No. 768,068. PATENTED AUG. 23, 1904.

W. S. McKINNEY.

ENGINE.

APPLICATION FILED FEB. 3, 1902. RENEWED JAN. 23, 1904.

NO MODEL. 2 SHEETS—SHEET 1.

Fig. 1.

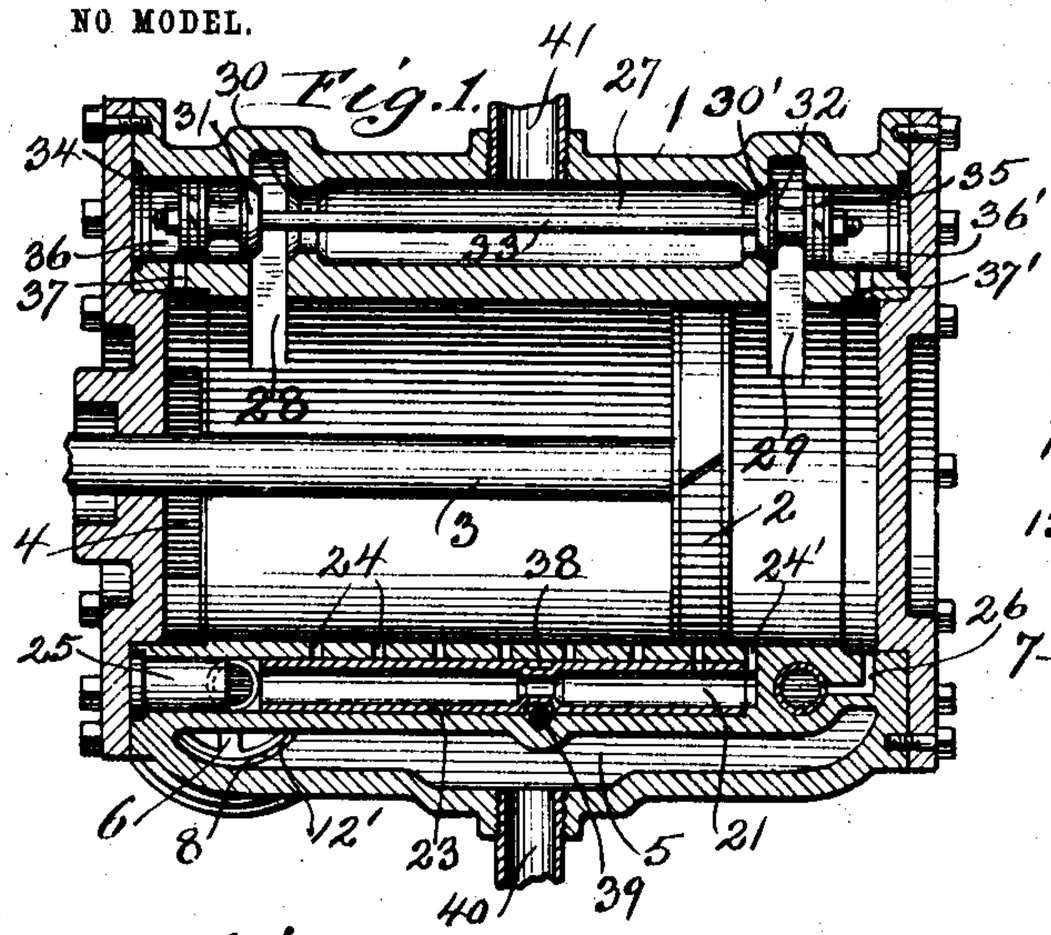


Fig. 2.

Fig. 3.

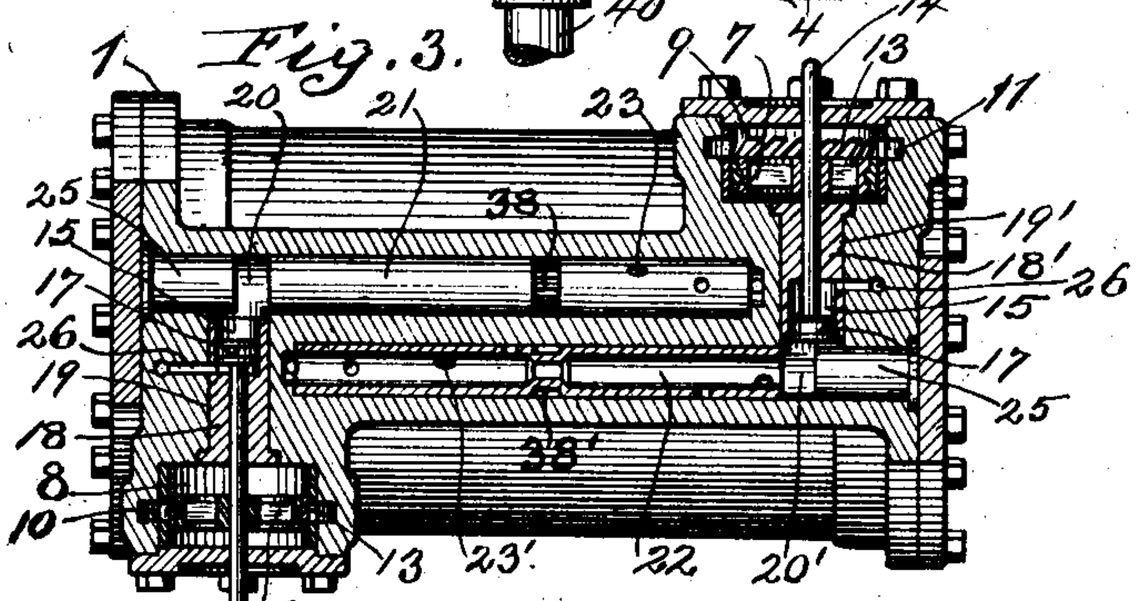


Fig. 4.

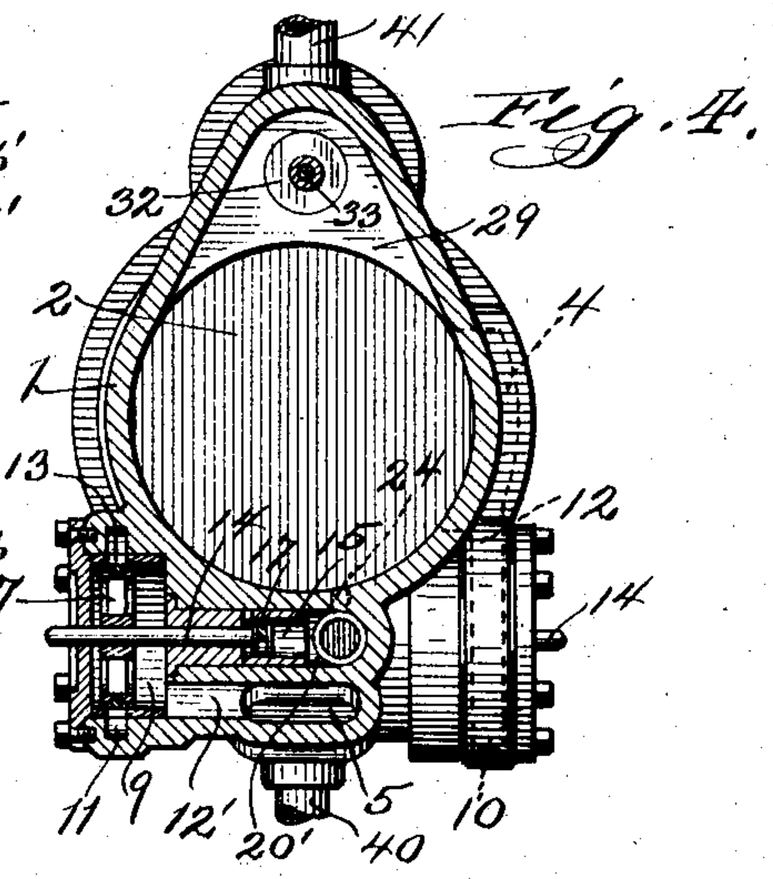


Fig. 5.

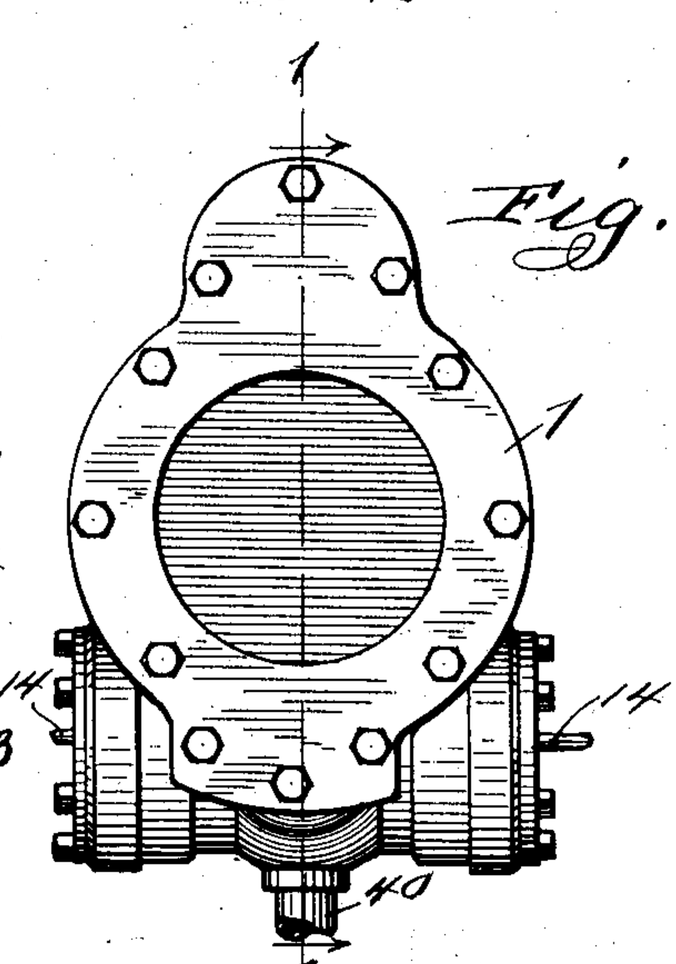
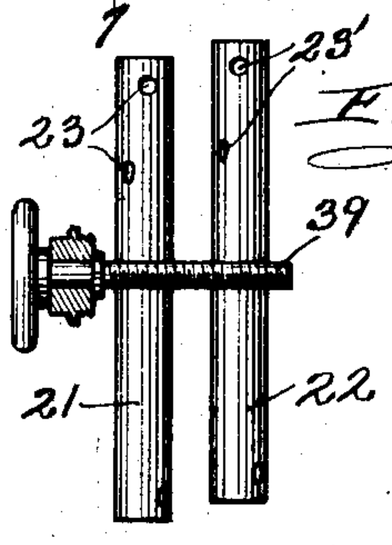


Fig. 6.



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NO MODEL. 2 SHEETS—SHEET 2.

Fig. 7.

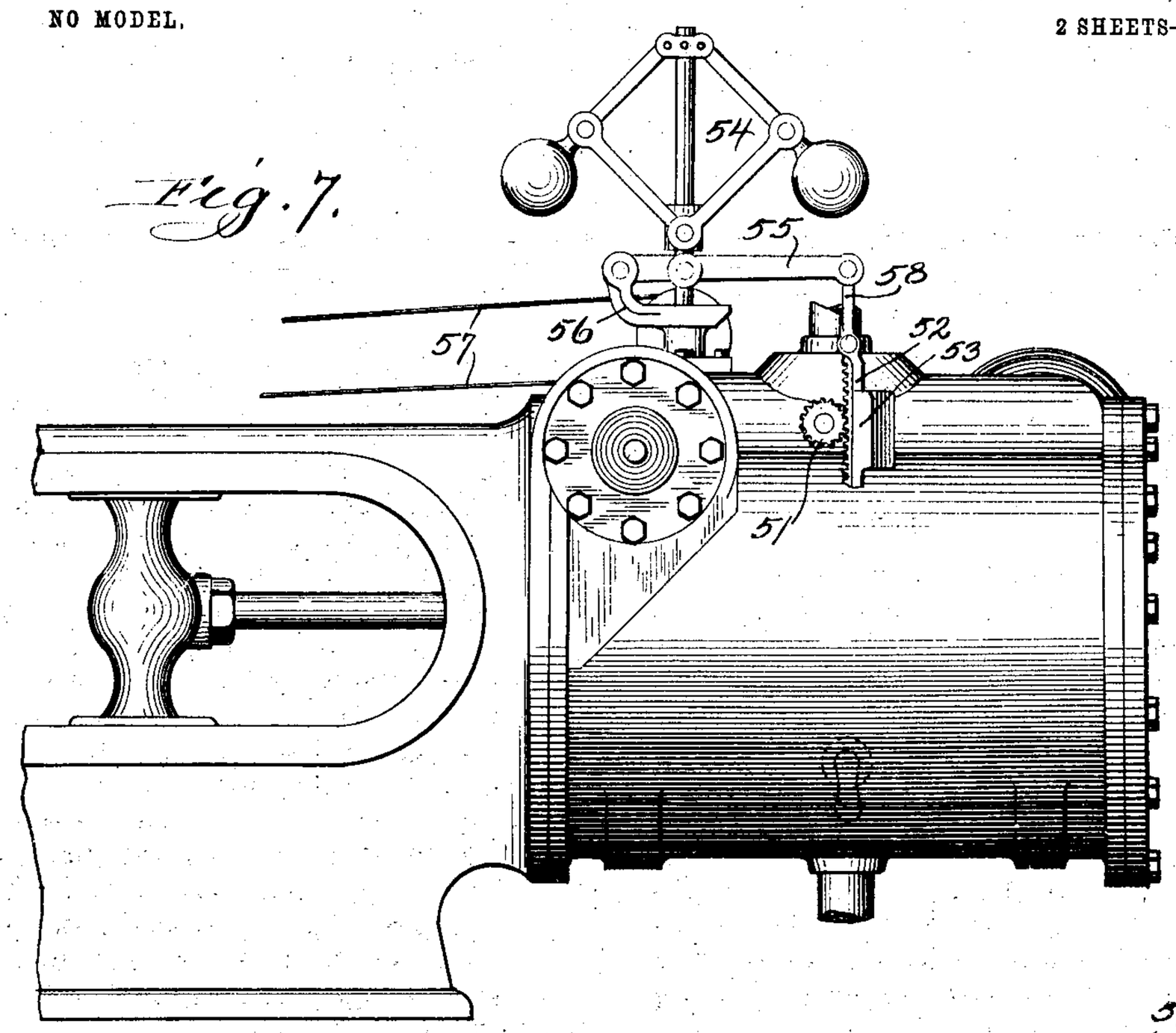


Fig. 8.

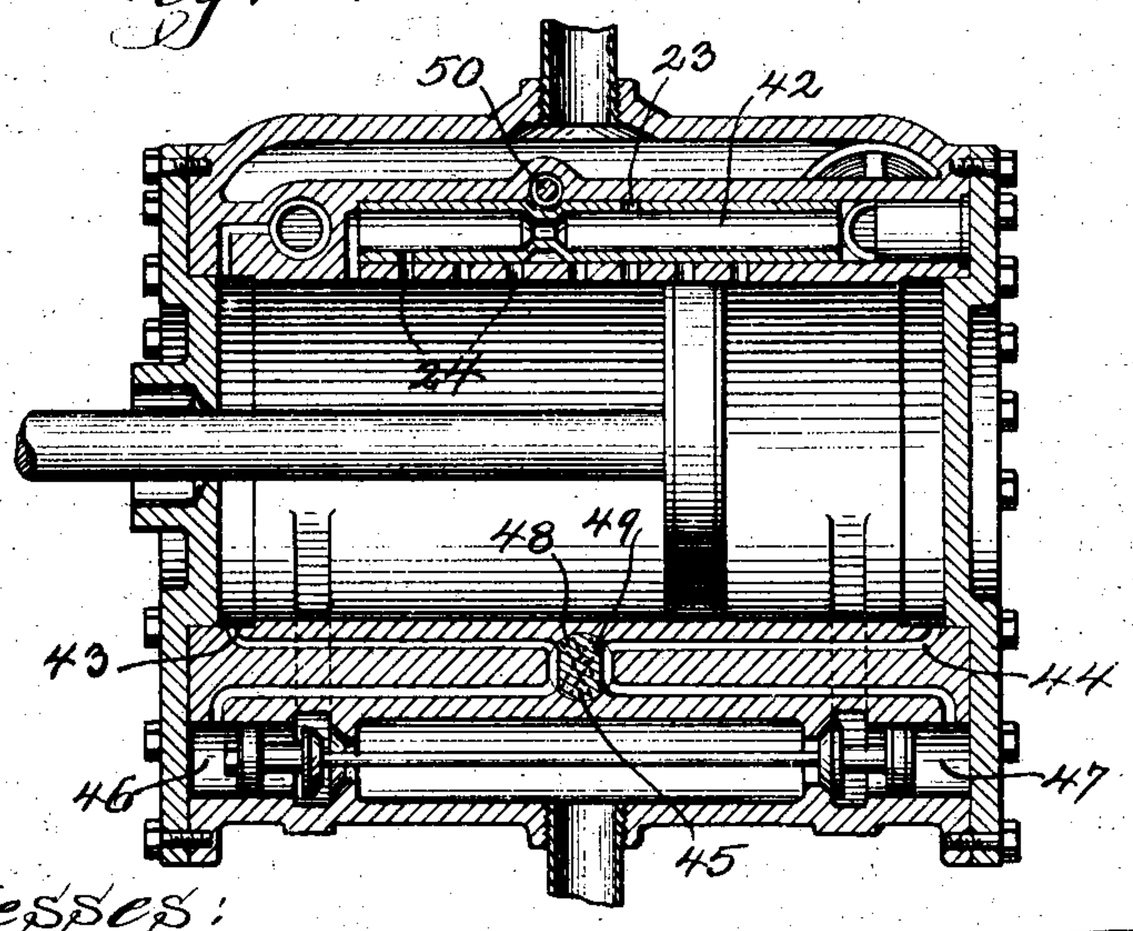
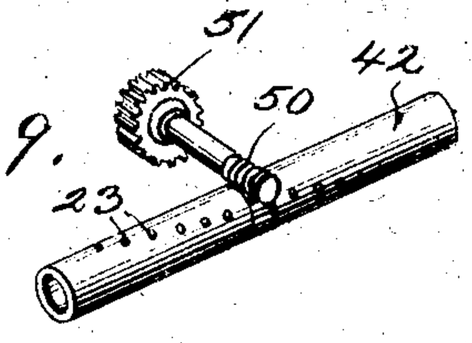


Fig. 9.



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No. 768,068. Patented August 23, 1904.

UNITED STATES PATENT OFFICE.

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ENGINE.

SPECIFICATION forming part of Letters Patent No. 768,068, dated August 23, 1904.

Application filed February 3, 1902. Renewed January 23, 1904. Serial No. 190,362. (No model.)

To all whom it may concern:

Be it known that I, WALTER SABIN McKINNEY, of No. 1545 Marquette Building, Chicago, Illinois, have invented certain new and useful Improvements in Engines, of which the following is a specification.

This invention relates to improvements in engines, and refers more specifically to improvements in the valve mechanism controlling the passage of the motive fluid through the cylinder of the engine.

Among the salient objects of the present invention are to provide an engine of high economy; to provide an improved valve mechanism which is directly controlled or actuated by the pressure of the motive fluid; to provide a construction in which the movement of the piston operates to uncover or open a port communicating with the cylinder and leading to and operating the cut-off valve; to provide in a construction of this general character a valve which operates to shift promptly from fully-opened to fully-closed position and independently of the movement of other parts of the engine, thereby effecting substantially instantaneous admission and cut-off of the motive fluid; to provide in a construction of this general character means for varying the position of cut-off at will; to provide means for varying the point of cut-off which dispenses with all complicated valve-gear and effects the variable cut-off by the simple change in registering position of a valve member controlling the cut-off at all times; to provide in a construction of this general character a mechanism for automatically effecting the cut-off as determined by the load requirements and through the medium of any suitable type of governor; to provide an improved exhaust-valve mechanism actuated by pressure directly from the cylinder of the engine and likewise characterized by being constructed to shift from fully-closed to fully-open position, and vice versa, independently of the movement of other parts of the engine; to provide a simple and improved mechanism for effecting a reversal of the engine; to provide an engine which is not only reversible, but in which the parts controlling the movement of the piston in each direction are duplicates or substantial duplicates of each other and are symmetrically, but reversely, arranged; to provide a construction in which the entire valve-gear is or may be self-contained within the body of the cylinder, and in general to provide a construction which may be economically manufactured, in which the parts may be machined to accuracy with the greatest facility, which will be durable and cannot readily get out of repair or adjustment, and which has no intricate mechanism requiring special skill or knowledge to properly operate the engine.

The invention consists in the matters hereinafter described, and more particularly pointed out in the appended claims, and the same will be more readily understood from the following description by reference to the accompanying drawings, forming a part of the description, and in which—

Figure 1 is an axial sectional view, taken on line 1 1 of Fig. 5, of the cylinder of an engine embodying a preferred form of my invention. Fig. 2 is a side elevation of the part shown in Fig. 1. Fig. 3 is a longitudinal sectional view taken on line 3 3 of Fig. 2. Fig. 4 is a transverse sectional view taken on line 4 4 of Fig. 2 and looking in the direction of the arrows. Fig. 5 is an end elevation. Fig. 6 is a fragmentary detail showing the relative arrangement of the valve-tubes and worm which is arranged to actuate the same. Fig. 7 is a side elevation of the cylinder and part of the engine-frame of an embodiment of my invention in which the point of cut-off is determined automatically by a governor and showing particularly the arrangement of the governor mechanism. Fig. 8 is a longitudinal or axial section taken vertically through the cylinder shown in Fig. 7, and Fig. 9 is a fragmentary detail showing the relation of the valve-tube to the worm which operates the same.

Referring first to the construction shown in Figs. 1 to 6, inclusive, 1 designates as a whole an engine-cylinder, within which is arranged to operate a piston 2, which imparts movement to a piston-rod 3 in the ordinary manner. At each end the cylinder is provided with an inlet-port, as 4, which ports in the preferred

construction shown herein communicate with a common inlet-chamber 5, formed in the main body of the cylinder outside of the main chamber to extend practically the full length of the cylinder, as shown clearly in Fig. 1. The passages between the inlet-chamber 5 and the two ports 4 at the respective ends of the cylinder are controlled by means of valves, (respectively designated as a whole 6 and 7,) which valves are of open-piston or ring form and are seated in suitable chambers formed in the body of the cylinder, preferably in oppositely-disposed relation, as seen clearly in the several figures of the drawings. In the preferred embodiment shown herein these valves are cylindric slide-valves seated in correspondingly-shaped valve-chambers 8 and 9, each valve-chamber being provided at a point in register with the valve-body when the latter is shifted to its outermost limit with a circumferentially-extending enlargement, as 10 and 11, which communicates with the interior of the cylinder through a passage (designated 12,) and terminating in one of the ports 4 hereinbefore referred to, these passages 12 being extended in the same plane with the annular enlargements 10 and 11. The communications extending from the inlet-chamber 5 to the respective valve-chambers 6 and 7 are, as best shown in Fig. 4, arranged to extend from the respective end portions of the inlet-chamber at an abrupt angle outwardly, as indicated at 12′, so as to communicate with the inner ends of the cylindric valve-chambers, the motive fluid passing from the passages 12′ directly through the ring-like piston-valve to the passage 12 when said valves are in open position. Obviously when the valves are shifted to their outermost limits, so as to overlap the annular enlargements 10 and 11, the communication between the inlet chamber and cylinder will be closed. In order that the piston-valves may reciprocate across the ports communicating with their chambers, diagonally-disposed ribs or guides are extended across said passages, as indicated at 13.

Each inlet-valve is provided with a stem 14, with which it is rigidly connected and which stem is arranged to extend inwardly into a piston-chamber 15, wherein it is connected with a piston 17, which serves to actuate the valve, as will hereinafter appear. As a convenient construction the piston-chambers 15 are formed in the inner ends of cylindric plug-like members 18 and 18′, which are seated in reduced extensions 19 and 19′ of the respective valve-chambers 8 and 9, said extensions being preferably concentrically disposed with the valve-chambers.

At their inner ends the piston-chambers 15 communicate with tubular valve-chambers 20 and 20′, which preferably extend parallel with the axis of the main cylinder and are so formed within the cylinder-body as to avoid interfering with each other, as shown best in Fig. 3.

Within the tubular valve-chambers 20 and 20′, respectively, are arranged tubular valve members 21 and 22, each having the form of an open-ended tube provided with a series of inlet-apertures 23 and 23′, arranged to extend in a spirally-disposed row throughout the length of the valve member. Through the inner side wall of the cylinder at points radially opposite the respective valve-chambers 20 and 20′ are formed two rows or series of ports 24, which ports are severally arranged to register with the corresponding apertures 23 or 23′ of the valve-tubes when the latter are rotated into proper angular relation therewith, and said tubular valve members terminate short of or are interrupted opposite the inner ends of the respective piston-chambers 15, so that said piston-chambers are in open communication with the interiors of the respective valve-tubes. At their opposite ends said valve-tubes are also preferably open (although not necessarily) and communicate through ports 24′ with the interior of the main cylinder. In the preferred construction shown herein the tubular valve-chambers are formed by boring inwardly from the opposite ends of the cylinder-body to the required distance and inserting the valve-tubes therein, the portions of the outer ends of said valve-chambers intervening between the piston-chambers 15 and the end caps of the cylinder being occupied by plugs 25.

The inner end of each piston-chamber 15 is placed in communication with the interior of the main cylinder at a point adjacent to the proximate end of said cylinder through passages 26, (see Figs. 1 and 3,) these passages serving to admit pressure to drive the pistons 17 in one direction, as will hereinafter appear.

Describing now the exhaust-valve mechanism, 27 designates a common exhaust-chamber, preferably formed in the body of the cylinder at a point substantially opposite the inlet-chamber 5 and arranged to extend the full length of the cylinder-body, said exhaust-chamber being desirably and most economically made interiorly cylindric or circular in cross-section. At points a short distance removed from the respective ends of the cylinder said exhaust-chamber is provided with annular enlargements forming inlet-ports 28 and 29, which are extended inwardly and open into the interior of the cylinder, as shown clearly in Fig. 1. At the points of juncture of the main central chamber 27 with the enlargements or ports 28 and 29 are formed annular valve-seats 30 and 30′, with which are adapted to coöperate valves 31 and 32, mounted upon a stem 33, common to both. The stem 33 is extended at each end beyond the valves and is provided or connected with pistons 34 and 35, arranged to operate in the cylindric end portions or piston-chambers 36 and 36′, formed by the extensions of the exhaust-chamber 27. Each pis-

ton-chamber 36 and 36′ is placed in communication with the corresponding end of the main cylinder-chamber through a port or passage, as 37 and 37′, these ports being arranged to communicate with the respective piston-chambers at points longitudinally outside of or beyond the outermost limits of movement of the corresponding piston 34 or 35.

As a convenient means of rotating or setting the valve-tubes 21 and 22 to bring any desired port 23 or 23′ thereof into register with the corresponding port communicating with the main cylinder I provide the exterior of each valve-tube with a worm-gear, as indicated at 38 and 38′, and suitably journal in the body of the cylinder a worm-screw 39, so as to engage said worm-gears and actuate the valve-tubes. The worm-gears 38 and 38′ are of equal diameter, so that said tubes are rotated simultaneously and coextensively, and the relative spiral arrangement of their ports 23 and 23′ is such that they will be brought into register with corresponding ports of the cylinder simultaneously—that is to say, if the valve-tube 21 be so rotated that its port nearest its inner end be arranged to communicate with the interior of the cylinder the corresponding port nearest the inner or opposite end of the valve-tube 22 will likewise be in communication with the cylinder. The inlet-chamber 5 communicates with any suitable source of steam or other motive-fluid supply through an inlet-pipe 40, while the common exhaust-chamber 27 is provided with an exhaust-pipe 41, leading therefrom, as shown clearly in the drawings.

An understanding of the additional features of the present invention to be hereinafter described will be facilitated by a description at this point of the general operation of the engine constructed as thus far described.

Referring more particularly to Figs. 1 and 3, the parts are therein shown in the position they assume when the piston is advancing toward the left-hand end of the cylinder, in which case the exhaust is through the left-hand exhaust-port and the steam-supply controlled by the right-hand end cut-off valve 7, which is shown in open position. With the tubular valve members adjusted as shown in the drawings the point of cut-off will be reached when the piston has approached toward the left-hand end of the cylinder far enough to uncover that port of the valve member 22 corresponding to the port of valve member 21 opposite which it is shown in Fig. 1, it being remembered that the ports of valve member 22 bear the same relation to the cylinder as to those of the valve member 21 shown in section in said Fig. 1—that is to say, the point of cut-off is determined by that one of the ports of the tubular valve member which communicates at its outer or foot end with the piston-chamber 15, which controls the supply-valve 7. In other words, the tubular valve members are shown as communicating with the cylinder through the ports which are nearest to their inner ends; but it is to be understood that it is the valve-tube which communicates with the piston-chamber 15 of the particular supply-valve admitting steam which controls said valve, and the fact that the ports of the other valve member are brought into communication with the live-steam part of the cylinder sooner has no effect upon the operation of the particular valve at that time controlling the inlet. When the piston reaches the point of cut-off, live steam admitted to the valve member 22 passes to the piston-chamber 15 and there acts upon the piston 17 to force the latter outwardly and with it the valve 7, mounted upon its stem, thereby cutting off the steam admission. It may be explained at this point that the pressure which acts to shift the piston 17 is a differential pressure, since the piston is subject to live-steam pressure upon both sides—through the valve member 22 on one side, as last explained, and through the passage 26 at its opposite side. Upon its opposite side, however, a substantial part of the area of the piston is occupied by its stem connection, so that it is in fact a differential piston and will therefore move in the direction of its side having lesser area. Obviously admission of live steam directly to the piston-chamber 15 will effect an almost instantaneous closure of the supply-valve. After the piston passes the point of cut-off it continues under the expansive action of the steam until it passes the exhaust-port 28, which, as hereinbefore mentioned, is located some distance from the proximate end of the cylinder. As soon as the piston passes the exhaust-port the volume of exhaust fluid contained between the piston and the end of the cylinder toward which it is approaching is trapped and forced out through the passage 37, leading to the outer end of the piston-chamber 36, controlling the exhaust-valve. The compression rapidly raises the pressure to a point above that at the opposite side of the piston, (which it will be observed is acting to hold the exhaust-valve open,) whereupon this pressure acting upon the piston 34 shifts the exhaust-valve into closed position as to that end of the cylinder. The same compression which operates to close the exhaust-valve at the same time forces the motive fluid through the passage 26 into the piston-chamber 15, which controls the supply-valve 6 at that end of the cylinder, thus forcing its piston 17 inwardly and opening the supply-valve. The return of the main piston thereupon begins, and the operations during the remaining half of the cycle of movement of the engine are obviously an exact repetition of those movements hereinbefore described, except, of course, that the valve-tube member 21 now determines the point of cut-off and

compression at the right-hand end of the cylinder closes the exhaust-valve at that end and opens the supply-valve 7 to reverse the piston.

Referring again to the first half of the cycle of movements, it will be seen that, as shown in Fig. 1, the interior of valve-tube 21 and the piston-chamber 15, with which it communicates, are in communication with the live-steam space of the main cylinder through the port 24′ and will be further placed in such communication as soon as the piston passes the registering port of that valve-tube. This, however, has no objectionable effect upon the operation of the engine, since the cut-off valve at the end of the cylinder toward which the piston is advancing has already been closed and such live-steam pressure would therefore simply act to hold it in closed position. As to the reversely-disposed valve-tube 22, however, live steam cannot obtain access to the latter until the piston has reached the point of cut-off.

With the construction shown in the figures thus far described the regulation of the point of cut-off is determined manually by operating the worm 39 through the medium of its hand-wheel and rotating the valve-tubes to bring that particular port of each into register with the corresponding port of the main cylinder at the particular desired point of cut-off. In view of the spirally-disposed arrangement of the ports in the valve members it will be obvious that as the valve member is rotated to bring a succeeding port into register that port theretofore in register will be closed. In other words, if the spiral arrangement of the ports is such that the angular interval between adjacent ports is equal to or greater than the diameter of the ports only one port will be at any time in communication with the interior of the cylinder. It thus becomes a simple matter of rotating the worm-screw more or less to change the point of cut-off to any point throughout practically the full length of the tubular valve members, and obviously in the case of such engines as may require frequent adjustment of the cut-off point—as, for example, in an automobile-engine—the adjustment may be made by means of any suitable hand-operated mechanism capable of operation more readily than the worm-screw mechanism described herein. In this same connection it is to be understood and will be entirely obvious to those skilled in the art that it is only necessary that the tubular valve members have relative movement to the series of ports affording communication with the interior of the main cylinder. This relative movement may be either rotative or reciprocatory or any other suitable movement, and if reciprocatory and rectilinear the valve members might obviously be of any preferred form in cross-section as well as circular. In this same connection it is to be understood that while the particular embodiment illustrated and described herein is deemed to be a highly-efficient and practical embodiment of the invention, yet in the broad sense this construction is merely illustrative and the principles of the invention may be embodied in various forms. It may also be noted that the most salient feature of the invention is the arrangement which provides a practically instantaneous cut-off of the motive fluid by direct action of the motive fluid, and especially when the construction is one in which the point of cut-off may be varied, while the particular exhaust mechanism shown and described is a subordinate feature of the invention and not in any sense an essential one—that is to say, the exhaust of the engine might be effected and controlled by any of the common expedients well understood in the art, as, for example, it might be actuated by an eccentric in the usual manner.

It may be further remarked that the restoration of the cut-off valves to their open or admission positions is not necessarily accomplished in the peculiar manner herein described, although the mechanism herein described for accomplishing this end is deemed an important feature of the invention.

Referring now to the construction shown in Fig. 7, *et sequitor*, an engine-cylinder is therein shown which is generally similar to that hereinbefore described, but is provided with certain modifications in the construction of the exhaust mechanism. In this case means are provided for effecting the reversal of the engine through control of the exhaust-valves. To this end passages 43 and 44 are provided corresponding in function and general position to the passages 37 and 37′ of the previously-described construction; but in the present instance these passages instead of being extended directly from the respective ends of the cylinder to the piston-chambers of the exhaust-chamber are extended first to a two-way cock or valve 45, and thence back to the piston-chambers 46 and 47, respectively. The two-way cock is provided with cross-passages, as indicated in dotted lines at 48 and 49, which when said cock is rotated an angular extent equal to ninety degrees from the position shown has the effect of crossing the passages 43 and 44, so that the passage 44 then communicates with the chamber 46 and the passage 43 with the chamber 47.

The reversal of the engine is accomplished by simply turning the two-way cock so as to cross the passages, thereby reversing the order of movement of the exhaust-valves and reversing the engine, and as soon as the engine has been reversed the two-way cock is restored to its normal position, or that indicated in the drawings, whereupon the engine continues to operate in its reverse direction.

Describing now the mechanism whereby the point of cut-off is controlled automatically, 50 designates a worm-screw which is inter-

geared with the pair of valve-tubes 42 (one of these not being shown in the drawings) in substantially the same manner as hereinbefore described. Upon the outer end of the worm-screw 50 is mounted a gear 51, which is arranged to intermesh with a slide-rack 52, working vertically through a guide 53. 55 designates the lever of an ordinary ball-governor, designated as a whole 54 and mounted, as usual, upon a suitable bracket 56 upon the engine and driven by means of a belt 57. The vibrating end of the lever 55 is connected with the upper end of the rack 52 by means of a link 58, so that movement of the governor is imparted to the rack and through the latter to the worm-screw, thereby rotating the valve-tube members 42 synchronously with the movement of the governor. The ports or passages 23 of the valve-tube members are in this instance, as in the previously-described construction, arranged spirally, while the ports 24, affording communication between said valve-tubes and the interior of the cylinder, are in a straight row, as shown clearly in Fig. 8.

The operation of the mechanism constructed and arranged as described is probably entirely obvious, but may be briefly indicated by stating that the valve-tubes are so interconnected with the governor that as the speed of the engine rises and the governor responds the valve-tubes will be rotated in a direction to open the ports leading into the valve-tubes successively nearer and nearer to the admission end of the cylinder or toward the foot of the valve-tubes, thereby admitting less and less steam and using more expansively. Vice versa, when the load increases the governor will fall, and thus rotate the valve-tubes to lengthen or advance the point of cut-off automatically.

It will be seen from the foregoing description that by the use of my invention I entirely dispense with the usual valve-gear and substitute therefor simple valve members, having comparatively slight movement, substantially all inclosed within the body of the engine, and operated, so far as the cut-off and exhaust-valves are concerned, directly by the motive fluid. The very slight movement of any part necessary to effect the control of the motive fluid reduces the wearing effects of momentum and rapid movement to a minimum, while at the same time the principal parts are so constructed that the wear is distributed over large areas and the parts are of a form capable of being readily and cheaply machined to accuracy. Moreover, the construction is such that access to all of the parts may be readily had for inspection, renewal, or repair.

The fact that the controlling-valves are shifted or operated by means of the motive fluid instead of by mechanical means enables me to adopt a construction of valve which may be shifted from one position or limit of movement to the opposite instantly, thereby affording the same efficiency which has heretofore been obtainable only in valve-gears of the general type known as the "Corliss" type, and entirely avoiding "wire-drawings" and its accompanying objections.

It will be obvious and is to be understood that the invention is not limited to a steam-engine, although possessing a special advantage when embodied in the form of an automatic variable cut-off steam-engine, nor is the invention in its broad sense limited to the peculiar arrangement of parts herein shown, and various modifications will readily occur to those skilled in the art. I do not, therefore, limit myself to the details shown and described except to the extent that they are herein claimed specifically.

I claim as my invention—

1. In an engine, the combination with the cylinder and piston arranged to operate therein, of an admission-valve, means for actuating said admission-valve comprising a part mechanically connected and moving with the admission-valve, and two passages independent of the main admission-passage, arranged to communicate with the cylinder at separated points and through which opposite sides of said part moving with the admission-valve is subject to pressure, an exhaust-valve, and means for actuating said exhaust-valve, functionally independent of the admission-valve, for the purposes set forth.

2. In an engine, the combination with the cylinder and piston arranged to operate therein, of an admission-valve, means for operating said admission-valve comprising a part mechanically connected and moving with said admission-valve and arranged within a secondary cylinder, and two passages independent of the main admission-passage affording communication between said secondary cylinder and main cylinder, one of said passages communicating with the main cylinder at or near the admission end thereof and the other at a point remote from the admission end, an exhaust-valve, and means for actuating said exhaust-valve, functionally independent of the movement of the admission-valve, for the purpose set forth.

3. In an engine, the combination with the cylinder and piston arranged to operate therein, of an admission-valve, a passage arranged to communicate with the cylinder at a point at or near the admission end thereof, a second passage arranged to communicate with the cylinder at a point remote from said admission end, a part moving with said admission-valve and subject to differential pressure through said passages at an interval during the outstroke of the piston to close the valve, and mechanism for effecting a compression within the cylinder as the piston approaches its return limit of movement whereby pressure is admitted through the first mentioned

of said valve-passages to that side of the valve-operating member having the lesser area subject to pressure.

4. In an engine, the combination with the cylinder and piston arranged to operate therein, of an admission-valve, a series of passages arranged to communicate with the cylinder at separated points along the travel of the piston and forming a variable cut-off, a part moving with said admission-valve adapted to be subjected to pressure through said passages, valve mechanism for controlling said passages, an exhaust-valve mechanism and means actuating said exhaust-valve mechanism independently of the admission-valve.

5. In an engine, the combination with the cylinder and piston arranged to operate therein, of an admission-valve, a series of passages arranged to communicate with the cylinder at separated points along and within the limits of travel of the piston, a part moving with said admission-valve and adapted to be subjected to pressure through either of said passages and a valve member common to all of said passages, one of said passages being arranged to communicate with a part of the main cylinder within which the exhaust fluid is trapped and compressed by the approach of the piston to its limit of movement in one direction, as and for the purpose set forth.

6. In an engine, the combination with the cylinder and piston arranged to operate therein, of a separate and independently-operable admission-valve, controlling the admission to each end of the cylinder, a series of passages for each admission-valve arranged to communicate with the cylinder at separated points along and within the limits of travel of the piston, a part moving with each admission-valve and adapted to be subjected to pressure through either of said passages, and means for effecting the opening of said admission-valve.

7. In an engine, the combination with the cylinder and piston arranged to operate therein, of an admission-valve, a steam chamber or passage arranged to extend longitudinally of the cylinder, a series of ports affording communication at longitudinally-separated points between said steam chamber or passage and cylinder, a part moving with said admission-valve, and subject to pressure through said steam chamber or passage and a movable valve member arranged within said steam chamber or passage, provided with a plurality of inlet-ports adapted to be alternatively variably brought into register with the ports communicating with the cylinder, means for controlling the relative position of said valve member, an exhaust-valve mechanism and means for operating said exhaust-valve mechanism independently of the movement of the admission-valve.

8. In an engine, the combination with the cylinder and piston arranged to reciprocate therein, of an admission-valve, a tubular passage arranged to extend longitudinally of the cylinder, a series of passages affording communication between said tubular passage and cylinder at various points along the travel of the piston, a part moving with said admission-valve subject to pressure through said tubular passage and a tubular valve member arranged to fit within said tubular passage and provided with a series of ports adapted to be brought into variable register with the passages or communicating with the cylinder, and means for rotating said tubular valve member, for the purpose set forth.

9. In an engine, the combination with the cylinder and piston arranged to operate therein, of an admission-valve, a series of passages arranged to communicate with the cylinder at separated points, a part moving with said admission-valve and subject to pressure through said passages, valve mechanism for controlling said passages and a governor arranged to automatically control said valve mechanism.

10. In an engine, the combination with the cylinder and piston arranged to operate therein, of an admission-valve, a plurality of passages arranged to communicate with the cylinder at longitudinally-separated points within the limits of travel of the piston, a part moving with said admission-valve and subject to pressure through said passages, a valve member common to and controlling a plurality of said passages, a governor and interconnections between said valve member and governor whereby the latter is operated to vary the point of cut-off substantially as described.

11. In an engine, the combination with the cylinder and piston arranged to operate therein, of an admission-valve, a tubular passage or chamber arranged to extend longitudinally of the cylinder, a series of ports or passages affording communication between the cylinder and longitudinally-extending passage or chamber at points throughout the length of the latter, a piston-chamber in communication with said tubular passage, a piston arranged therein and operatively connected with said admission-valve, a tubular valve member the interior of which forms a steam-passage arranged within said tubular passage, and provided with a corresponding series of ports adapted to be brought into variable register with the ports leading to the cylinder, and means for controlling the relative position of said valve member.

12. In an engine, the combination with the cylinder and piston arranged to operate therein, of an admission-valve, a tubular passage or chamber arranged to extend longitudinally of the cylinder, a series of ports or passages affording communication between the cylinder and longitudinally-extending passage or chamber at points throughout the length of

the latter, a piston-chamber in communication with said tubular passage, a differential piston arranged within said piston-chamber and operatively connected with said admission-valve, a tubular valve member the interior of which forms a steam-passage arranged within said tubular passage, and provided with a corresponding series of ports adapted to be brought into variable register with the ports leading to the cylinder, means for controlling the relative position of said valve member, and a passage affording communication between the admission end of the cylinder and that side of the piston-chamber containing the differential piston wherein the latter is subject to a lesser area of pressure.

13. In a double-acting engine, the combination with the cylinder and piston arranged to operate therein, of an independent admission-valve for admitting motive fluid to each end of said cylinder, a plurality of passages arranged to communicate with the cylinder at separated points, and parts moving with said respective admission-valves subject to differential pressure through said passages, and an exhaust-valve controlling the exhaust from each end of the cylinder, and means for actuating said exhaust-valves independently of the movement of the corresponding admission-valves.

14. In a double-acting engine, the combination with the cylinder and piston arranged to reciprocate therein, of an independent admission-valve for admitting motive fluid to each end of said cylinder, a plurality of passages arranged to communicate with the cylinder at longitudinally-separated points within the limits of travel of the piston, a part moving with each of said admission-valves and subject to pressure on one side through said passages and other passages communicating with the cylinder at or adjacent to the ends thereof through which said parts moving with the respective admission-valves are subjected to pressure upon their opposite sides, an exhaust-valve, and means for actuating said exhaust-valve independently of the movement of either admission-valve.

15. In a double-acting engine, the combination with the cylinder and piston arranged to reciprocate therein, of an admission-valve for admitting motive fluid to each end of said cylinder, a plurality of passages arranged to communicate with the cylinder at longitudinally-separated points within the limits of travel of the piston, a part moving with each of said admission-valves and subject to pressure on one side through said passages and other passages communicating with the cylinder at or adjacent to the ends thereof through which said parts moving with the respective admission-valves are subjected to pressure upon their opposite sides, and exhaust-ports communicating with the respective ends of the cylinder at points within the limits of travel of the piston.

16. In an engine, the combination with the cylinder and piston arranged to operate therein, of an exhaust-port communicating with the cylinder at a point substantially within the limits of travel of the piston, an exhaust-valve arranged to control said port, a passage communicating with the cylinder between the exhaust-port and the proximate end of the cylinder and a part moving with the exhaust-valve and subjected to pressure through said latter passage after the piston passes the exhaust-port.

17. In an engine, the combination with the cylinder and piston arranged to reciprocate therein, of an exhaust-port arranged to communicate with the cylinder, at points substantially within the limits of movement of the piston so that the latter reciprocates beyond said exhaust-port, a valve arranged to control said exhaust-port, a piston-chamber and piston therein operatively connected with said exhaust-valve and a passage communicating with the main cylinder at a point beyond the exhaust-port and affording communication to the piston-cylinder controlling the exhaust-valve substantially as described.

18. In a reversible engine, the combination with the cylinder and piston arranged to reciprocate therein, of exhaust-ports at the respective ends of the cylinder located substantially within the limits of movement of the piston so that the latter reciprocates beyond the same, valves arranged to control said several exhaust-ports, interconnections whereby said valves are connected to move into closed and open position alternatively, parts moving with said valves and constituting in effect piston members, passages affording communication with the respective ends of the main cylinder and the chambers within which said valve-operating piston members operate, and valve mechanism for cross-connecting said latter passages, as and for the purpose set forth.

19. In an engine, the combination with the cylinder and piston arranged to operate therein, of an admission-valve, two passages arranged to communicate with the cylinder at separated points, a part moving with said admission-valve and subject to differential pressure through said passages for controlling movement of the admission-valve, an exhaust-port communicating with the cylinder near one end thereof but substantially within the limits of movement of the piston, a valve arranged to control said port, a passage communicating with the cylinder at a point beyond the exhaust-port or at that side of the latter toward which the piston is moving while exhausting through said exhaust-port, and a part moving with the valve controlling said exhaust-port which is subjected to pres-

sure through said last-mentioned passage after the piston passes the exhaust-port.

20. In an engine, the combination with the cylinder and piston arranged to reciprocate therein, of an admission-valve, a plurality of passages arranged to communicate with the cylinder at longitudinally-separated points, a part moving with the admission-valve and subject to differential pressure through said passages for controlling movement of the admission-valve, an exhaust-port communicating with the cylinder near one end thereof but substantially within the limits of movement of the piston, a valve arranged to control said port, a passage communicating with the cylinder at a point beyond the exhaust-port or at that side of the latter toward which the piston is moving while exhausting through said exhaust-port, and a part moving with the valve controlling said exhaust-port which is subjected to pressure through said last-mentioned passage after the piston passes the exhaust-port.

21. In a double-acting engine, the combination with the cylinder and piston arranged to reciprocate therein, of admission-valves arranged to control admission of motive fluid to each end of the cylinder, a plurality of passages arranged to communicate with the cylinder at longitudinally-separated points, a part moving with each admission-valve, and subject to differential pressure through said passages, to operate said admission-valves, an exhaust-port located near each end of the cylinder but substantially within the limits of travel of the piston in each direction, exhaust-valves arranged to control each of said exhaust-ports, interconnections whereby said exhaust-valves are connected to move alternately into open and closed positions, a part moving with each exhaust-valve and constituting in effect a piston, chambers within which said piston members are respectively arranged, passages affording communication between said chambers and the corresponding end portions of the main cylinder and a two-way valve arranged to cross-connect said passages substantially as shown.

22. In an engine, the combination with the cylinder, piston arranged to operate therein and source of motive-fluid supply, of an admission-valve controlling the supply of motive fluid, a differential piston forming a part of or moving with said admission-valve subject upon both sides to the direct pressure of the motive fluid, an independently-operated exhaust-valve mechanism and means for varying the point of cut-off through the medium of said differential piston.

23. In an engine, the combination with the cylinder, piston arranged to operate therein and source of motive-fluid supply, of an admission-valve controlling the supply of motive fluid, a differential piston forming a part of or moving with said admission-valve, and having its side of lesser area subject to the motive-fluid pressure at all times during admission, and means for admitting pressure to the opposite side of said differential piston at variable points of travel of the main piston, an exhaust-valve mechanism and means operating said exhaust-valve mechanism out of synchronism with the admision-valve.

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