Nov. 10, 1942. A. R. EARNSHAW ET AL 2,301,175

ENGINE

Filed Sept. 5, 1939 3 Sheets-Sheet 1

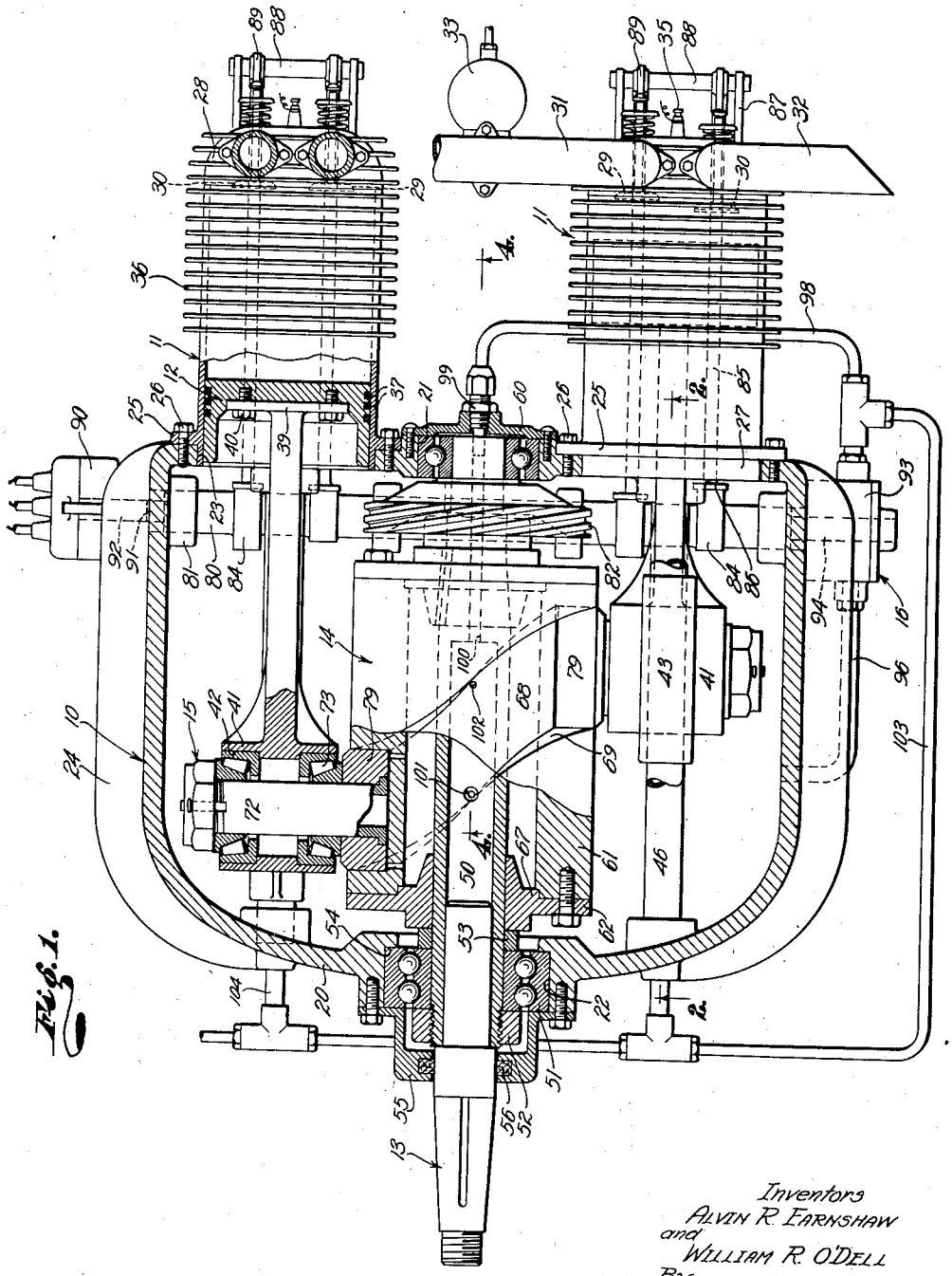


Fig. 1.

Inventors
ALVIN R. EARNSHAW
and
WILLIAM R. O'DELL
By
Their Attorney

Nov. 10, 1942. A. R. EARNSHAW ET AL 2,301,175

ENGINE

Filed Sept. 5, 1939 3 Sheets-Sheet 2

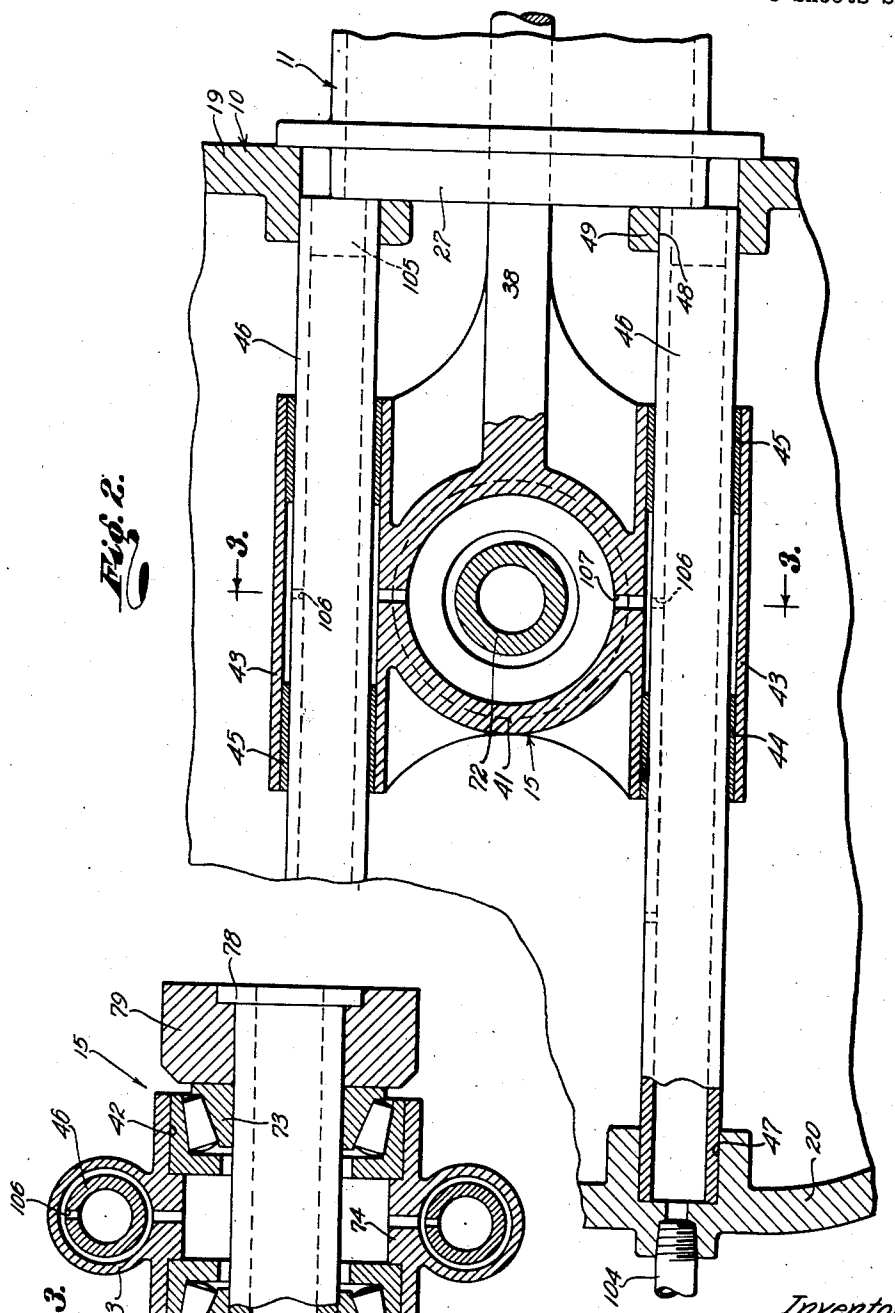


Fig. 2.

Fig. 3.

Inventors
ALVIN R. EARNSHAW
and
WILLIAM R. O'DELL
By
Their Attorney

Nov. 10, 1942. A. R. EARNSHAW ET AL 2,301,175

ENGINE

Filed Sept. 5, 1939 3 Sheets-Sheet 3

Fig. 5.

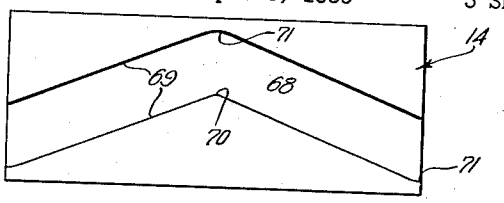


Fig. 4.

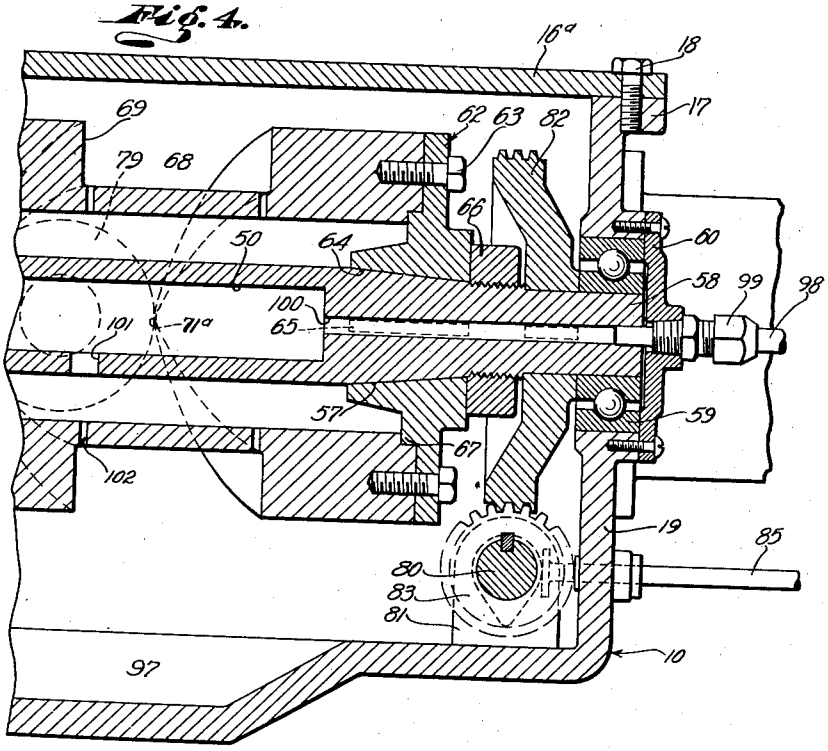
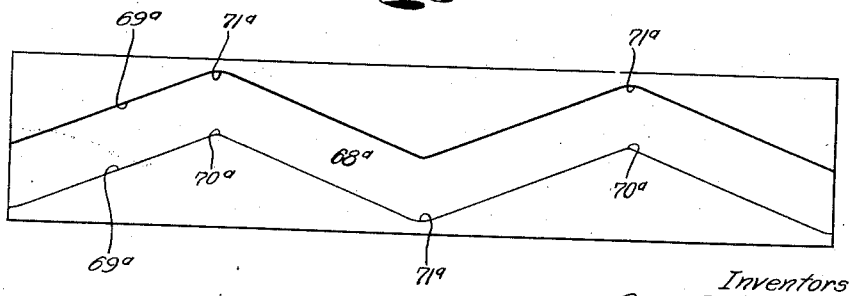


Fig. 6.



Inventors
ALVIN R. EARNSHAW
and
WILLIAM R. O'DELL
By
Their Attorney

Patented Nov. 10, 1942 2,301,175

UNITED STATES PATENT OFFICE

2,301,175

ENGINE

Alvin R. Earnshaw and William R. O'Dell,
Bakersfield, Calif.

Application September 5, 1939, Serial No. 293,338

3 Claims. (Cl. 74—57)

This invention relates to engines and relates more particularly to internal combustion engines. A general object of this invention is to provide an internal combustion engine that is compact, light in weight, and very efficient.

Another object of this invention is to provide an engine embodying novel and very effective means for converting the reciprocatory motion of the pistons to rotary motion of the shaft, which means overcomes and fully avoids the disadvantages and deficiencies of the cranks now generally used for this purpose. It is well known that the cranks as now employed in the cylinder and piston type engines are inefficient and lose a substantial part of the power due principally to the change in leverage during the crank motion or crank stroke. The means embodied in the engine of the present invention for the translation of the power and motion from the pistons to the engine shaft produces a uniform leverage throughout the strokes of the pistons to produce rotation of the shaft with a minimum power loss.

Another object of this invention is to provide an engine in which the shaft is in parallel relation to the cylinders, greatly conserving space and reducing vibration and wear.

Another object of this invention is to provide an internal combustion engine that operates with a minimum of vibration and imposes practically no lateral or transverse forces on the shaft.

Another object of this invention is to provide an internal combustion engine embodying a cam connected with the engine shaft in co-axial relation thereto and having a single track in which parts connected with the pistons operate to efficiently transmit the power between the pistons and shaft. The engine of the present invention embodies a single integral cam having a single track in which rollers connected with the several pistons operate to provide a drive or transmission between the reciprocating pistons and the rotating shaft. The single cam track is of great importance as it simplifies the structure and makes the engine compact and the single track may be designed or contoured to provide the desired speed ratio between the pistons and the shaft thereby obtaining maximum power with high speed engine operation, without resorting to the use of gearing or other speed reduction means.

Another object of this invention is to provide an engine of the character mentioned in which rollers associated with the pistons cooperate with the cam track to produce rotation of the cam and shaft with a minimum of friction and are related in such a manner that the thrusts or forces on the cam and shaft are balanced, providing for practically vibrationless operation.

Another object of this invention is to provide an engine of the character mentioned in which the cam may be of as large diameter as desired or required without materially increasing the aggregate weight of the engine. The cam embodied in the engine of the present invention is tubular or hollow and constructed to be very light in weight, adapting the engine for air craft use, etc.

Another object of this invention is to provide an engine of the character mentioned embodying an effective yet very simple lubrication system.

A further object of this invention is to provide an internal combustion engine of the character mentioned that requires a minimum number of bearings and that is easily serviced and repaired.

The various objects and features of my invention will be fully understood from the following detailed description of typical preferred forms and applications of the invention, throughout which description reference is made to the accompanying drawings, in which:

Fig. 1 is a central longitudinal detailed sectional view of the engine of this invention with a portion of the cam and certain other parts in side elevation. Fig. 2 is an enlarged fragmentary vertical detailed sectional view taken substantially as indicated by line 2—2 of Fig. 1. Fig. 3 is a vertical detailed sectional view taken as indicated by line 3—3 on Fig. 2. Fig. 4 is an enlarged fragmentary vertical detailed sectional view taken as indicated by line 4—4 on Fig. 1. Fig. 5 is a diagrammatic stretch-out view of the cam illustrated in the preceding figures, and Fig. 6 is a similar view of another form of cam that may be embodied in the invention.

The engine of the present invention may be said to comprise, generally, a case 10, cylinders 11 on the case 10, pistons 12 operable in the cylinders 11, a shaft 13 entering the case 10, a cam 14 on the shaft 13 within the case 10, means 15 associating the pistons 12 with the cam 14 whereby the pistons drive or rotate the cam, a lubrication system 16 and other parts the functions and details of which will be later described.

The case 10 may house and carry the various other parts of the engine and, of course, may be varied considerably depending upon the intended use of the engine, the size of the engine, etc. As illustrated, the case 10 is a generally

rectangular hollow member or structure closed at its upper side by a removable plate or cover 16a. Lugs 17 are provided along the upper edge of the case 10 and screws 18 pass through openings in the plate 16a and thread into the lugs 17 to removably secure the plate in place. One end wall 19 of the case 10 is flat and generally vertical, while the other end wall 20 of the case 10 is rounded to have a concave internal surface and a convex external surface. Aligned openings 21 and 22 are provided in the end walls 19 and 20, respectively, of the case 10 to receive bearings for the shaft 13, as will be later described. The openings 21 and 22 are preferably co-axial with the major longitudinal axis of the case 10. Openings 23 are provided in the case wall 19 to receive the cylinders 11. The openings 23 are equally spaced from the common axis of the openings 21 and 22 and are symmetrically disposed. Thus, where the engine has two cylinders 11 the openings 23 are diametrically opposite. The case 10 may be cooled, as found most desirable. In the construction illustrated the case 10 has longitudinal cooling fins 24.

The cylinders 11 project axially or outwardly from the wall 19 and are arranged to have their longitudinal axes in parallel relation with the shaft receiving openings 21 and 22. The cylinders 11 are suitably secured to the wall 19. In the preferred construction the cylinders 11 have flanges 25 secured to the case wall 19 by screws 26. Skirts 27 on the inner ends of the cylinders 11 may cooperate with the openings 23 to assist in locating and securing the cylinders. The cylinders 11 are closed at their outer ends by suitable heads 28. The heads 28 have the usual inlet ports and outlet ports controlled by inlet and outlet valves 29 and 30. Manifolds 31 and 32 communicate with the inlet and outlet ports and a suitable carburetor 33 may be associated with the inlet manifold 31. Spark plugs 35 are mounted in the cylinder heads 28 to ignite the charges in the cylinders 11. The mechanisms for operating the valves 29 and 30 will be later described. The cylinders 11 and their heads 28 are suitably cooled. In the form of the invention illustrated the cylinders 11 and the heads 28 have series of spaced cooling fins 36. The cylinders 11 are, of course, of equal length and bore.

The pistons 12 for operating in the cylinders 11 may be of any selected or required type and construction. As illustrated the pistons 12 are of simple construction and carry sets of suitable rings 37 for slidably sealing with the walls of the cylinders 11. The backs of the pistons 12 are preferably concave. Stems or rods 38 are secured to the backs of the pistons 12. The piston rods 38 may have heads 39 on their outer ends secured in the concave backs of the pistons 12 by screws 40. The piston rods 38 extend into the case 10 and are provided at their inner ends with enlargements 41. The enlargements 41 have rather large cylindrical openings 42 whose axes are transverse of the rods 38 and radial relative to the longitudinal axis of the case 10. The openings 42 receive elements of the means 15 as will be later described. Each piston rod enlargement 41 has a pair of diametrically opposite wings or side parts 43. The parts 43 are tubular, having central longitudinal openings 44. The openings 44 are spaced from and parallel with the piston rods 38 and each opening 44 carries a pair of spaced bushings 45.

Guides 46 pass through the tubular parts 43 to guide the rods 38 and the pistons 12 and to relieve the parts of strains as will be later described. The guides 46 are elongate tubular members extending longitudinally through the case 10 from the wall 19 to the wall 20. The inner ends of the guides 46 are set in openings or sockets 47 in the case wall 20 while the outer parts of the guides 46 are received in openings 48 provided in lugs 49 at the inner ends of the openings 23. The guides 46 are passed to their positions by entering them through the openings 48 prior to the attachment of the cylinders 11 to the case 10 and when the cylinders are secured to the wall 19 by the screws 26 the inner ends of the cylinders engage the ends of the guides 46 to hold the guides in position. The ends of the guides 46 engage the bottom walls of the sockets 47. It will be seen that the spaced guides 46 effectively guide the rods 38 and support the rods against lateral forces.

The shaft 13 passes through the opening 22 to extend centrally into or through the case 10. The projecting outer portion of the shaft 13 may be tapered, threaded, and provided with a keyway to facilitate its connection with a part or mechanism to be driven by the engine. The major portion of the shaft 13 has a longitudinal opening 50 and in the preferred construction illustrated the projecting outer portion of the shaft 13 is a plug-like section whose inner portion is fixed in the opening 50. A suitable anti-friction bearing 51 supports the shaft 13 in the opening 22. The bearing 51 may be engaged between a nut 52 screwed on the shaft 13 and a collar 53 on the shaft. One end of the bearing 51 engages against a shoulder 54 in the opening 22 while a cap 55 is secured to the case wall 20 and engages against the other end of the bearing. The cap 55 has suitable packing 56 sealing about the shaft 13. The inner part of the shaft 13 has a tapered portion 57 and a reduced portion 58 (see Fig. 5). An anti-friction bearing 59 supports the reduced shaft portion 58 in the opening 21. A cap 60 is secured to the case wall 19 to extend across the outer end of the opening 21 and the cap serves to hold the bearing 59 in place. The shaft 13 mounted as just described is in spaced parallel relation to the guides 46 and the piston rods 38.

The cam 14 is a novel element and is an important operating part of the engine. The cam 14 is fixed to the shaft 13 within the case 10. In the preferred construction the cam 14 comprises an integral tubular section 61 and end members 62. The tubular cam section 61 surrounds the shaft 13 in spaced concentric relation thereto and the members 62 serve to mount the section on the shaft 13. Screws 63 secure the members 62 to the opposite ends of the section 61. One end member 62 is formed with a tapered opening 64 receiving the tapered shaft portion 57 and a key 65 cooperates with keyways in the portion 57 and the opening 64 to key the cam 14 to the shaft 13. A nut 66 is screwed on the shaft 13 to retain the end member 62 on the tapered shaft portion 57. The end member 62 surrounding the plain portion of the shaft 13 may engage the collar 53 adjacent the bearing 51. It is to be noted that the shaft 13 and the cam 14 are hollow or chambered to reduce the weight of the assembly. The cam section 61 preferably has a thick wall and is centered on the end members 62 by sockets or counterbores cooperating with bosses 67 on the end members.

In accordance with the invention the cam sec-

tion 61 is provided with a track or cam groove 68. The cam groove is cut or formed in the periphery of the section 61 and the section 61 may be plain and cylindrical except for the groove 68. It is a feature of the invention that there is a single continuous track or cam groove 68 provided in the cam. The groove 68 is preferably of uniform depth and of substantially uniform width throughout its length. The inner wall of the cam groove 68 is cylindrical and concentric with the longitudinal axis of the cam 14 and the side walls 69 of the groove are at right angles to the inner wall and are substantially parallel at any given axial plane of the cam. The contour or shape of the cam groove 68 is important and in accordance with the invention may be varied to produce the desired or required engine operation. The groove 68 is pitched or curved axially and circumferentially of the cam 14, being of double or compound helical curvature. In the form of cam 14 illustrated in Figs. 1 to 5, inclusive, the groove 68 is of double helical curvature, that is, it is formed so that each side wall 69 has one peak 70 and one depression 71. The peak 70 of one wall 69 is directly opposite the depression 71 in the opposite wall 69. The peak 70 and depression 71 of a groove wall 69 lie in a common axial plane but are disposed at opposite sides of the axis of the cam 14. In the form of the invention illustrated the groove 68 is symmetrical, that is, the slope or pitch of the walls 69 are the same at the opposite sides of the cam 14. It is to be understood that the degree of angularity or pitch of the walls 69 may be varied as desired, and that the pitch of a wall 69 may be different at the opposite sides of the cam. The purpose of varying the pitch of the cam groove walls 69 and of making the pitch different at opposite sides of the cam will be later described. Figs. 1 and 4 illustrate the shape and formation of the cam groove 68 while Fig. 5 illustrates the relationship of the peaks 70 and depressions 71.

Fig. 6 of the drawings illustrates a cam groove 68^a that may be formed in the cam 14 to provide for a differential in the speed of operation of the pistons 12 and the shaft 13. In this construction the groove 68 is continuous, extending completely around the cam 14, and is made up of a multiplicity of oppositely pitched portions. The cam groove 68^a is formed so that its side walls 69^a have series of alternate peaks 70^a and depressions 71^a. The peaks 70^a of one wall 69^a directly oppose the depressions 71^a of the other wall. The sets or pairs of opposing peaks 70^a and depressions 71^a are symmetrically or equally spaced around the cam. Thus where there are four pairs of peaks 70^a and depressions 71^a the pairs of peaks and depressions are spaced 90° apart. The pitch or inclination of the cam groove 68^a may be varied as found desirable and the angularity or pitch of certain portions of the groove may differ from other portions of the groove. While Figs. 5 and 6 show the grooves 68 and 68^a provided with straight pitched parts it is to be understood that these portions are curved or helical as shown in Figs. 1 and 4. The cam section 61 provided with the groove 68 or the groove 68^a, as the case may be, is formed of a material that is resistant to wear and that is capable of being tempered, hardened, or otherwise treated so that the walls of its groove are hard and wear resistant.

The means 15 is an anti-friction roller means associated with the piston rods 38 and cooperating with the groove in the cam 14 to convert reciprocation of the pistons 12 into rotation of the shaft 13 and vice versa. There is a means 15 provided in the enlargement 41 of each piston rod 38. Figs. 1 and 3 of the drawings illustrate the details of the means 15. Each means 15 includes a rotatable shaft or pin 72 passing longitudinally through the opening 42 of a piston rod enlargement 41 with substantial clearance. Pairs of anti-friction bearings 73 support the pins 72 in the openings 42. The inner ends of the bearings 73 engage against flanges 74 formed on the walls of the openings 42. Nuts 75 are screwed on the outer ends of the pins 72 and the outer ends of the outer bearings 73 engage against the nuts. Means is provided for locking the nuts 75 in place. These means include keys 76 cooperating with longitudinal grooves or keyways in the nuts 75 and the pins 72 and cotter keys 77 pass through radial openings in the nuts 75 and keys 76. The pins 72 are tubular and the inner portions of the cotter keys 77 project into the pins so that they may be turned over. The lock means just described eliminates the necessity for lock nuts on the pins 72 and thus reduces the overall length of the assembly. Heads 78 are provided on the inner ends of the pins 72 and rollers 79 are pressed or otherwise fixed on the inner portions of the pins 72 to engage against the heads 78.

The rollers 79 are received in and cooperate with the cam groove 68 of the cam 14. The peripheries of the rollers 79 ride on or cooperate with the side walls 69 of the groove 68. The parts are related so that the ends of the rollers 79 have clearance with the inner wall of the groove 68. During operation the cooperation of the rollers 79 with the groove walls 69 causes rotation of the rollers 79 and their pins 72 and the rollers roll along the groove walls. During the power stroke of a piston 12 the related roller 79 cooperates with the pitched wall 69 of the groove 68 to rotate the cam 14 and the shaft 13. During the compression, exhaust and intake strikes of the pistons the cooperation of the rollers 79 and the groove 68 causes movement of the pistons. It will be seen that the diameter of the cam 14 and the pitch of the cam groove walls 69 determine the ratio between the piston speed and shaft speed or rotation.

The engine includes a valve operating means for operating the intake and exhaust valves 29 and 30 of the cylinders 11. This means includes a cam shaft 80 rotatably supported in the case 10 by spaced pairs of spaced bearings 81 on the bottom wall of the case. The shaft 80 is arranged at right angles to the main shaft 13 and is preferably spaced below the main shaft. A gear drive is provided between the shaft 13 and the shaft 80 to produce the required rotation of the cam shaft. This gear means includes a helical gear 82 fixed or keyed to the shaft portion 58 and a mating gear or pinion 83 keyed to the cam shaft 80. Pairs of spaced cams 84 are provided on the cam shaft 80. Rods 85 pass through openings in the case wall 19 and have heads 86 engaging the cams 84. Brackets 87 on the cylinder heads 28 carry rocker shafts 88 and the outer ends of the rods 85 operatively engage rockers 89 on the shafts 88. The rockers 89 cooperate with the spring held stems of the valves 29 and 30. The invention is not primarily concerned with the details of the valve operating mechanism and these details may be conventional.

The ignition system of the engine may com-

prise a distributor 90 arranged at the exterior of the case 10 in axial alignment with the cam shaft 80. A suitable driving connection 91 operatively connects the distributor shaft 92 with an end of the cam shaft 80 so that the distributor is driven by the cam shaft. The ignition system of course includes the battery or other source of electrical energy and the leads extending to the distributor 90 and the spark plugs 35 and the other conventional parts of such a system.

The lubrication system or lubricating means 16 includes a pump or pump unit 93 arranged in axial alignment with the cam shaft 80. The shaft 94 of the pump unit 93 has a suitable connection 95 with one end of the shaft 80 to be driven by the cam shaft. An intake or low pressure line 96 extends from a sump 97 in the bottom wall of the case 10 to the low pressure side of the pump unit 93. A high pressure lubricant line 98 extends from the pump unit 93 to a fitting 99 on the cap 60. The inner portion of the shaft 13 is bored to have a longitudinal opening 100 and the fitting 99 discharges the lubricant into the opening 100. The opening 100 communicates with the shaft opening 50 to supply lubricant under pressure thereto. The shaft 13 has radial ports 101 for discharging the lubricant into the tubular cam section 61 and lateral ports 102 are provided in the wall of the cam section 61 to discharge the oil or lubricant into the cam groove 68. The ports 102 are preferably located to discharge at the inner wall of the groove 68 adjacent the groove side walls 69. The lubricant under pressure discharged from the ports 102 effectively lubricates the walls of the groove 68 and the rollers 79.

The lubricating system further includes a high pressure lubricant line 103 extending from the high pressure side of the pump unit 93 and provided with branches 104 which deliver the lubricant to the sockets 49 in the case wall 20. This lubricant discharges into the tubular guides 46. Plugs 105 close the outer ends of the tubular guides 46 to prevent the oil or lubricant from discharging into the cylinders 11. Lateral ports 106 are provided in the walls in the tubular guides 46 to discharge the lubricant. The ports 106 are preferably provided in the upper sides of the guides 46 so that the guides normally retain a supply of lubricant. The ports 106 are adapted to communicate with the openings 44 in the parts 43 to effectively lubricate the guides 46 and the bushings 45. In practice the spaces between the bushings 45 at all times contain baths of the lubricant. Radial ports 107 are formed in the piston rod enlargements 41 to conduct the lubricant from the openings 44 to the openings 42. This lubricant effectively lubricates the bearings 73 and the other elements of the means 15. With the engine in operation the pump unit 93 continuously supplies lubricant under pressure to the lines 98 and 103 to lubricate the various working parts. The lubricant discharging from the ports 102 forms a spray or mist in the case 10.

In the operation of the engine it may be assumed that a suitable fuel is supplied to the carburetor 33 and that the ignition system is associated with a suitable source of electrical energy to provide electric discharges at the spark plugs 35. The engine illustrated and described is a four cycle engine and the ignition system and the valves 29 and 30 are, of course, suitably timed to provide for a four cycle operation. As illustrated in Fig. 1 of the drawings the cam 14 is constructed so that one piston 12 is at the inner end of its stroke while the other piston 12 is at the outer end of its stroke. With this relationship the cam 14 cooperating with the means 15 provides for simultaneous reciprocation of the pistons in opposite directions. Accordingly, when one piston 12 begins its power stroke the other piston 12 is at the start of its exhaust stroke. The power stroke of a piston 12 of course results in the forcible inward movement of the piston rod 38 and the roller 79 carried by that rod cooperates with an inclined groove wall 69 to transmit the movement and force to the cam 14 and the shaft 13. The engagement of the roller 79 with the cam groove wall 69 converts the axial movement of the piston 12 to turning movement of the cam 14 and shaft 13. The cam groove wall 69 may be of uniform pitch or inclination and the cam 14 may be of uniform diameter so that there is a uniform leverage or mechanical advantage throughout the power stroke of the piston. This distinguishes the engine of the present invention over the usual engine embodying a crank shaft wherein the leverage changes during the stroke. The cam 14 may be formed to obtain a very high efficiency or horse power output with a minimum piston displacement. The momentum or inertia of the cam 14, the shaft 13 and the associated parts carries the cam through its complete revolutions so that the rollers 79 travel past the pairs of peaks 70 and depressions 71 at the opposite ends of the piston strokes 12. The peaks 70 and depressions 71 are formed in such a manner that reversal of movement of the rollers 79 is smooth and devoid of vibration. In this connection it is to be observed that the thrusts given the pistons 12 upon the firing of the fuel charges in the cylinders 11 are directed parallel with the shaft 13 so that the cam and the shaft are subjected to little or no lateral thrust. The cooperation of the parts 43 with the guides 46 dependably supports the piston rods 33 against the lateral thrusts and forces resulting from the cooperation of the rollers 79 with the cam groove 68. The rollers 79 at all times engage the cam 14 at diametrically opposite points so that the forces on the cam and the shaft 13 are balanced. Accordingly, the cooperation of the rollers 79 with the cam groove 68 imposes a minimum strain on the cam and shaft assembly and produces practically no vibration.

When the cam groove 68 is symmetrical, as illustrated in the drawings, the speed of piston travel 12 bears a given relation to the speed of rotation of the shaft 13 throughout the several strokes of the pistons. By making one portion or one half of the cam groove 68 of greater inclination than the other half the pistons 12 may be made to travel at a higher speed relative to the rate of rotation of the shaft 13 during certain phases of the operation. For example, it may be desired to increase the speed of travel of the pistons 12 during the compression and exhaust strokes and this may be accomplished by increasing the pitch of the cam groove 68 at one side of the cam 14 where the cam is of the type illustrated in Figs. 1 and 5. If it is desired to drive the shaft 13 at a relatively slow speed and with great power a cam of the character illustrated in Fig. 6 of the drawings may be employed so that there is a differential in the speed of operation between the pistons 12 and the shaft 13. When employing a cam of the character shown in Fig. 6 the engine, that is, the pistons 12, may be operated at a high rate to develop great power without driving the shaft at a high speed. It will

be seen that where a cam of the character shown in Fig. 6 is employed each piston 12 has four complete strokes or movements during each rotation of the cam 14, whereas each piston has only two strokes during rotation of the cam when the cam is constructed as shown in Fig. 5. The engine of the present invention embodying the novel cam 14 eliminates the use of the conventional cranks, connecting rods, etc. and makes it possible to arrange the cylinders, shaft, case, etc. in a compact unit. The engine of the present invention operates to develop the maximum power in relation to its size and displacement.

Having described only typical preferred forms and applications of our invention, we do not wish to be limited or restricted to the specific details herein set forth, but wish to reserve to ourselves any variations or modifications that may appear to those skilled in the art or fall within the scope of the following claims.

Having described our invention, we claim:

1. In an engine having a cylinder, a piston operable in the cylinder and a rotatable cam provided with a cam groove, the combination of, a rod connected with the piston, an enlargement formed on the outer end of the rod and provided with an opening transverse of the rod and openings parallel with and spaced at opposite sides of the longitudinal axis of the rod, bearing means in the transverse opening, a pin rotatably carried by the bearing means to project in one direction therefrom and having an enlargement of its projecting end, a roller tight on the pin in engagement with the enlargement on the projecting end of the pin and cooperating with the cam groove, and fixed guides extending through the second named openings for guiding the rod and roller.

2. In an engine having a cylinder, a piston operable in the cylinder and a rotatable cam provided with a cam groove, the combination of, a rod connected with the piston, an enlargement formed on the outer end of the rod and provided with an opening transverse of the rod and openings parallel with and spaced at opposite sides of the longitudinal axis of the rod and communicating with the transverse opening, a pin received in the transverse opening, bearing means rotatably supporting the pin in the transverse opening, a roller on the pin for cooperating with the cam groove, fixed tubular guide rods passing through the second named openings to guide the piston rod and roller and provided with ports for communicating with said second named openings, and means for supplying lubricant to the tubular guide rods to lubricate both the guide rods and said bearing means.

3. In an engine having a piston rod carrying a roller, the combination of a rotatable shaft extending parallel with the rod and having a tapered portion, a tubular cam body surrounding the shaft in concentric relation thereto and having a cam groove for receiving the roller, end members at the ends of the cam body carried by the shaft, one end member having a tapered opening for receiving the tapered portion of the shaft and at least one end member being keyed to the shaft, and means detachably securing the cam body to the end members to be mounted on the shaft thereby.

ALVIN R. EARNSHAW.
WILLIAM R. O'DELL.