not shown is admitted into the hollow rod 94 from which it flows through the piston 93, as best shown in Fig. 8. The lower portion of cylinder 92 communicates with duct 95 and the upper part of cylinder 92 communicates with duct 96. The ducts 95 and 96 lead to the fuel oil reversing valve 97 which is operated through rods 98 and 99 by the handwheel 100 located at the control position. When the valve 97 is in the position shown in Fig. 10, the passage 101 connects duct 96 with duct 102, and passage 101' connects duct 95 with duct 102' which leads to a container under atmospheric pressure (not shown). When valve 97 is turned to the position with passages 101 and 101' shown in dotted lines, the passage 95 is connected to duct 102 and passage 96 is connected to the container under atmospheric pressure. At any suitable place in duct 102, a non-return or check valve 102' is used to prevent a return of oil in the direction of valve 97.

When valve 97 is set in the position shown, which is for the forward running of the engine, the oil flowing through the hollow rod 94 passes through the ducts 104 and 105 into the chamber 106 and the valve 107 is raised off its seat by the suction in the cylinder. It then flows from chamber 108 through hole 109 into the upper part of cylinder 92. At this time, cylinder 92 is moving upward. On the downward stroke of cylinder 92, the oil in the upper part of the cylinder is forced through ducts 96 and 102 into ducts 115 and 120. Duct 115 leads to the pressure regulating valve 121, and when a suitable oil pressure is attained, as described hereinafter, the valve opens, permitting the oil to be forced through duct 122 and through the fuel oil nozzle 123 into the engine cylinder. The duct 115 connects to duct 120 which connects to the cylinder 124 of the fuel oil regulating valve 125. Cylinder 124 moves up and down but the piston 126 having a control edge 127 is rotatably mounted on shaft 128 which is prevented from upward and downward movement by its mounting on platform 71. In order to vary the amount of fuel injected through the nozzle 123, the piston 126 is turned to the desired position by means of the manually operated wheel 130 which is connected by rod 131 and gears 132 and 133 with piston rod 128. The turning of piston 126 varies the position of the control edge 127 with respect to the inlet to duct 120 and this varies the period during which duct 120 is closed. During the time duct 120 is thus closed, the fuel oil is being injected through valve 121 and nozzle 123. When the desired measured quantity of oil has been injected into the engine, the control edge 127 moves over the opening to duct 120 by reason of the movement of cylinder 124, permitting the excess oil to flow into cylinder 124 and through pipe 134 from which it is returned to the fuel oil supply. When piston 126 is below duct 120, the excess oil flows into the upper part of cylinder 124 and then through passage 124' in piston 126 into the lower part of cylinder 124 from which it returns to the fuel oil supply through pipe 134.

Again referring to Fig. 8, it will be noted that the valve 140 has a stem slidable over the stem of valve 107 and that both valves are pressed into engagement with their respective seats by the spring 141. During the aforementioned operation, the valve 140 has remained closed. When the engine is reversed, the wheel 100 is turned to change the position of the valve 97 from the position with the passage 101 and 101' shown in full lines to the position shown in dotted lines. In this position, the oil flow from duct 95 to duct 102 and duct 96 is connected through passage 101 to the container. When cylinder 92 moves downward, valve 140 opens and the fuel oil flows through rod 94 into the lower portion of cylinder 92. On the upward stroke of cylinder 92, valve 140 closes and the oil is forced through duct 95, valve 97, ducts 102 and 115, pressure regulating valve 121, duct 122, and through nozzle 123, assuming, of course, that valve 126 has closed duct 120. It will be noted that the control edge 127 of valve 126 is tapered to a thin edge at the right side of the drawings and that the valve may be set with wheel 130 in a position which does not permit the injection of any fuel oil into the engine cylinders. In other words, duct 120 may always remain open and the oil from cylinder 92 is returned to the source through pipe 134.

It is, of course, necessary, when changing the direction of fuel admission from forward travel

to reverse as just described, to change the movement of the engine cylinder 1 by effecting a suitable change in the movement of the oil operated pistons 56 and 59. It is accordingly necessary when changing the direction of fuel admission by the manipulation of wheel 100 to effect a simultaneous manipulation of lever 86, first to set valve member 85 to the stop position to stop the flow of oil through pipes 74 and 79, and then to move the starting lever 86 to either the forward or reverse position as desired.

While the engine is operating and the cylinder and its immediately connected assembly of movable elements are moving upward and downward, the rods 54 and 55 operating in the cylinders 50 and 51 move with the engine cylinder and alternately compress the two springs 52 and 52', as best shown in Figs. 6 and 7. These springs exert maximum pressure on the rods at the dead end positions of cylinder 1 and cooperate with the pump pistons in forcing the cylinder 1 upward and downward.

I claim:

1. An opposed-piston internal combustion engine which comprises at least one cylinder having two pistons reciprocable therein, a separate crankshaft for each piston, gear means connecting the crankshafts to a common power shaft, each piston being connected to its crankshaft by a connecting rod which does not pivot with respect to its piston, and bearing guide means operatively connected to the cylinder permitting movement of the cylinder in a direction transverse to the movement of the pistons, said crankshafts having force components which move the cylinder in the transverse direction.

2. An opposed-piston internal combustion engine which comprises at least one cylinder having two pistons reciprocable therein, a separate crankshaft for each piston, gear means connecting the crankshaft to a common power shaft, each piston being connected to its crankshaft by a connecting rod which does not pivot with respect to its piston, bearing guide means operatively connected to the cylinder permitting movement of the cylinder in a direction transverse to the movement of the pistons, said crankshafts having force components which move the cylinder in the transverse direction, and pump means connected to the engine cylinder for moving the cylinder transversely to start the engine.

3. An opposed-piston internal combustion engine which comprises at least one cylinder having two pistons reciprocable therein, a separate crankshaft for each piston, gear means connecting the crankshaft to a common power shaft, each piston being connected to its crankshaft by a connecting rod which does not pivot with respect to its piston, bearing guide means operatively connected to the cylinder permitting movement of the cylinder in a direction transverse to the movement of the pistons, said crankshafts having force components which move the cylinder in the transverse direction, and resilient means connected to the engine cylinder to impart an oscillatory motion thereto.

4. An opposed-piston internal combustion engine which comprises at least one cylinder having two pistons reciprocable therein, a separate crankshaft for each piston, each piston being connected to its crankshaft by a connecting rod which travels in the longitudinal direction of the pistons throughout its travel, bearing guide means operatively connected to the engine cylinder permitting movement of the cylinder in a direction transverse to the movement of the pistons, and means for moving the engine cylinder upward and downward through one complete cycle of movement while the crankshafts make one revolution.

5. An opposed-piston internal combustion engine which comprises at least one cylinder having two pistons reciprocable therein, a separate crankshaft for each piston, gear means connecting the crankshafts to a common power shaft, each piston being connected to its crankshaft by a connecting rod which travels in the longitudinal direction of the pistons throughout its travel, bearing guide means operatively connected to the engine cylinder permitting movement of the cylinder in a direction transverse to the movement of the pistons, said crankshafts having force components tending to move the engine cylinder in the transverse direction, and pump means connected to the engine cylinder and operated in synchronism with the crankshafts to force the engine cylinder in the transverse direction.

6. An opposed-piston internal combustion engine which comprises at least one cylinder having two pistons reciprocable therein, a separate crankshaft for each piston, gear means connecting the crankshafts to a common power shaft, each piston being connected to its crankshaft by a connecting rod which travels in the longitudinal direction of the pistons throughout its travel, bearing guide means operatively connected to the engine cylinder permitting movement of the cylinder in a direction transverse to the movement of the pistons, said crankshafts having force components tending to move the engine cylinder in the transverse direction, pump means connected to the engine cylinder and operated in synchronism with the crankshafts to force the engine cylinder in the transverse direction, and resilient means connected to the engine cylinder to aid in the transverse movement of the engine cylinder.

7. An opposed-piston internal combustion engine which comprises at least one cylinder having two pistons reciprocable therein, a separate crankshaft for each piston, means connecting the crankshaft to a common power shaft, each piston being connected to its crankshaft by a connecting rod which travels in the longitudinal direction of the pistons throughout its travel, bearing guide means operatively connected to the engine cylinder permitting movement of the cylinder in a direction transverse to the movement of the pistons, said crankshafts having force components tending to move the engine cylinder in the transverse direction, an oil pump connected to the engine cylinder to move the engine cylinder in the transverse direction, and means for operating the oil pump by oil from the lubricating oil system of the engine.

8. An opposed-piston internal combustion engine which comprises at least one cylinder having two pistons reciprocable therein, a separate crankshaft for each piston, means connecting the crankshaft to a common power shaft, each piston being connected to its crankshaft by a connecting rod which travels in the longitudinal direction of the pistons throughout its travel, bearing guide means operatively connected to the engine cylinder permitting movement of the cylinder in a direction transverse to the movement of the pistons, said crankshafts having force components tending to move the engine cylinder in the transverse direction, an oil pump connected to the engine cylinder to move the

engine cylinder in the transverse direction, means for operating the oil pump by oil from the lubricating oil system of the engine, and means in operative connection with the oil pump for reversing the operation thereof to reverse the operation of the engine.

9. An opposed-piston internal combustion engine which comprises at least one cylinder having two pistons reciprocable therein, a separate crankshaft for each piston, each piston being connected to its crankshaft by a connecting rod which travels in the longitudinal direction of the pistons throughout its travel, guide means operatively connected to the engine cylinder permitting movement of the cylinder in a direction transverse to the movement of the pistons, at least one pump connected to the engine cylinder arranged to move the engine cylinder in its transverse direction, and means for reversing the operation of the pump to reverse the operation of the engine.

10. An opposed-piston internal combustion engine which comprises at least one cylinder having two pistons reciprocable therein, a separate crankshaft for each piston, each piston being connected to its crankshaft by a connecting rod which travels in the longitudinal direction of the pistons throughout its travel, guide means operatively connected to the engine cylinder permitting movement of the cylinder in a direction transverse to the movement of the pistons, at least one pump connected to the engine cylinder arranged to move the engine cylinder in its transverse direction, means for reversing the operation of the pump to reverse the operation of the engine, and resilient means connected to the engine cylinder to aid in the transverse motion.

11. An opposed-piston internal combustion engine which comprises at least one cylinder having two pistons reciprocable therein, a separate crankshaft for each piston, means connecting the crankshaft to a common power shaft, each piston being connected to its crankshaft by a connecting rod which travels in the longitudinal direction of the pistons throughout its travel, guide means operatively connected to the engine cylinder permitting movement of the cylinder in a direction transverse to the movement of the pistons, at least one oil pump connected to the engine cylinder and operated by the transverse movement thereof, and means at a control position for reversing the operation of the pump in reversing the operation of the engine.

12. An opposed-piston internal combustion engine which comprises at least one cylinder having two pistons reciprocable therein, a separate crankshaft for each piston, gear means connecting the crankshaft to a common power shaft, each piston being connected to its crankshaft by a connecting rod which travels in the longitudinal direction of the pistons throughout its travel, guide means operatively connected to the engine cylinder permitting movement of the cylinder in a direction transverse to the movement of the pistons, pump means connected to the engine cylinder arranged to move the engine cylinder in its transverse direction, fuel supply means for the engine, means at a control position for reversing the supply of fuel and for reversing the operation of said means when it is desired to reverse the operation of the engine.

13. An opposed-piston engine according to claim 9 which comprises a fuel oil pump cylinder attached to and movable with the engine cylinder, and a piston in the cylinder secured in a stationary position for pumping the fuel oil.

14. An opposed-piston engine according to claim 9 which comprises at least two pumps one mounted on each side of the engine cylinder, and a set of springs on each side of and attached to the engine cylinder for aiding in the transverse movement of the engine cylinder.

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