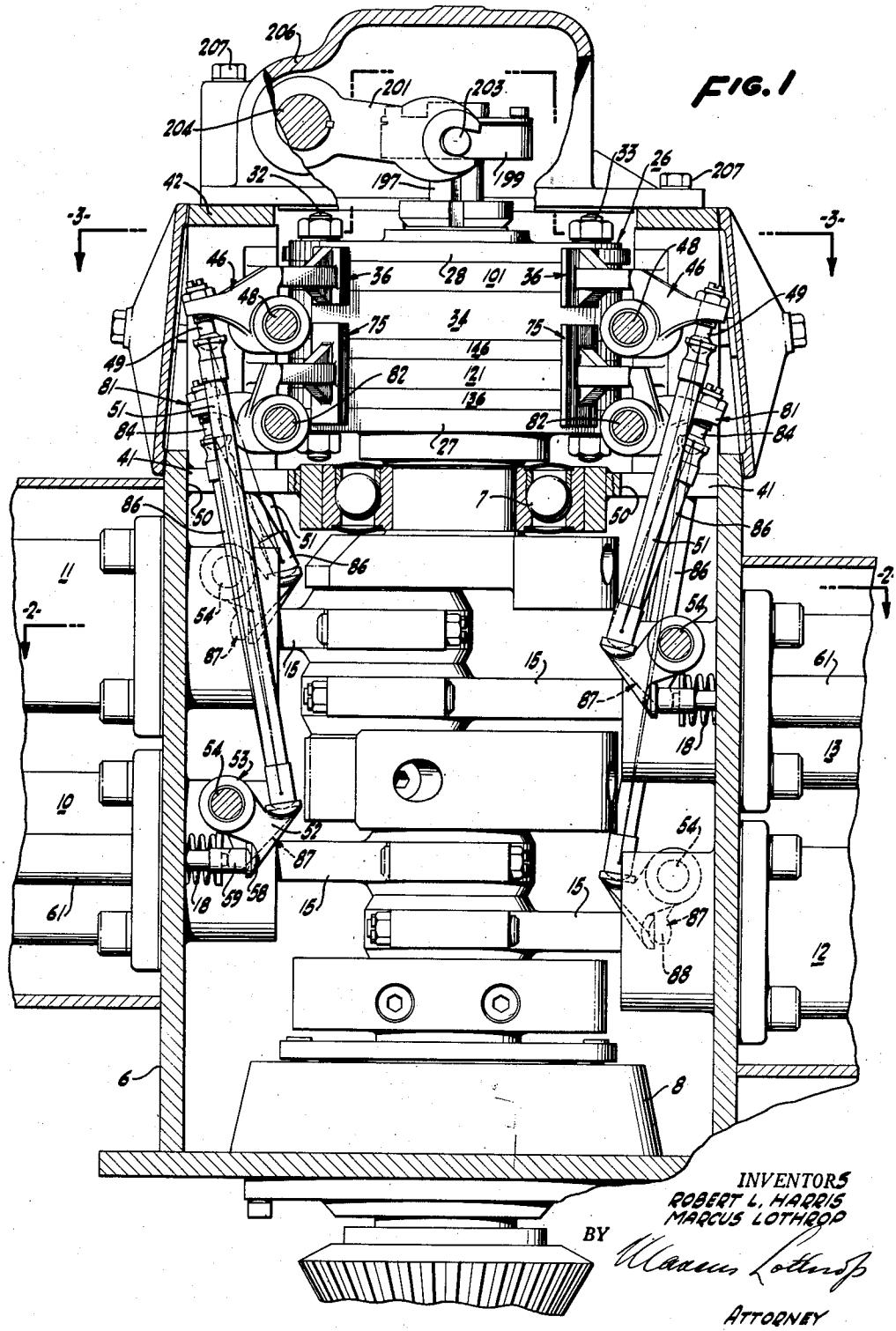
Sept. 28, 1954 R. L. HARRIS ET AL 2,690,165

STEAM ENGINE WITH CAM ACTUATED VALVES

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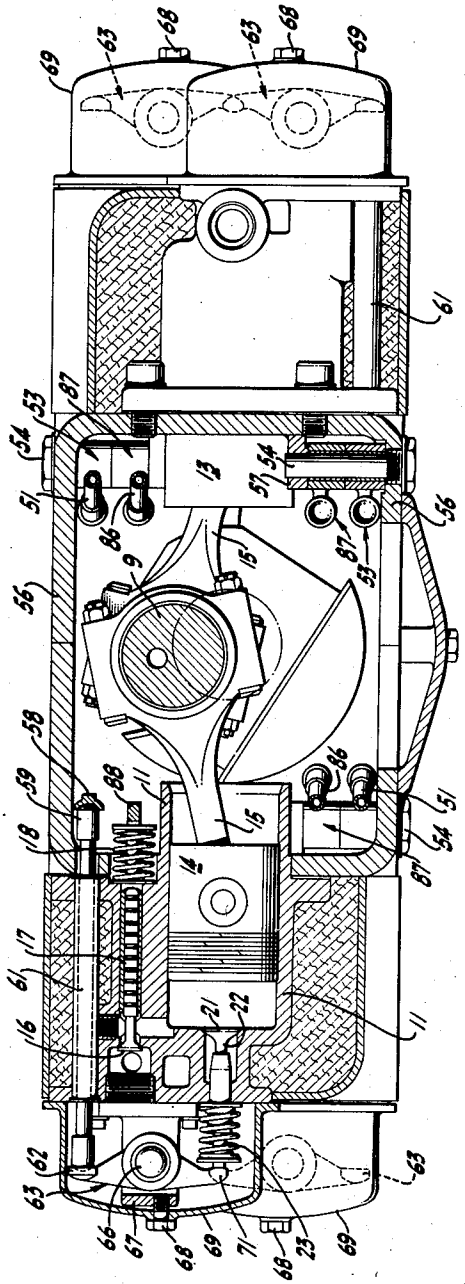


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STEAM ENGINE WITH CAM ACTUATED VALVES

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FIG. 2



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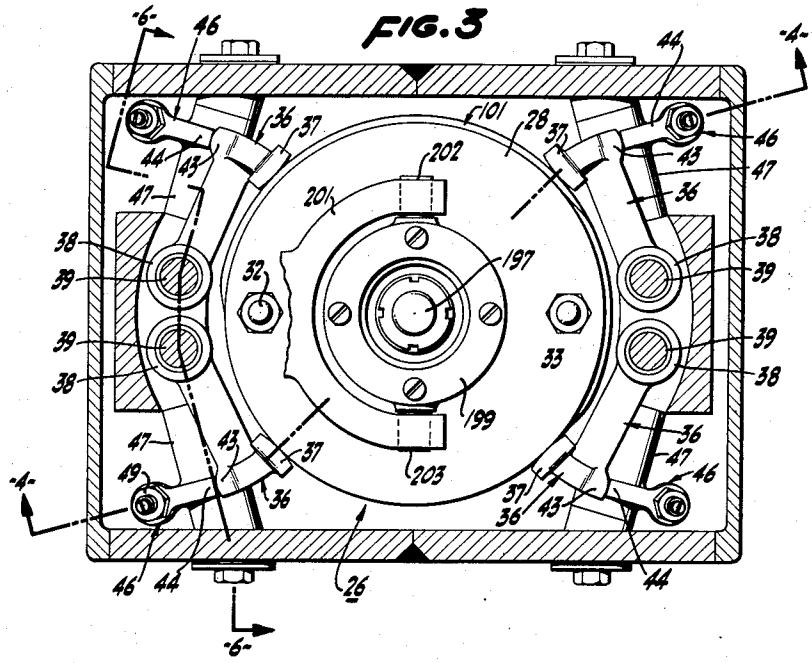
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STEAM ENGINE WITH CAM ACTUATED VALVES

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FIG. 3



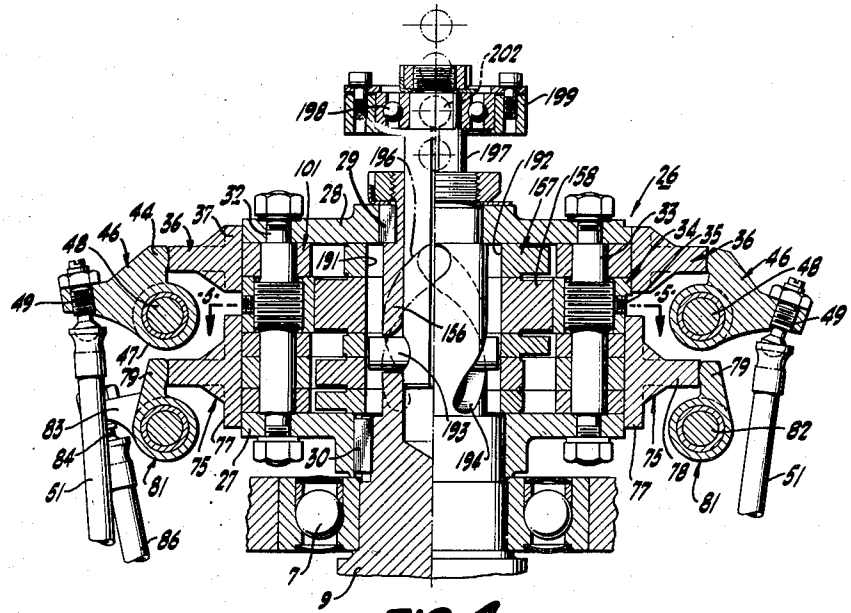


FIG. 4

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STEAM ENGINE WITH CAM ACTUATED VALVES

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FIG. 5

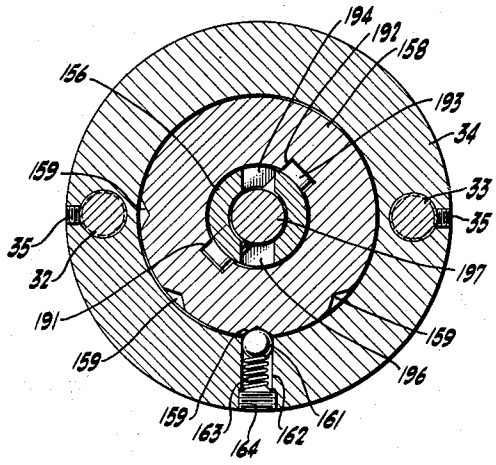
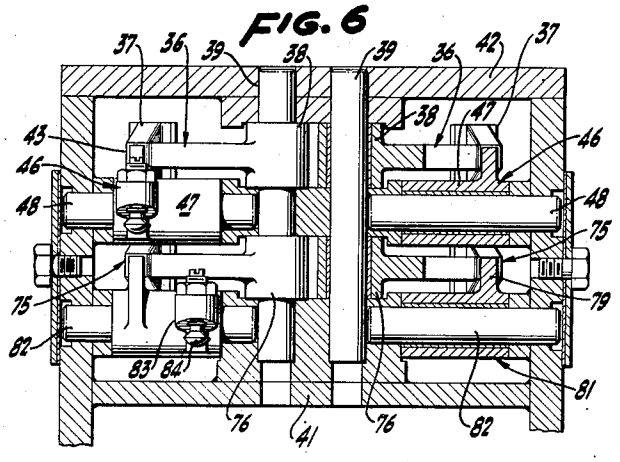


FIG. 6



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STEAM ENGINE WITH CAM ACTUATED VALVES

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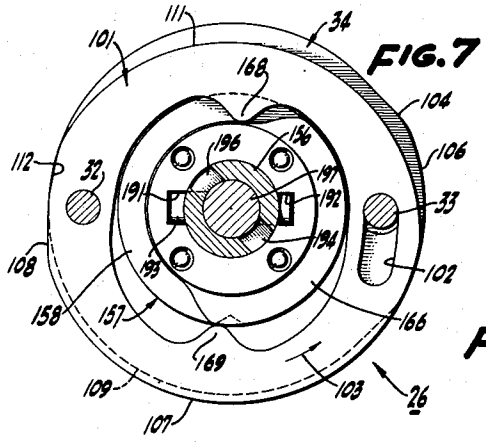


FIG. 7

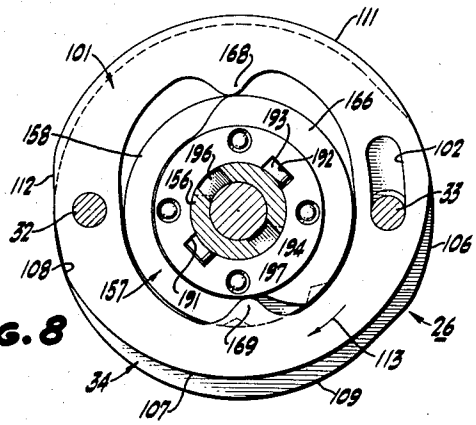


FIG. 8

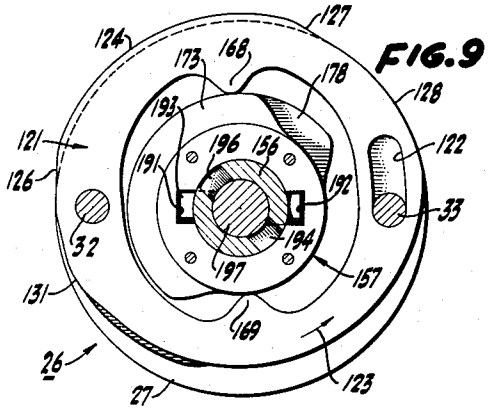


FIG. 9

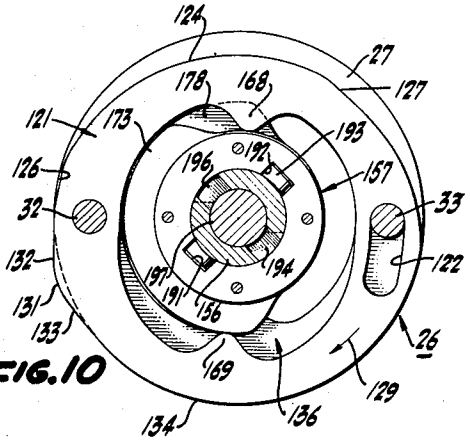


FIG. 10

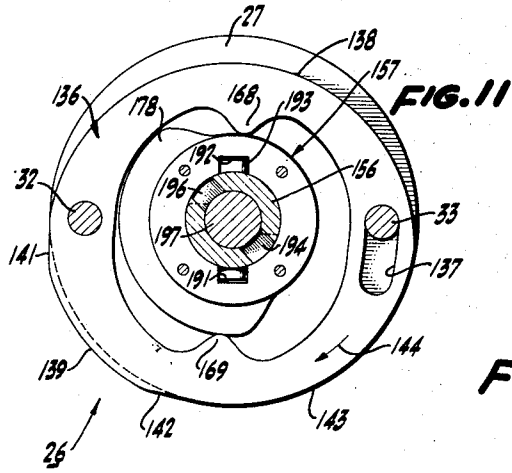


FIG. 11

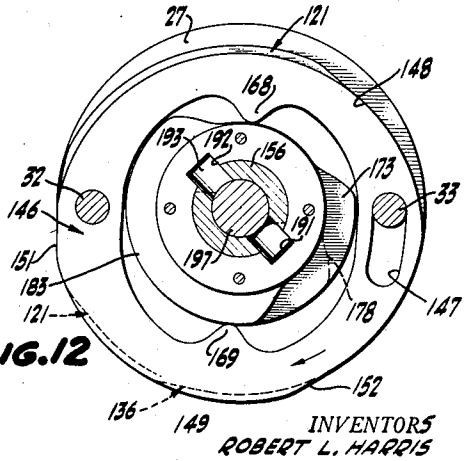


FIG. 12

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STEAM ENGINE WITH CAM ACTUATED VALVES

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FIG. 13

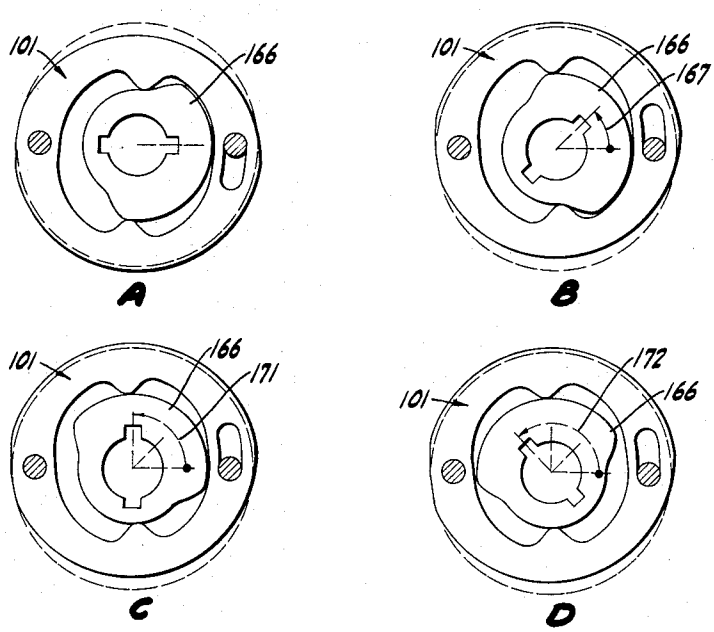
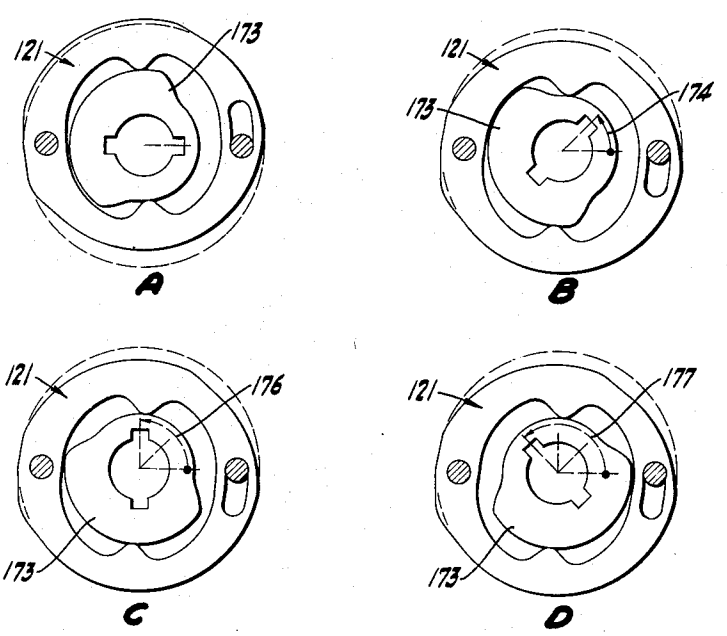


FIG. 14



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STEAM ENGINE WITH CAM ACTUATED VALVES

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FIG. 15

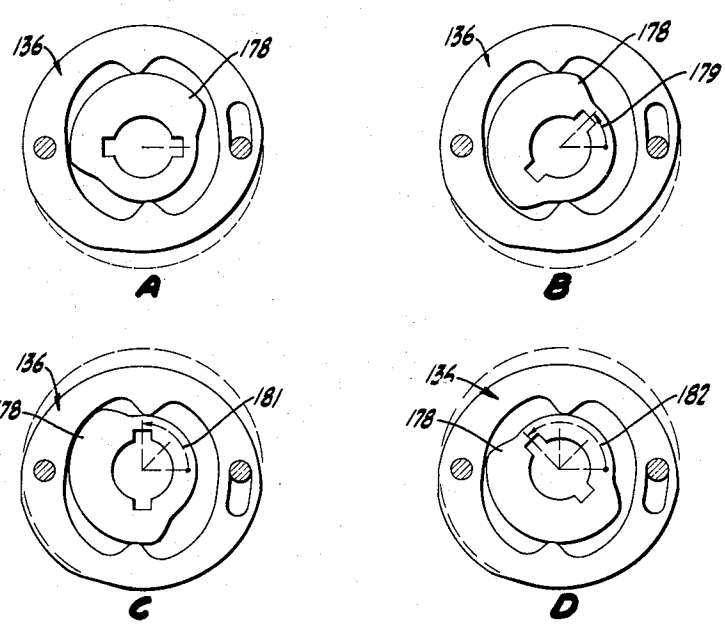
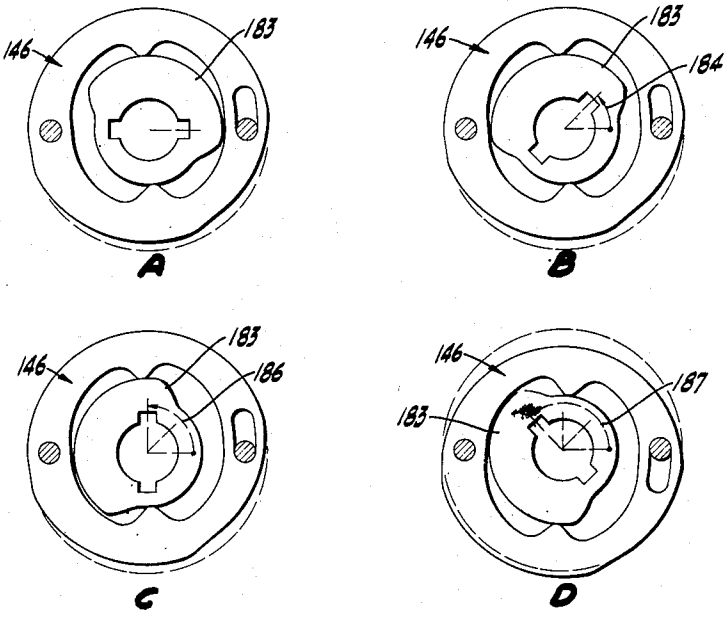


FIG. 16



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STEAM ENGINE WITH CAM ACTUATED VALVES

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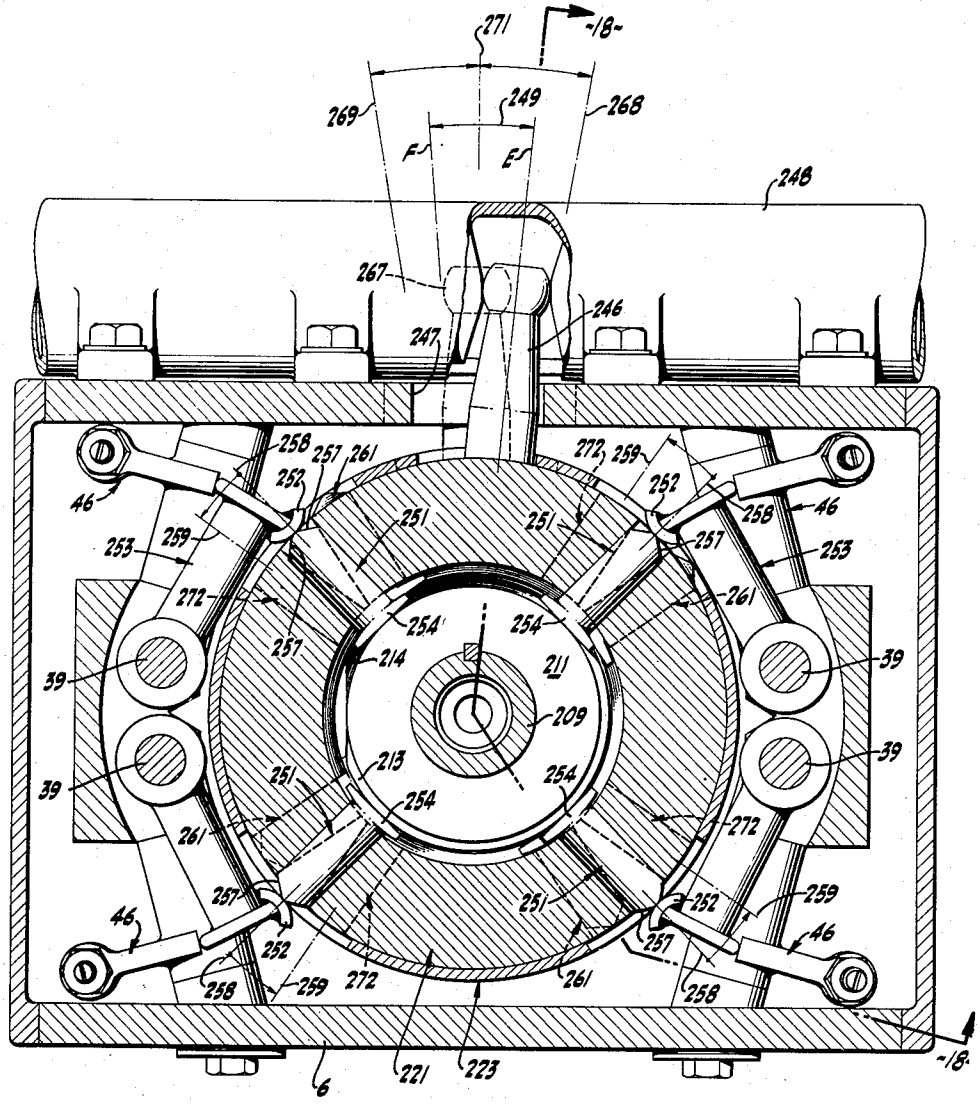


FIG. 17

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STEAM ENGINE WITH CAM ACTUATED VALVES

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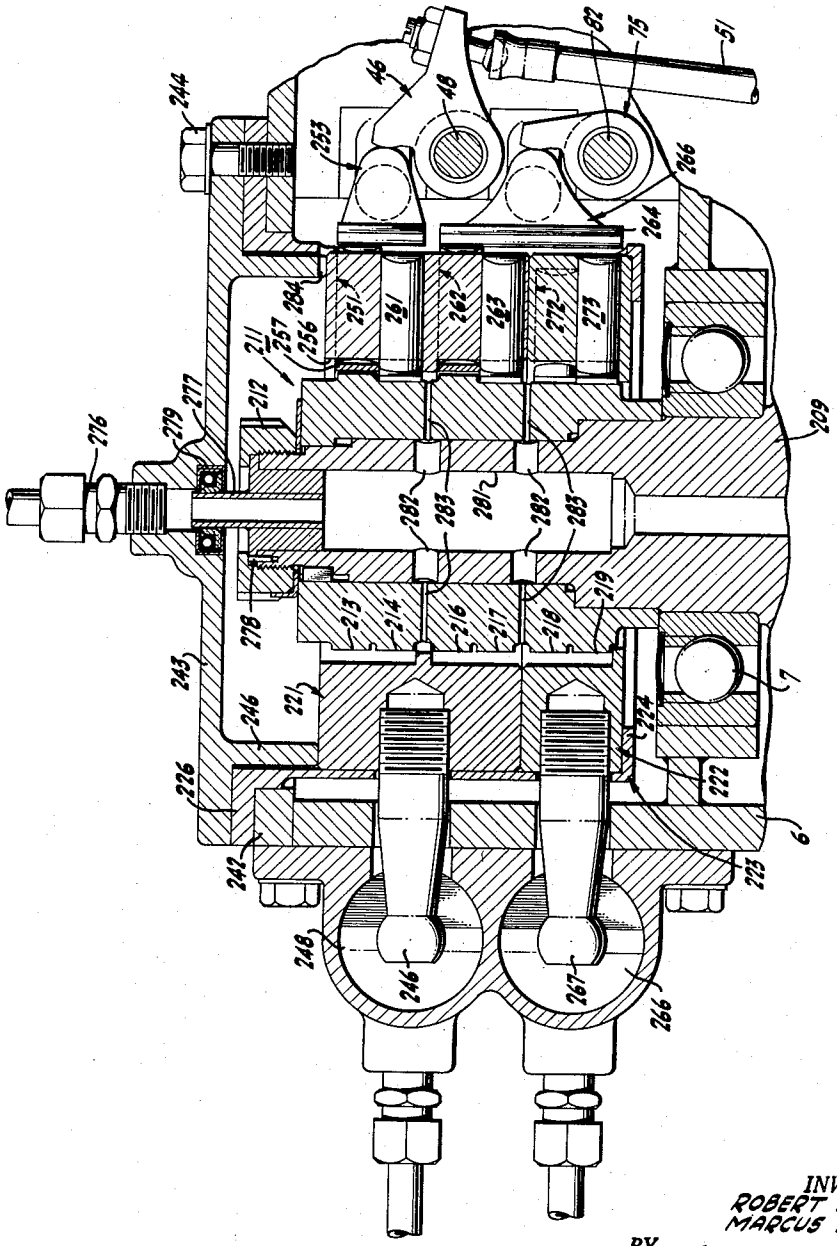


FIG. 18

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Patented Sept. 28, 1954

2,690,165

UNITED STATES PATENT OFFICE

2,690,165

STEAM ENGINE WITH CAM ACTUATED VALVES

Robert L. Harris and Marcus Lothrop, Berkeley, Calif., assignors to Yuba Manufacturing Company, a corporation

Application March 28, 1952, Serial No. 279,128

14 Claims. (Cl. 121—127)

1

Our invention relates to engines operated by fluids and is especially concerned with engines primarily for vehicular use and of the type shown in our co-pending application, Serial Number 52,662, filed October 9, 1948, and entitled "Steam Engine Having a Unitary Valve Actuator," now Patent No. 2,591,933, issued April 8, 1952.

One of the types of reciprocating, fluid-actuated engines employs unbalanced poppet valves in the cylinders to control the admission and release of operating fluid. For vehicular engine use it is customary to provide a forward motion valve actuation, a rearward motion valve actuation, and almost always several positions of steam cutoff of the inlet valve. Presently used steam temperatures and pressures are moderately high, usually approximating 1000 degrees Fahrenheit and 2000 pounds per square inch. It is desirable to operate a reciprocating steam engine at a relatively high speed, say, 2500 revolutions per minute. All of these factors make it difficult to provide satisfactory valve motion. It is difficult to shift the valve actuating structure from forward to reverse position. It is difficult to change the inlet cutoff positions. It is even more difficult to accomplish these changes at high speed and at high temperatures and high pressures. It has been found hard in actual practice to keep wear to a reasonable amount. Some of the wear is apparently due to high loads and some of it is apparently due to unsatisfactory lubrication.

It is therefore an object of our invention to provide an improved steam engine with cam actuated valves.

Another object of our invention is to provide a valve mechanism for a steam engine which can easily be shifted into various different operating positions.

A further object of our invention is to provide a steam engine with adequate lubrication.

A still further object of our invention is to provide a steam engine valve mechanism capable of long life under severe operating conditions, i. e. high pressure, high temperature and high speed.

An additional object of our invention is to provide an engine with cam actuated valves which can readily be fabricated without costly machining and by ordinary techniques.

Other objects, together with the foregoing, are attained in the embodiments of the engine described in the accompanying description and illustrated in the accompanying drawings, in which:

Figure 1 is a cross section through an engine constructed in accordance with our invention,

2

many of the parts being shown in side elevation and some portions being broken away to disclose the interior construction and to reduce the size of the figure.

Figure 2 is a cross section of an engine constructed in accordance with our invention, the principal planes of section being indicated by the lines 2—2 of Figure 1 and the scale being reduced. Certain parts are shown in different planes of section and other portions are removed for clarity of disclosure.

Figure 3 is a cross section, the plane of which is indicated by the line 3—3 of Figure 1.

Figure 4 is a cross section, the several planes of which are indicated by the lines 4—4 of Figure 3.

Figure 5 is a detail in cross section, the plane of which is indicated by the line 5—5 of Figure 4.

Figure 6 is a side elevation with portions in section, the general planes of the view being indicated by the line 6—6 of Figure 3.

Figure 7 is a fragmentary view showing in plan a portion of the exhaust cam mechanism in reverse position.

Figure 8 is a fragmentary view showing in plan a portion of the exhaust cam mechanism in forward position.

Figure 9 is a fragmentary plan showing an inlet cam in reverse position.

Figure 10 is a fragmentary plan showing the inlet cam of Figure 9 in 10% cutoff forward position.

Figure 11 is a fragmentary plan showing an inlet cam for 40% cutoff forward position.

Figure 12 is a fragmentary plan showing an inlet cam for 75% cutoff forward position.

Figure 13 shows in fragmentary plan in views A, B, C and D the several positions of the exhaust cam for the four operating conditions of the engine.

Figure 14 shows in fragmentary plan in views A, B, C and D the four positions of one of the inlet cams for the four conditions of the engine.

Figure 15 shows in fragmentary plan in its four views A, B, C and D the positions of another inlet cam for the four conditions of the engine.

Figure 16 shows in fragmentary plan in its four views A, B, C and D the positions of an additional inlet cam for the four conditions of the engine.

Figure 17 is a view somewhat like Figure 3 showing a modified form of engine cam mechanism partially in plan and partially in cross section on a transverse plane.

Figure 18 is a cross section, parts being in side elevation, of the modified form of structure illustrated in Figure 17, the various planes of sec-

tion being indicated by the lines 18—18 of Figure 17.

In the practical embodiment of the invention as illustrated in Figures 1 to 16, there is provided an engine assembly having a generally rectangular crank case 6 carrying bearings 7 and 8 to mount a crank shaft 9 with its axis substantially vertical. Arranged on either side of the crank shaft are pairs of cylinders 10 and 11 as well as 12 and 13. Within each of the cylinders is a piston 14 connected by a suitable connecting rod 15 to its respective portion of the crank shaft 9.

As especially shown in Figure 2, each of the cylinders is provided with an inlet poppet valve 16 designed to control the influx of operating fluid, such as steam, to the engine. The valve 16 has a stem 17 arranged with its axis in one plane parallel to the axis of the crank shaft and also in another plane perpendicular to the axis of the crank shaft.

The valve is closed by a spring 18 in the customary fashion and is operated by reciprocation in the direction of its axis. Somewhat similarly, the cylinder is provided with an exhaust valve 21 having a stem 22 the axis of which is substantially coincident with that of the cylinder, is parallel to the axis of the valve 16 and is in a plane perpendicular to the axis of the crank shaft. The valve stem 22 emerges from the head of the cylinder and carries a return spring 23 in the usual way. Operation of the exhaust valve in the direction of its axis controls the outflow of steam from the cylinder.

There is provided mechanism for operating the various valves in the various cylinders not only in proper sequence or time but also at several selected times in accordance with the desires of the operator. The crank shaft 9 adjacent its upper end is provided with a cam assembly 26 (Figures 1 and 4). The cam assembly is made up of a number of individual cam rings and is also inclusive of a bottom plate 27 and a top plate 28, both provided with connecting keys 29 and 30 for securing the cam assembly for rotation in unison with the engine crank shaft. The plates are held in proper relationship by spacer bolts 32 and 33 disposed on a diameter of the cam assembly.

Located on the bolts 32 and 33 between the top and bottom plates 27 and 28 is an intermediate ring 34 (Figures 4 and 5). This is mounted in correct axial position by threaded engagement with the bolts 32 and 33 and is locked by appropriate set screws 35. The outlines or envelope contours of the ring 34 and of the plates 27 and 28 are largely but not entirely circular and their peripheries serve in part as positioning surfaces for the cam mechanism.

Since there are four cylinders there are provided four substantially identical valve actuating devices, the description of one applying generally to the others. As an example, there is provided for the cylinder 10 an appropriate cam follower 36 (Figures 1, 3 and 4) constituted by a lever having a broad axially extending shoe 37 of sufficient extent to overlap the edge of the plate 28 and part of the ring 34. The lever or follower 36 is also provided with a hub 38 oscillatable on a pin 39 anchored in the top bearing wall 41 (Figure 1) and in the cover wall 42 of the crank case. As the follower 36 oscillates about the axis of the pin 39, the shoe 37 moves with a substantial radial component with respect to the crank shaft axis.

In abutment with a contact boss 43 on the follower 36 is a similar contact boss 44 on a rocker 46. The rocker 46 includes a hub 47 rotatable about a pin 48 appropriately mounted in the crank case 6. Also included in the rocker 46 is an adjustable ball end 49 socketed in the cooperating end of a push rod 51 extending through an appropriate opening 50 in the crank case wall 41. The lower end of the push rod 51 (Figure 1) extends to an appropriate seat in an arm 52 of a bell crank 53. The hub of the bell crank is journaled for oscillation on a stub shaft 54 removably anchored between an outer wall 56 (Figure 2) of the crank case and an inner bracket wall 57 therein. The push rod axis is not exactly parallel to the axis of the crank shaft but is in the same general direction and can be characterized as approximately or substantially parallel to the crank shaft.

Extending into the crankcase with its axis in a plane approximately perpendicular to the axis of the crankshaft is a thrust rod 59, one end of which is received in a socket 58 on the bell crank 53. The thrust rod 59 passes through a tube 61 included in the cylinder casting and emerges at the cylinder head to engage a socket 62 at one end of a rocker lever 63, a symmetrical and corresponding lever being shown in full lines in the upper left hand portion of Figure 2. The rocker lever 63 is journaled on a central pin 66 secured in a bracket 67 fastened to the cylinder casting. The bracket also carries a bolt 68 for holding a cover 69 in position. The other end of the rocker lever 63 has an enlarged boss 71 in abutment with the end of the valve stem 22. With this motion train, any movement of the follower 36 and of the shoe 37 in a radial direction causes oscillation of the rocker 46, a longitudinal motion of the push rod 51, a rotary oscillation of the bell crank 53 and a corresponding longitudinal motion of the thrust rod 59. This is productive of a rocking motion of the rocker lever 63 and a corresponding translation of the valve stem 22 and actuation of the exhaust valve.

In a comparable fashion for each of the cylinders an inlet valve actuating mechanism is provided. This includes a follower 75 (Figures 4 and 6) having a hub 76 also journaled on the pin 39 and carrying an axially extended shoe 77 effective to span in an axial direction from the ring 34 to the lower plate 27. The follower 75 also has an extension 78 abutting a pad 79 on a rocker crank 81. This crank includes a relatively long hub journaled on a pin 82 parallel to the pin 48 and similarly mounted. Extending from the hub of the crank 81 is an arm 83 carrying an adjustable ball mechanism 84 received in the socketed end of a push rod 86. The push rod also extends through the opening 50 in the wall 41 of the crank case and at its lower end is received in a bell crank 87 (Figure 2) also journaled on the stub shaft 54. The axis of the push rod 86 is inclined somewhat more to the axis of the crankshaft than is that of the push rod 51, but still can be characterized as being substantially parallel to the crankshaft. Motion of the bell crank 87 is imparted to the adjacent inlet valve by an arm 88 depending from the bell crank 87 and in immediate contact with the inlet valve stem 17 itself.

With this motion train, when the follower shoe 77 is given a rotary motion having a radial component, the rocker crank 81 is oscillated and the push rod 86 is similarly moved in a longitudinal direction. The bell crank 87 is rotated on its

shaft 54 and the stem 17 of the associated inlet valve is operated. Substantially identical actuating mechanisms are provided at four equally spaced points around the periphery of the cam assembly 26 and by appropriate pairs of push rods, like the push rods 51 and 86, the motion is transmitted in proper sequence to the various cylinders of the engine. The push rods are of different lengths and are of different inclinations because of the geometry of the engine layout but all of them are characterized as having their axes substantially or approximately parallel to that of the crank shaft. While this valve motion train is inclusive of a large number of different parts and is in some respects somewhat more massive than is desirable for high speed operation, yet it provides a relatively rigid or stiff system. Despite the number of elements involved in the valve motion train movements imparted to the shoes 37 and 77 are transmitted without substantial variation or change to the stem 17 of the inlet valve and to the stem 22 of the exhaust valve. The motion train is susceptible of operation at relatively high speeds and under high pressures without substantial error in the valve action.

The particular time at which the followers 36 and 75 are operated with respect to the rotary position of the crankshaft determines whether or not the engine will run forward or backward. The particular duration of movement of the inlet follower 75 determines whether the steam admitted to the cylinder adjacent top dead center position of the piston will be cut off near the end of the inlet stroke, near the middle of the inlet stroke, or near the beginning of the inlet stroke. To provide the various valve events desired, the cam assembly 26 is not entirely a fixed or rigid mechanism although the bottom plate 27, the top plate 28 and the intermediate ring 34 are held by the bolts 32 and 33 in fixed relationship to the crank shaft. Other parts of the cam assembly are movable.

As shown particularly in Figures 7 and 8, for example, there is provided an exhaust cam 101 which is essentially a ring journaled to oscillate or swing about the bolt 32 as a hub from one extreme position as shown in Figure 7 to an opposite extreme position as shown in Figure 8. The cam ring 101 is provided with an elongated arcuate slot 102 so that the movement can take place without interference with the bolt 33. In the cam ring position shown in Figure 7, it being understood that the direction of engine rotation is counterclockwise as shown by the arrow 103, upon rotation of the cam assembly with the crankshaft the exhaust follower shoe 37 is first actuated in a valve opening direction by ramp surfaces 104 and dwell surfaces 106 formed on both the upper plate 28 and the adjacent portion of the intermediate ring 34. The force for opening the valve is imposed on the shoe by these two spaced and fixed members of the cam assembly.

The contour of the dwell surface 106 is continued by an exactly coincident dwell surface 107 on the cam ring 101. This dwell surface in the stated position of the cam is concentric with the axis of the crankshaft. The surface 107 terminates in a ramp 108 leading to the base circle configuration 109 of the plate 28 and the ring 34. In effect, therefore, in this position of the cam ring 101, the projected or envelope curvature of the cam ring, of the plate 28 and of a portion of the intermediate ring 34 is a cam contour effective to open the exhaust valves approximately 45 degrees before bottom dead center position of the pistons in the associated cylinders and to close the exhaust valves at approximately top dead center position of the pistons in the associated cylinders. The timing is such that this cam position operates the exhaust valves properly within the time limits for reverse engine rotation.

When the cam 101 is shifted from its reverse position at one extreme as shown in Figure 7 to its forward position at its other extreme as shown in Figure 8, the surface 107 and the ramp 108 are both completely withdrawn within the envelope curvature 109 of the top plate 28 and the intermediate ring 34. The contour 111 across the diameter of the cam is such that in the position shown in Figure 8 part of the cam is concentric with and continues the dwell surface 106. The cam contour 111 then merges with a ramp portion 112 symmetrical with the ramp portion 108. The direction of engine rotation with the exhaust cam in this position is clockwise as indicated by the arrow 113 in Figure 8. When the cam 101 is projected on one side of a center plane the envelope curvature of the cam is proper for one direction or rotation of the engine with the other portions of the cam being withdrawn or masked or made inoperative. With the cam projected to the opposite extreme position for the opposite direction of engine rotation, the previously masked or inoperative portions of the cam are projected for operation and the previously operating portions of the cam are themselves masked. There is consequently provided by the combination of the top plate 28 the intermediate ring 34 and the shiftable intervening cam 101 what amounts to a variable cam for the exhaust functions of reverse and forward motion.

In a somewhat similar fashion, there is provided, as especially shown in Figures 9 and 10, a cam ring 121 arranged to rotate about the bolt 32 as a hub and having an arcuate slot 122 to limit its motion about the bolt 33. This cam ring is designed to operate the inlet valves both in the reverse engine rotation and in the forward rotation with a short or early cutoff, approximately 10 per cent. The operation of the cam ring 121 is quite similar to that of the cam ring 101. When the direction of rotation is as shown by the arrow 123 in Figure 9, that is, in reverse, the cam is positioned so that all of its contour not taking part in the reverse sequence is withdrawn. There is then a projecting portion 124 with appropriate ramps 126 and 127 and a concentric portion 128. The concentric portion registers in plan with corresponding portions of the intermediate ring 34 and of the lower plate 27. The resulting envelope contour with this direction of rotation lifts the inlet valves by cam actuation against the follower shoe 77 at top dead center position of the pistons in the cylinders and then closes the inlet valves at about 60 degrees before bottom dead center positions of the pistons in their cylinders.

When the cam ring 121 is swung to its opposite extreme position as shown in Figure 10, the direction of rotation is forward as shown by the arrow 129. The previously described cam surfaces are then withdrawn within the envelope curvature of the intermediate ring and the bottom plate 27 but a short cutoff portion 131 with adjacent ramps 132 and 133 then projects. The remaining portion 134 is concentric. The angular extent of the cam portion 131 is only sufficient to open the inlet valve at approximately top dead center position of the piston and then to close the valve again at a short cutoff approximately ten per cent of the stroke of the piston away from

top dead center location. The cam ring 121 therefore in one extreme position is effective to control the inlet valves during reverse motion with a relatively long cutoff and in its other extreme position is effective to control the inlet valves for forward rotation but with short cutoff.

To supplement the operation of the cam ring 121 there is, as shown in Figure 11, another cam ring 136 included in the cam assembly. This cam ring is likewise freely rotatable about the bolt 32 and is provided with an arcuate slot 137 for clearance and limitation of motion with respect to the bolt 33. The cam ring 136 is so arranged that it has a portion 138 which never projects beyond the envelope boundary of the corresponding portion of the intermediate ring 34 or of the lower plate 27. On its opposite side, however, it is provided with an extended portion 139 and adjacent ramps 141 and 142 as well as a concentric portion 143. This extreme position of the cam ring 136 is effective in forward rotation as shown by the arrow 144 in Figure 11 to actuate the inlet valves. Each valve is held open from approximately top dead center position of the piston to an intermediate cutoff position at approximately 40 per cent of the total piston stroke. Preferably, the cam rings 121 and 136 operate simultaneously in the 40 per cent stroke cutoff position so that the inlet follower shoe 77 is actuated by both cams for the opening motion but is finally permitted to close solely by the ramp 142 of the cam ring 136. In its opposite extreme position, the cam ring 136 is ineffective.

To provide the third forward inlet valve closing option at about 75 per cent of the piston stroke away from top dead center, there is supplied an additional cam ring 146 as shown in Figure 12. This cam ring is rotatable about the bolt 32 as a hub and is also provided with a slot 147 giving clearance and affording a stop with regard to the bolt 33. The cam ring 146 is like the cam ring 136 in that it has an inactive periphery 148 around substantially half of its circumference. This never projects beyond the envelope boundary of the intermediate ring 34 or of the lower plate 27. The remaining portion of the cam ring 146 is provided with an extended dwell portion 149 and adjacent ramps 151 and 152. Thus, when the cam ring is swung into one extreme position, the surface 148 is ineffective because it never projects whereas in the opposite extreme position the dwell portion 149 is projected and the inlet valve is held open to about 75 per cent of the stroke of the corresponding piston. As indicated in Figure 12, the location of the various cam rings 121, 136 and 146 is preferably such that for the forward opening of an inlet valve the shoe 77 is simultaneously engaged by all of the lifting ramps 132, 141, and 151 whereas the closure of the valve depends on the ramp last exposed, such as 152. With this mechanism, therefore, it is possible by suitably orienting the various cam rings to produce both exhaust and inlet functions for both reverse and forward movement and to provide a total of three different cutoff closures for the inlet valves in forward motion.

In order that the cam rings 101, 121, 136, and 146 can be projected to one side or the other in appropriate order, I provide an internal actuating member particularly as shown in Figures 4 and 7 to 12. The crank shaft 9 at its upper end between the keys 29 and 30 is provided with a circular cylindrical portion 156 on which is journaled an assembly 157 of cam actuators, sometimes referred to as "cam cams." The cam actuators are all of substantially identical shape as shown in Figures 13 to 16 and can occupy any rotary position but primarily occupy four selected positions.

The central portion of the cam actuator assembly 157 is provided with an enlarged ring 158 (Figure 5) having a plurality of depressions 159 at appropriate locations. Engageable with these depressions is a detent ball 161 movable in a radial hole 162 in the intermediate ring 34 and pressed radially inward by a spring 163 retained by a plug 164. While the cam assembly 157 is freely rotatable on the crankshaft, it is normally retained in any one of four positions by the detent 161.

As particularly illustrated in Figures 13 to 16 inclusive, there are shown the various locations of the individual cam actuators in each of the four positions of the cam assembly 157 to produce the correspondingly correct locations for the cam rings 101, 121, 136 and 146 respectively. For example as shown in Figure 13 the exhaust cam ring 101 is actuated by a cam 166. When the actuator cam 166 is in one extreme position as shown in Figure 13A, the exhaust cam ring 101 has the reverse position also illustrated in Figure 7. When, as shown in Figure 13B, the actuator cam 166 is advanced one step, approximately through an angle 167; that is, from retention by one of the detent notches 159 to the next detent notch, the cam cam 166 engaging inward projections 168 and 169 on the interior of the cam ring 101 shifts the cam ring 101 from one extreme position to the other. The dimension measured across any diameter of the cam cam is substantially constant. The diametrical distance between the projections 168 and 169 is fixed. The effect of rotation of the actuating cam 166 with respect to the crankshaft 9 is to shift the cam ring 101 from one extreme position into another extreme position or substantially against the bolt 33 by rotation about the bolt 32. The actuating movement therefore shifts the cam ring 101 between its reverse position and its forward position.

As shown in Figure 13C, a further increment of rotation of the actuating cam, illustrated by the arrow 171, produces no further projecting movement of the cam ring 101 but does serve to hold the cam ring in proper position during the time the engine operates in its 40 per cent cutoff forward condition. Similarly, as shown in Figure 13D, an additional increment of rotation of the cam cam 166 as illustrated by the arrow 172 retains the cam ring 101 in its forward position while the engine is conditioned for 75 per cent forward inlet cutoff.

The positions of the cam ring 121 responsive to the four positions of its actuating cam 173 are illustrated in Figures 14A to D. In the initial positions of the cam 173 (displaced from that of the actuating cam 166) the cam ring 121 is projected (Figure 14A) but as the actuating cam 173 is rotated through an increment represented by the arrow 174 into the position illustrated in Figure 14B, the cam ring 121 is retracted from its previously projected position and is projected on the opposite side. This serves to shift the inlet valve actuation from 75 per cent cutoff during reverse rotation to a 10 per cent cutoff during forward rotation. A further increment of motion of the cam cam 173 as illustrated in Figure 14C and represented by the arrow 176 is effective to hold the cam ring 121 in its 10 per cent cutoff position. Similarly, as shown in Figure 14D, a still further increment of motion represented by the arrow 177 retains the

cam ring 121 in its 10 per cent cutoff location.

As illustrated in Figures 15A to D, the cam ring 136, although provided with an actuating cam 178 of the same shape as those previously described, operates somewhat differently in that it does not project beyond a circular envelope position on one side of the cam assembly 26. The cam ring position during reverse rotation is shown in Figure 15A within the envelope curvature and has no effect. Even when the actuating cam 178 advances through an increment of motion indicated by the arrow 179, the cam ring 136 remains within the circular envelope. The cam ring 136 remains in retracted condition during reverse rotation and also during 10 per cent cutoff forward rotation of the engine.

When the cam actuator 178 advances through a further increment illustrated by the arrow 181 in Figure 15C, the cam ring 136 is shifted across center so that its surface 139 is effective to produce a 40 per cent duration of opening of the inlet valves. A further increment of motion of the actuating cam 178, illustrated by the arrow 182 in Figure 15D, retains the cam ring 136 in its projected position during the time the engine operates at 75 per cent cutoff forward rotation.

Finally, as shown in Figures 16A to D, the cam ring 146 during reverse rotation is held within a circular envelope by virtue of the actuating cam 183. This is the position shown in Figure 16A. As shown in the Figure 16B, during operation of the engine at 10 per cent cutoff forward condition, the cam ring 146 is held in ineffective position even though the actuating cam 183 has moved through one increment indicated by the arrow 184. When the actuating cam 183 has moved through another increment as indicated by the arrow 186 in Figure 16C, the cam ring 146 is still ineffective. But when the actuating cam 183 has moved through its final increment of movement, as illustrated by the arrow 187 in Figure 16D, the cam ring 146 is then shifted so that its actuating portion 149 projects to hold the inlet valve motion trains open for 75 per cent cutoff.

With this arrangement, the various cam rings operate directly upon the several valve actuators or followers and are positioned in such a way that they are either effective or ineffective to provide the forward and reverse movements and the various positions of cutoff desired.

The relative rotation of the group 157 of cam cams or cam actuators with respect to the crankshaft 9 is effectuated by structure particularly illustrated in Figures 1, 3 and 4. The assembly 157 is formed with a pair of diametrically opposite axially extending grooves 191 and 192. Designed to operate in the grooves is a cross pin 193 also passing through a pair of helical apertures 194 and 196 cut diametrically opposite each other through the hollow end of the crankshaft. The pin 193 pierces an operating rod 197 coaxial with the crankshaft and movable longitudinally with respect thereto. A thrust bearing 198 in an operating collar 199 is mounted on the end of the operating rod 197.

When the collar 198 is moved up and down in the direction of the crankshaft axis it simultaneously moves the thrust bearing with it. The collar 199 does not revolve with the crankshaft. The operating rod 197 revolves with the crankshaft and is translated with respect thereto. As it travels, it carries the pin 193 axially and rotatably with respect to the crankshaft because of contact with the boundaries of the helical apertures 194 and 196. The rotation of the pin 193 produces a corresponding rotation of the assembly 157 with respect to the crankshaft and moves the various actuating cams with respect to the crankshaft.

Motion is imparted to the shifting collar 199 by a fork 201 bifurcated and notched at its ends to engage stubs 202 and 203. The fork lever 201, as shown especially in Figure 1, is mounted on a rotatable shifting shaft 204 journaled in a cover 206 secured to the crankcase by fastenings 207. An appropriate mechanism (not illustrated) is utilized to rotate the shaft 204 into any of four selected positions corresponding to the four positions of the detent mechanism shown in Figure 5. By simply moving the shaft 204, in most cases accomplished by an operator controlled hydraulic mechanism, the rod 197 is axially displaced and the actuator cams are revolved into appropriate positions to shift the cams 101, 121, 136, and 146 into proper positions to produce the requisite operation of the engine.

In an alternative form of the invention disclosed especially in Figures 17 and 18, the engine for the most part is substantially unchanged. In place of the cam assembly 26, a cam drum 211 is keyed to the upper end of the crankshaft 209 for rotation therewith and is held against axial movement by a jam nut 212. The cam drum 211 includes a reverse exhaust cam 213, a forward exhaust cam 214, a reverse inlet cam 216, a forward 10 per cent cutoff inlet cam 217, a forward 40 per cent inlet cam 218, and a forward 75 per cent cutoff inlet cam 219. These cams all revolve in unison with the crankshaft.

Encompassing the cam drum 211 are two cam follower rings 221 and 222. These rings are coaxial with the crankshaft 209 and are mounted for rotation in a circular cylindrical cage 223 interrupted at various areas of its periphery. The cage 223 includes a lower inturned flange 224 on which the ring 222 rests and has an upper out-turned flange 226 resting on the crankcase top wall 242. A cover plate 243 is secured by fastenings 244 to the crankcase and incorporates an internal downturned flange 246 resting at intervals on the upper ring 221 to act as a confining means for the rings.

The rings carry cam followers of the plunger type. Since for each cylinder there is an appropriate set of followers, a description of one set applies to the others. As shown particularly in Figure 17, the upper cam ring 221 is rotatable between two extreme positions by an operating lever 246 projecting through an aperture 247 in the rear wall of the crankcase 6. A hydraulic actuating mechanism 248 is preferably utilized to move the lever 246 with an arcuate motion designated by the arrow 249 between one extreme position, indicated by the line E and another extreme position indicated by the line F. In the position shown for reverse engine rotation, the ring 221 is so turned that each of four exhaust valve actuating plungers or followers 251 is in appropriate position to operate a shoe 252 on a rocker follower 253 corresponding to the follower 36 as shown in Figure 3. The follower 253 connects with the rocker 46 exactly as shown in Figure 3 and the rest of the motion train is the same as previously described.

In this position of the mechanism, a flat shoe 254 on the inner end of the follower 251 is contacted by the revolving reverse exhaust cam 213. The shoe 254 is extended to abut the subjacent shoe which itself abuts the wall of a

groove 256 turned in the ring 211 and so rotation of the follower 251 is prevented. If the shoe extension is omitted, the follower is free to rotate in its bore in the ring 211. The outer end of the follower 251 is turned or is provided with a double bevel 257. In any radial position of the parts, upon rotation of the ring 221 and the follower 251 (Figure 17) can move between one extreme position (shown by the line 258) out of contact with the shoe 252 and another extreme position (shown by the line 259) in contact with the shoe. When the plunger 251 is out of contact with the shoe, the cam 213 is ineffective upon the follower 253, but when the plunger 251 is in its active position, the cam 213 is effective to produce corresponding motion of the follower 253. All of the valve operating mechanisms are similarly actuated and disposed. The reaction of the valve actuating mechanisms against the ring 221 which might tend to displace the ring from either of its extreme positions is appropriately resisted by the hydraulic shift mechanism 246. Any sort of retainer or lock which will hold the lever 246 in either extreme position when desired is effective for the purpose.

At the time the reverse exhaust follower 251 is shifted out of contact with the shoe 252, a forward exhaust follower 261, previously located in ineffective position as shown in Figure 17, is moved into active position. The cam 214 rather than the cam 213 then is effective to control the exhaust valve events. Which cam, 213 or 214, is effective depends upon the position of the lever 246. The exhaust function of all cylinders for forward and reverse rotation is so controlled.

Since with a change in the exhaust function it is necessary also to effectuate a change in the inlet function, the ring 221 also carries a pair of inlet followers 262 and 263 or plungers similar to and spaced immediately below their corresponding exhaust followers. One of the inlet followers is actuated by the reverse inlet cam 216, and the other inlet follower is actuated by the forward 10 per cent cutoff cam 217. Thus when the ring 221 is shifted between forward and reverse position, the inlet followers 262 and 263 are similarly shifted and are individually made active or effective upon an elongated shoe 264 on a follower lever 266 substantially identical with the inlet follower lever 75 as shown in Figure 4. The follower 266 connects with the inlet rocker 81 as before and the remaining part of the inlet valve motion train remains exactly the same. Consequently, when the ring 221 is shifted, both the exhaust and the inlet events are changed by cutting into or out of effect the respective cams 213 and 216 for reverse motion and 214 and 217 for forward motion at 10 per cent cutoff.

Since ten per cent cutoff inlet cam 217 is always effective or may be left in effective position in the 40 per cent and 75 per cent forward cutoffs, there is provided a duplicate shift mechanism 266 effective upon a lever 267 like the lever 246 and connected to the ring 222. Preferably, the lever 267 swings from one extreme position 268 (Figure 17) to another extreme position 269 and may also be retained in a neutral or central position 271 by the shifting mechanism 246. The ring 222 carries a pair of followers 272 and 273 like the other plunger followers in the set and disposed to bear on the forward 40 per cent cutoff cam 218 and the forward 75 per cent cutoff cam 219 respectively.

When it is desired to operate in forward 10 per cent cutoff with the cam 217 effective upon the follower 263, the lever 267 is left in its central or neutral position 271. When a forward 40 per cent cutoff is desired, the lever 267 is actuated to revolve the ring 222 into an extreme position to bring the various followers 272 bearing on the cam 218 into contact also with the shoe 264. Under these circumstances, both the cams 216 and 218 through their followers 262 and 272 are effective simultaneously to give an opening impulse to the shoe 264 and although the cam follower 263 may retract with the cam 217, the follower 272 remains projected until the cam 218 permits it to withdraw at the 40 per cent cutoff position.

Similarly, when a forward 75 per cent cutoff is desired, the lever 267 is actuated to its opposite extreme position bringing the followers 273 into effect upon the shoe 264. Under these circumstances, the follower 263 operates as before in connection with the follower 273 to effectuate the opening movement of the valve. Although the follower 263 may withdraw at the forward 10 per cent cutoff position, the follower 273 cannot withdraw until the forward 75 per cent cutoff position, at which time the shoe 264 returns to its previous location and permits the valves to close. With this alternative mechanism, the same events are obtained as are obtained with the previously described structure.

In the alternative form particularly, the lubrication is improved by the provision of a supply of oil through a lubricating oil pressure tube 276 anchored in the cover 243. A tube 277 held in the hollow end of the crankshaft 209 to rotate therewith by the jam nut 212 and a pin 278 communicates through a seal ring 279 with the tube 276. Some oil under pressure passes through the interior bore 281 of the crankshaft while some digresses through ports 282 to holes 283 extending through the cam drum 211. At its lower end the ring 222 is close to the cam hub and permits only slight oil leakage. Oil discharged from the holes 283 is retained by the rings 221 and 222 except for some that leaks out between the rings and around the various plungers. The remaining oil overflows the top ring 221 and passes through notches 284 in vertical registry with the plungers contacting the various follower shoes. A cascade of oil thus falls over these parts and finally drains into the engine crankcase for reuse. Some oil is also distributed by the motion of the parts so that good lubrication is continuously provided.

What is claimed is:

1. A steam engine with cam actuated valves comprising a crankcase, cylinders in line on said crankcase, pistons in said cylinders, a crankshaft in said crankcase arranged with the rotational axis of said crankshaft paralled to said line, means connecting said pistons and said crankshaft, valves in said cylinders for controlling steam flow, cams on said crankshaft, bell cranks in said crankcase, push rods arranged approximately parallel to said axis and disposed between said cams and said bell cranks, motion transmitting means between said cams and said push rods, and thrust rods between said bell cranks and said valves.

2. A steam engine with cam actuated valves comprising a crankcase, a crankshaft mounted in said crankcase for rotation about an axis, a plurality of cylinders arranged on said crankcase in alignment axially of said crankshaft, pistons in said cylinders, means connecting said pistons and said crankshaft, a plurality of valves in each of

said cylinders for controlling steam flow, a plurality of cams on said crankshaft adjacent one end thereof, bell cranks in said crankcase, push rods extending approximately parallel to the rotational axis of said crankshaft and arranged between said cams and said bell cranks, motion transmitting means between each of said cams and certain of said push rods, and thrust rods extending approximately perpendicular to the rotational axis of said crankshaft between at least some of said bell cranks and said valves.

3. A steam engine with cam actuated valves comprising a crankcase, a crankshaft mounted in said crankcase for rotation about an axis, a cylinder mounted on said crankcase with the axis of said cylinder perpendicular to the axis of said crankshaft, a piston in said cylinder, means connecting said piston and said crankshaft, valves in said cylinder for controlling steam flow, bell cranks in said crankcase for actuating said valves, cams on said crankshaft adjacent one end thereof, push rods extending approximately parallel to the axis of said crankshaft between said cams and said bell cranks, and means for transmitting motion between said cams and said push rods.

4. A steam engine with cam actuated valves comprising a crankcase, a crankshaft mounted in said crankcase for rotation about an axis, a cylinder mounted on said crankcase with the axis of said cylinder perpendicular to the axis of said crankshaft, a piston in said cylinder, means connecting said piston and said crankshaft, valves in said cylinder movable in a direction perpendicular to the axis of said crankshaft for controlling steam flow, bell cranks for actuating said valves, cams on said crankshaft, followers actuated by said cams, and push rods approximately parallel to the axis of said crankshaft arranged to transmit motion between said followers and said bell cranks.

5. A steam engine with cam actuated valves comprising a crankcase, a crankshaft mounted in said crankcase for rotation about an axis, a cylinder on said crankcase, a piston in said cylinder, means connecting said piston and said crankshaft, valves in said cylinder movable in a direction perpendicular to the axis of said crankshaft for controlling steam flow, bell cranks for actuating said valves, cams on said crankshaft, followers rotatable about axes parallel to the axis of said crankshaft and actuated by said cams, rockers rotatable about axes in planes perpendicular to said crankshaft and engaging said followers, and push rods approximately parallel to the axis of said crankshaft in motion transmitting relationship between said rockers and said bell cranks.

6. A steam engine with cam actuated valves comprising a crankcase, a crankshaft mounted in said crankcase for rotation about an axis, a cylinder on said crankcase, a piston in said cylinder, means connecting said piston and said crankshaft, a stub shaft in said crankcase, a pair of bell cranks on said stub shaft, a first steam controlling valve in said cylinder movable in a direction perpendicular to the axis of said crankshaft and engaging one of said bell cranks, a second steam controlling valve in said cylinder movable in a direction perpendicular to the axis of said crankshaft, a rocker lever on said cylinder and engaging said second valve, a thrust rod extending between said rocker lever and the other of said bell cranks, a pair of cams on said crankshaft adjacent one end thereof, followers rotatable about axes parallel to the axis of said crankshaft and actuated by said cams, rockers rotatable about axes in planes perpendicular to said crankshaft and engaging said followers, and push rods approximately parallel to the axis of said crankshaft in motion transmitting relationship between said rockers and said bell cranks.

7. A steam engine with cam actuated valves comprising a crankcase, a crankshaft mounted in said crankcase for rotation about an axis, a cylinder on said crankcase, a piston in said cylinder, means connecting said piston and said crankshaft, valves in said cylinder for controlling steam flow, cam followers movable in planes perpendicular to said axis, means for connecting each of said cam followers to actuate an associated one of said valves, a plurality of axially spaced and axially fixed cams on said crankshaft, and means rotatable about the axis of said crankshaft for actuating said cam followers with alternatively selected ones of said cams.

8. A steam engine with cam actuated valves comprising a crankcase, a crankshaft mounted in said crankcase for rotation about an axis, a cylinder on said crankcase, a piston in said cylinder, means connecting said piston and said crankshaft, valves in said cylinder for controlling steam flow, a plurality of axially spaced and axially fixed cams on said crankshaft, axially fixed cam followers of substantially the same axial extent as said plurality of cams, means rotatable about the axis of said crankshaft for making selected ones of said cams effective upon said followers, and means for transmitting motion of said followers to said valves.

9. In a steam engine with cam actuated valves, a plurality of cams arranged side by side along an axis and rotatable about said axis, means for holding said cams against shifting movement along said axis, a follower mounted to move in a direction having a component perpendicular to said axis, said follower being of substantially the same axial extent as said plurality of cams, and means rotatable about said axis for selectively making individual ones of said cams effective upon said follower.

10. In a steam engine with cam actuated valves, a plurality of cams arranged side by side along a first axis and rotatable about said first axis, means for holding said cams against shifting along said first axis, a cam follower of substantially the same axial extent as said plurality of cams, means mounting said cam follower to rock about a second axis parallel to said first axis, and means rotatable about said first axis for making selected ones of said cams effective upon said follower and simultaneously making other ones of said cams ineffective upon said follower.

11. In a steam engine with cam actuated valves, a plurality of cams arranged side by side along an axis, means mounting said cams for rotation about said axis, means for holding said cams against shifting along said axis, a cam follower having a portion overlying all of said plurality of cams, means mounting said cam follower for motion having a component perpendicular to said axis, means for holding said follower against shifting along said axis, means rotatable about said axis effective in different rotated positions thereof for rendering different selected ones of said cams effective upon said portion of said follower, and means for holding said rotatable means against shifting along said axis.

12. In a steam engine with cam actuated valves, a plurality of cams arranged side by side along

an axis, means mounting said cams for rotation about said axis and supporting said cams for shifting crosswise of said axis, means for holding said cams against shifting along said axis, a cam follower having a portion overlying all of said plurality of cams, means mounting said cam follower for motion having a component perpendicular to said axis, means for holding said follower against shifting along said axis, means rotatable about said axis effective in different rotated positions thereof for shifting different selected ones of said cams crosswise of said axis to be effective upon said portion of said follower, and means for holding said rotatable means against shifting along said axis.

13. In a steam engine with cam actuated valves, a plurality of cams arranged side by side along an axis, means mounting said cams for rotation about said axis, means for holding said cams against shifting along said axis, a cam follower having a portion overlying all of said plurality of cams, means mounting said cam follower for motion having a component perpendicular to said axis, means for holding said follower against shifting along said axis, a ring interposed between said cams and said portion of said follower, means mounting said ring for rotation about said axis, means for holding said ring against shifting along said axis, a plurality of tappets mounted in said ring in different axial and circumferential locations, and means for rotating said ring to interpose different ones of said tappets between different ones of said cams and said portion of said follower.

14. In a steam engine with cam actuated valves, a plurality of forward and reverse cams arranged side by side along an axis, means mounting said cams for rotation in unison about said axis, means for holding said cams against shifting along said axis, a cam follower having a portion overlying all of said forward and reverse cams, means mounting said cam follower for motion having a component perpendicular to said axis, means for holding said follower against shifting along said axis, a pair of rings interposed between said cams and said portion of said follower, means mounting said rings for rotation about said axis, means for holding said rings against shifting along said axis, a plurality of tappets mounted in said rings in different axial and circumferential locations, and means for rotating said rings individually to interpose different ones of said tappets between said forward and reverse cams and said portion of said follower.

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