(No Model.) 5 Sheets—Sheet 1.

M. C. BULLOCK.

STEAM ENGINE.

No. 571,892. Patented Nov. 24, 1896.

Fig. 1.

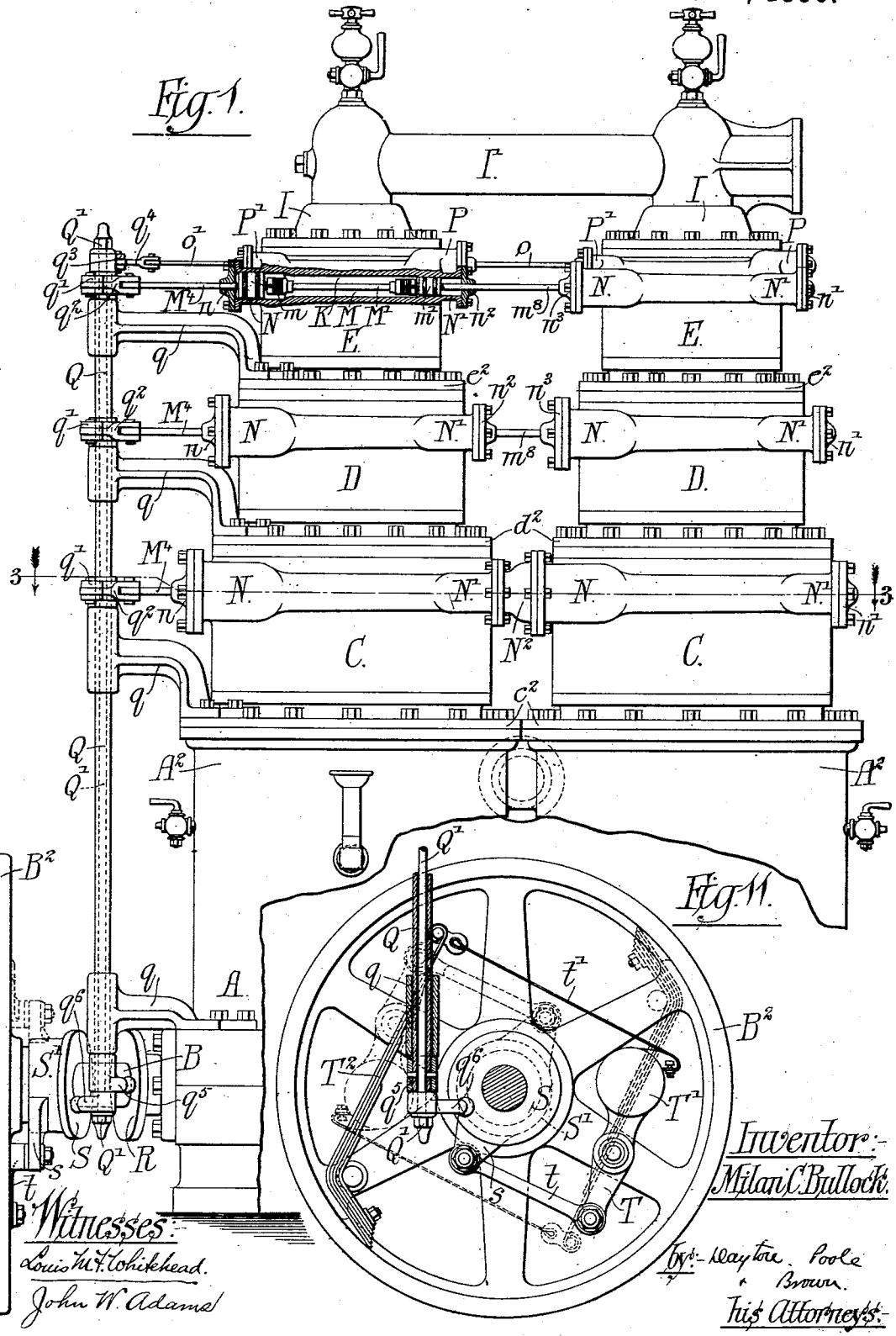

Fig. II.

Witnesses:
Louis H. T. Whitehead.
John W. Adams

Inventor:
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By: Dayton, Poole & Brown.
His Attorneys.

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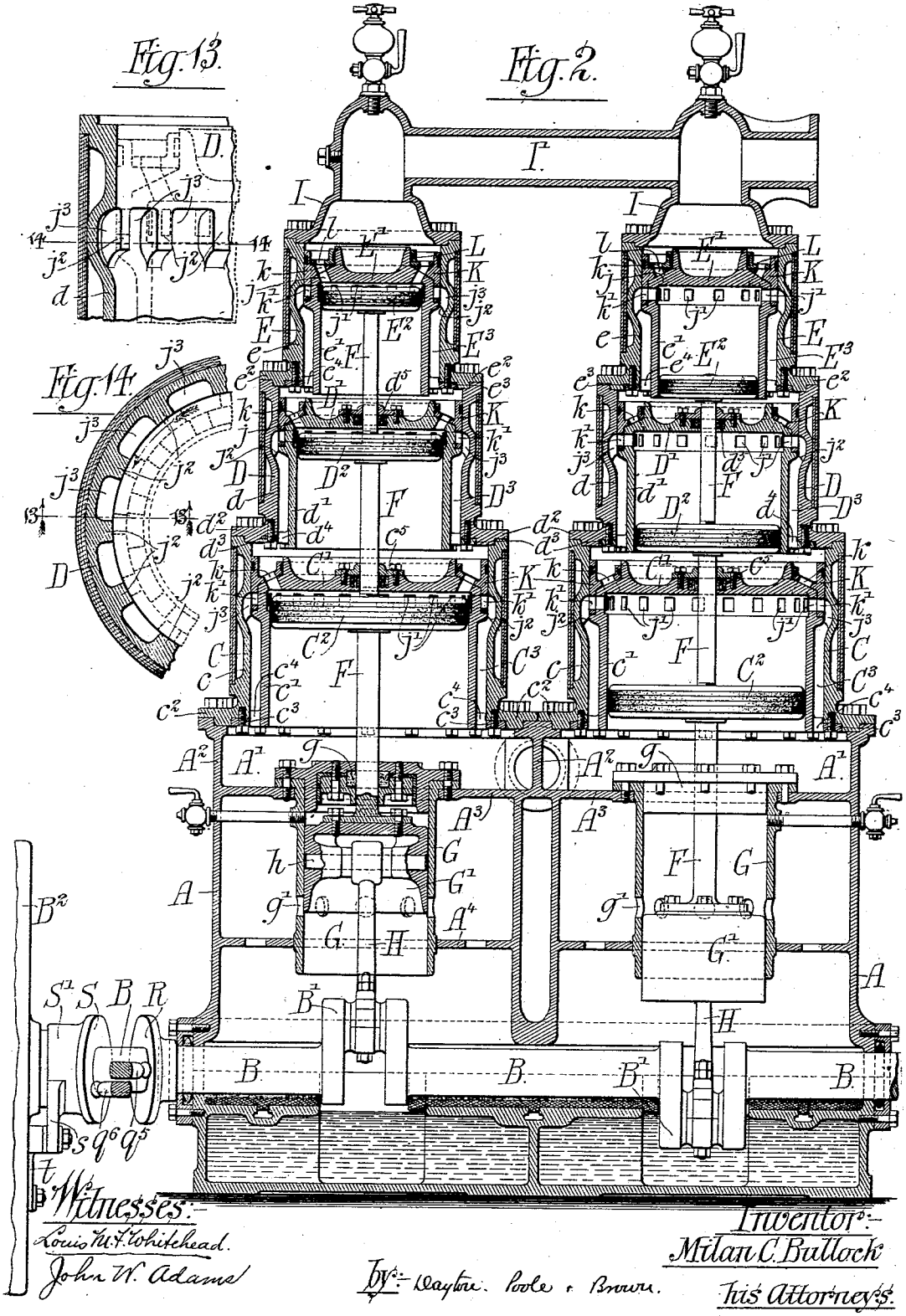

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Fig. 12.

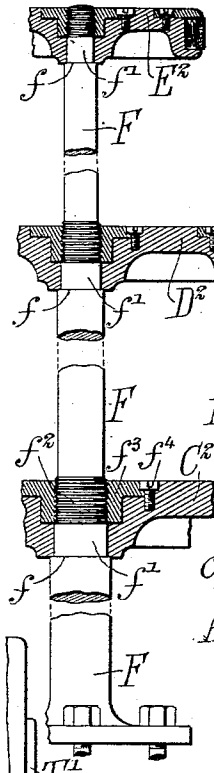

Fig. 4.

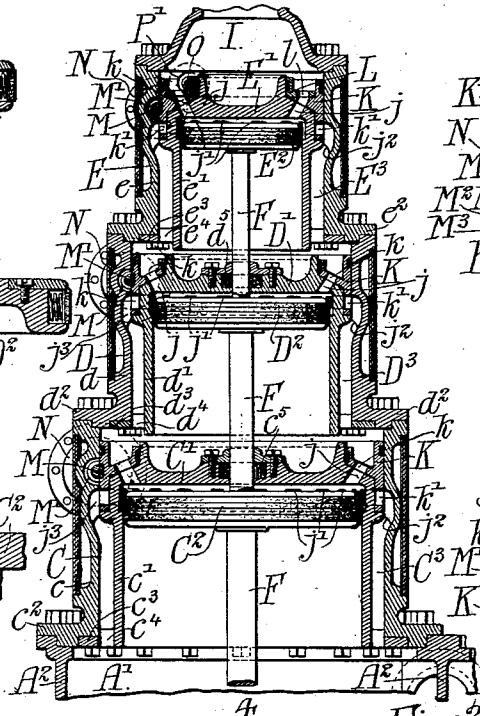

Fig. 6.

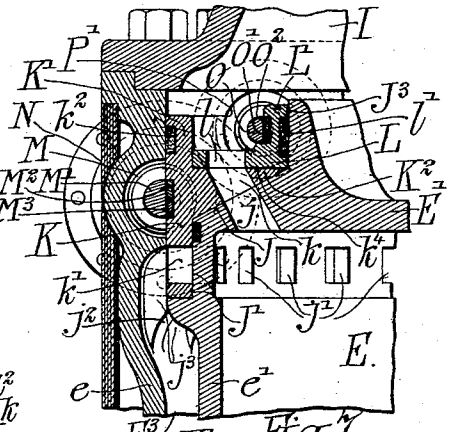

Fig. 7.

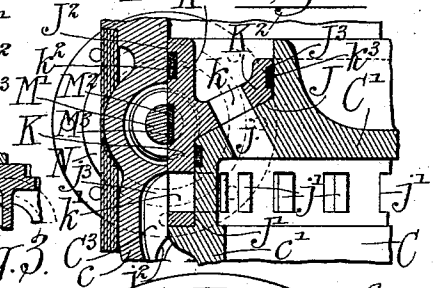

Fig. 3.

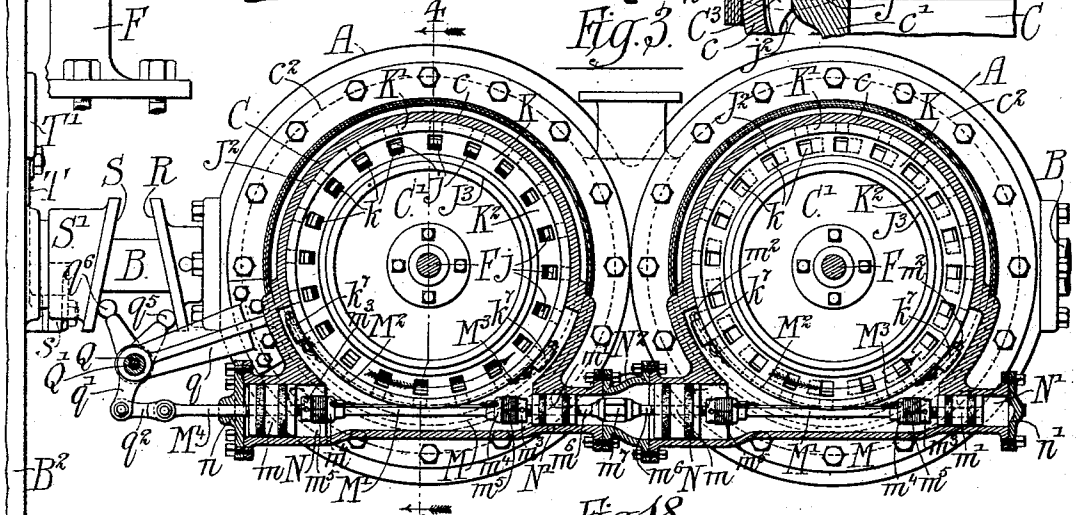

Fig. 18.

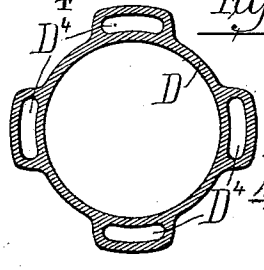

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Fig. 5.

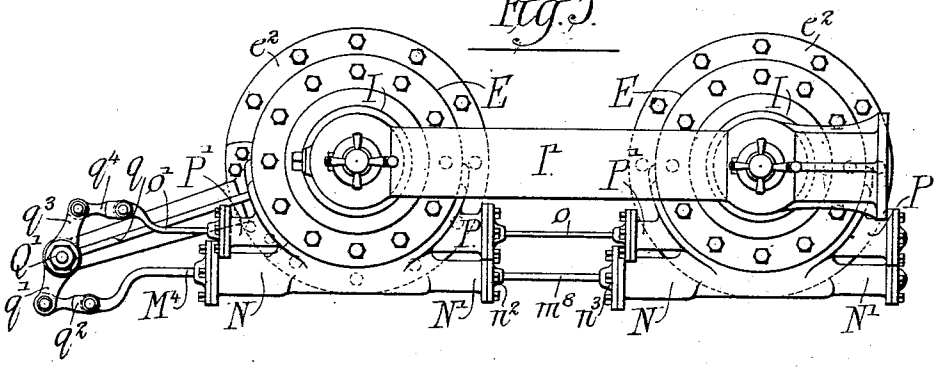


Fig. 8.

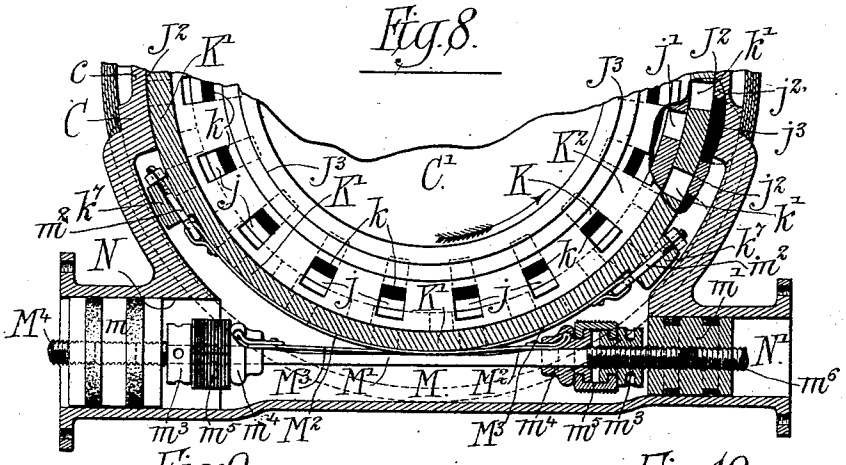


Fig. 9.

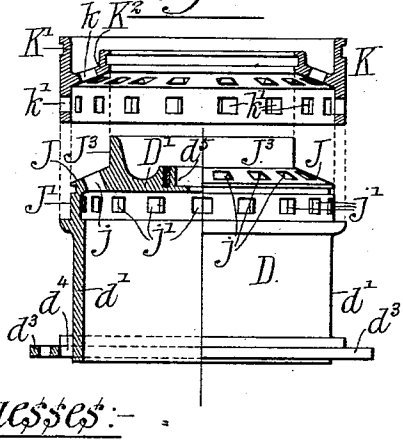
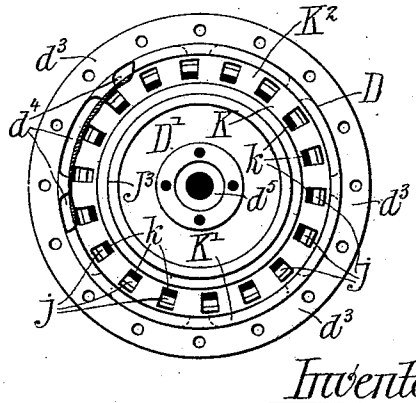


Fig. 10.



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STEAM ENGINE.

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Fig. 15.

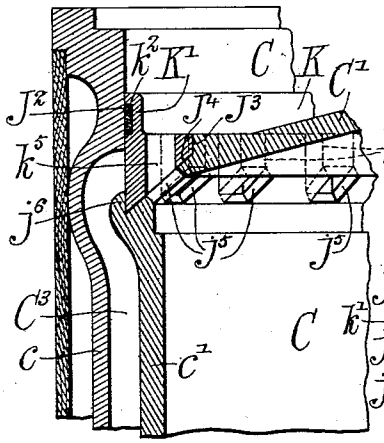


Fig. 21.

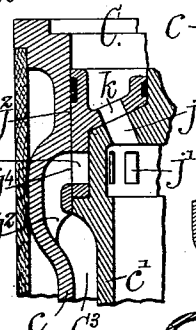


Fig. 17.

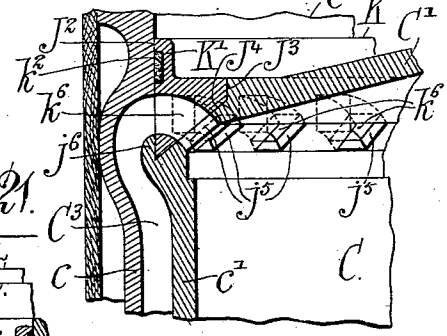


Fig. 19.

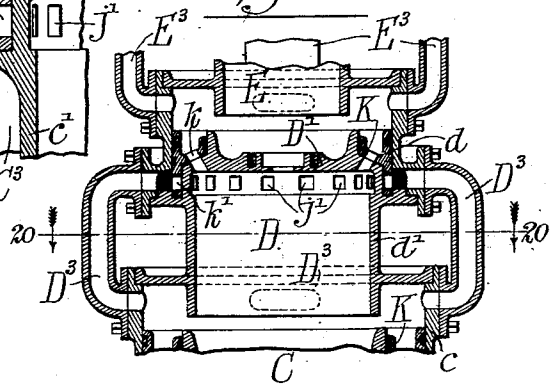


Fig. 16.

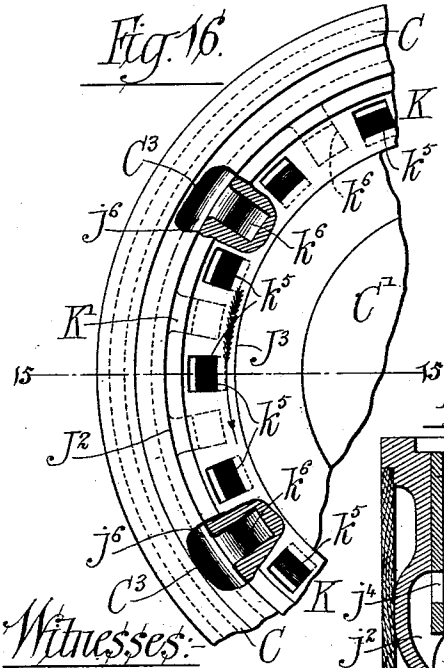


Fig. 20.

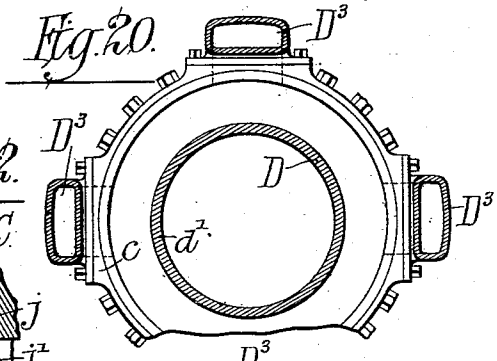
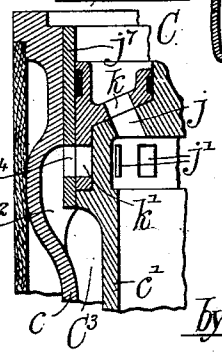


Fig. 22.



Witnesses:-

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THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

MILAN C. BULLOCK, OF CHICAGO, ILLINOIS.

STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 571,892, dated November 24, 1896.

Application filed March 16, 1893. Serial No. 466,237. (No model.)

To all whom it may concern:

Be it known that I, MILAN C. BULLOCK, of Chicago, in the county of Cook and State of Illinois, have invented certain new and useful Improvements in Steam-Engines; and I do hereby declare that the following is a full, clear, and exact description thereof, reference being had to the accompanying drawings, and to the letters of reference marked thereon, which form a part of this specification.

This invention relates to improvements in reciprocating steam-engines; and it consists in the matters hereinafter described, and pointed out in the appended claims.

The engine herein illustrated as embodying my invention is a single-acting engine, or one in which the piston is moved in one direction only by steam-pressure within the cylinder and wherein the return stroke of the piston is accomplished by the action of the crank-shaft, and is of that kind known as a "double-tandem compound engine," having a vertically-arranged cylinder supported on a common base and having two piston-rods and a single crank-shaft mounted in said base and provided with two cranks, with which the piston-rods are severally connected. The novel features constituting my invention may, however, be applied to horizontal engines and some of the features of the invention may be applied to double-acting and to simple as well as compound engines.

In the accompanying drawings, illustrating my invention, Figure 1 is a view in side elevation of an engine embodying my invention. Fig. 2 is a central vertical section thereof, taken axially through both cylinders. Fig. 3 is a sectional plan view taken on line 3 3 of Fig. 1. Fig. 4 is a vertical axial section taken on line 4 4 of Fig. 3. Fig. 5 is a detail plan view illustrating the actuating devices for the main and cut-off valves. Figs. 6 and 7 are enlarged sectional views illustrating in detail the valves shown in Fig. 4. Fig. 8 is an enlarged sectional view taken horizontally through the valve-actuating device. Fig. 9 illustrates in side elevation the exterior of one of the cylinders, showing the valve-ports formed in the upper end thereof, together with a sectional view of the valve-ring which fits over the upper end of the cylinder. Fig. 10 is a plan view of the parts shown in Fig. 9 when placed together. Fig. 11 is a view in side elevation of the fly-wheel governor, illustrating its connection with the valve-actuating devices of the engine. Fig. 12 is a detail section of the piston-rod and pistons, showing devices employed for attaching the pistons to the rod. Fig. 13 is a detail section of that part of the outer shell of one of the cylinders adjacent to the valve. Fig. 14 is a detail plan section of the same, taken on line 14 14 of Fig. 13. Fig. 15 is an enlarged section showing a modified form of the valve, taken on line 15 15 of Fig. 16. Fig. 16 is a plan view of same. Fig. 17 is a detail section taken on said line 15 15 of Fig. 16, showing the valve-ring in another position than that shown in Fig. 15. Fig. 18 is a sectional view of one of the main cylinders, showing exhaust-steam passages cast integral therewith. Fig. 19 is a view in central vertical section of a cylinder and parts of adjacent cylinders, showing steam-passages separate from the cylinder-walls. Fig. 20 is a plan section taken on line 20 20 of Fig. 19. Figs. 21 and 22 are sectional views illustrating modifications in the construction of the seat for the valve-ring shown in the other figures of the drawings.

A indicates a hollow casting constituting the base of the engine, and within which is mounted the horizontal crank-shaft B, having two cranks B′ B′.

C C are two upright cylinders affixed to the top of the casing A, said cylinders being provided with horizontal partitions or diaphragms C′ C′, located below the upper ends of the cylinders and constituting the heads thereof, the cylinders being open at their lower ends. These cylinders C C constitute the low-pressure cylinders of the engine.

D D are other cylinders affixed to the tops of the cylinders C C and smaller in diameter than the same, said cylinders D D being provided at points below their upper ends with horizontal partitions or diaphragms D′ D′, forming the cylinder-heads.

E E are other cylinders smaller than the cylinders D D and affixed to the upper ends of the latter, said cylinders constituting the high-pressure cylinders of the engine. The said cylinders E are provided near their up-

per ends with horizontal partitions or diaphragms E′ E′, which constitute the heads of said cylinders. The lower ends of the cylinders E E open into the upper ends of the cylinders D D, and the upper parts of the latter constitute steam chambers or receivers between said high and low pressure cylinders D and E. Similarly the cylinders D D open at their lower ends into the upper parts of the cylinders C C, and said upper parts of said cylinders C C constitute steam chambers or receivers between the high and low pressure cylinders D and C.

F F are vertical piston-rods extending through the cylinders C and D and into the cylinder E, the cylinder-heads C′ C′ D′ D′ E′ E′ being provided with glands or packings c^5 c^5 d^5 d^5 to prevent escape of steam past the heads. Attached to the piston-rods F F, within said cylinders, respectively, are pistons C^2 D^2 E^2.

Within the base-casting A are two upright air-cylinders G G, which are located between the crank-shaft and the lowermost steam-cylinders C C and are arranged in alinement with the said steam-cylinders. Within the air-cylinders G G are located pistons G′ G′, to which the piston-rods F F are attached at their lower ends. The air-cylinders G G are open at their lower and closed at their upper ends, the piston-rods F F passing through packing boxes or glands *g g* in the top walls of the said air-cylinders. The pistons G′ G′ are connected with the cranks B′ B′ of the shaft by means of connecting-rods H H, which engage at their upper ends with transverse bearing-pins *h h*, attached to said pistons. In the particular construction shown the pistons G′ G′ have the form of hollow cylinders closed at their upper ends and the pins *h h* are inserted transversely through the opposite side walls of the pistons. The air-cylinders and the pistons therein thus constructed take the place of the cross-head guides and cross-heads such as are commonly employed in steam-engines, and said cylinders and pistons serve, by the compression of the air between the pistons and the upper ends of the cylinders in the upstroke of the piston-rods, to gradually retard the movement of said piston-rods and connected parts in the upstroke thereof and to maintain the connecting-rod in compression at all times during the upstroke. Said cylinders G G are provided with air-inlet openings *g′ g′* to afford access of air to the cylinders at each downstroke of the piston.

The tops of the upper cylinders E E are closed by means of heads I I, which form, with the heads E′ E′, steam chests or chambers at the upper ends of the high-pressure cylinders, to which steam is supplied by means of a steam-supply pipe I′, connected with central openings in the said heads I I in the manner illustrated.

The pistons of the several cylinders are actuated by steam acting in the upper ends of the cylinders only, the steam entering the upper ends of the several cylinders through ports or passages extending from the steam-spaces above the cylinder heads or diaphragms C′ D′ E′ to the spaces below said diaphragms, while the exhaust-steam from each cylinder in the upward stroke of the piston therein passes from the upper end of the cylinders through suitable steam-passages to the steam space or receiver in the upper part of the larger cylinder below it. Each cylinder being in communication at its lower end with the upper compartment of the adjacent larger cylinder, exhaust-steam entering the upper parts of the cylinders C and D in the upstroke of the several pistons will be free to enter the lower parts of the cylinders D and E below the pistons therein, so that the upper chambers of the said cylinders D and E, together with the lower parts of the cylinders D and E, below the pistons in the latter, in effect constitute the steam chambers or receivers between the said cylinders.

C^3 D^3 E^3 indicate the vertical passages for exhaust-steam leading from the upper ends of the several chambers C, D, and E to the lower ends thereof and discharging into the upper ends of the cylinders below them in the case of the high-pressure cylinders D and E and into the exhaust-chamber A′ at the upper part of the base A in the case of the largest or low-pressure cylinders C. Said steam-passages are herein shown as formed in the walls of the cylinders; but as far as the general operation of the engine is concerned they may be cast in the walls of the cylinders, as shown in Fig. 18, formed by separate external pipes, as illustrated in Figs. 19 and 20, or formed in any other manner found convenient or desirable. I have, however, herein shown in Figs. 1 to 14 a special construction in these parts by which they may be cheaply and easily constructed, wherein each of the cylinders C, D, and E consists of separate inner and outer parts, of which the outer parts are cylindric shells *c d e*, while the inner parts consist of cylinders *c′ d′ e′*, shorter than the outer cylinders *c d e*, and cast integral with the diaphragms or partitions C′ D′ E′. One of the inner cylinders and its connected head is shown detached in Fig. 9.

The steam inlet and exhaust ports, together with the valves for controlling the same, are alike in the several cylinders, (with the exception of an added cut-off valve in the case of the high-pressure cylinder E,) and a description of the valve mechanism for one cylinder will therefore serve for all, the valves, ports, and parts of the valve mechanism connected with all the cylinders being for convenience lettered in the same manner in the drawings.

Referring first to the more simple form of valve or that belonging to the low-pressure cylinders C and D, the same, as more clearly shown in Figs. 7, 8, 9, and 10, is made as follows:

J is an annular valve-seat formed at the

upper margin of the diaphragm or partition forming the cylinder-head, and in which is formed a series of ports or openings *j j j*, which lead through said diaphragm or partition from the steam space or receiver above the same to the cylinder below it and which are arranged at equal distances apart throughout the entire circumference of the cylinder-head. Said ports constitute the live-steam or supply passages of the cylinder.

J′ is a second annular valve-seat extending around the head adjacent to the other seat J and provided with a plurality of ports or openings *j′ j′ j′*, which constitute the exhaust-ports of the cylinder and connect the exhaust-passage C^3, D^3, or E^3 with the interior of the cylinder. The seat J′ is preferably made of cylindric form and extends downwardly below the inner surface of the top wall of the cylinder, so that the ports *j′ j′ j′* extend directly through the cylindric side wall of the cylinder, and their length is only equal to the thickness of the cylinder-wall between the interior of the cylinder and the exhaust-passage at this point. The seat J is preferably arranged at an angle with the seat J′ and extends over the cylinder-head, so that the ports *j j j* extend directly through said cylinder adjacent to its outer margin where it joins the side wall of the cylinder.

K is a valve-ring adapted to fit against the annular valve-seat J and J′ and to also fit and bear against an annular cylindric bearing or seat J^2, formed on the inner surface of that part of the cylinder adjacent to the cylinder-head, the annular valve-ring K being adapted to fill the space between the exterior seat J^2 and the internal seats J and J′, so as to close the space between the receiver and the exhaust-passage, and thus prevent the escape of steam directly from the receiver to said exhaust-passage. For this purpose the said annular valve K consists of an outer cylindric part K′, the lower portion of which overlaps the valve-seat J′ and extends between the valve-ports *j′ j′* and the exhaust-passage and the upper part of which bears at its outer surface against the annular seat J^2, and an inwardly-extending flange K^2, which extends over the seat J and serves to control the admission of steam to the ports *j j*, formed in said seat. The inner part or flange K^2 of the valve is provided with a plurality of ports *k k*, corresponding in size and distance apart with the said ports *j j*, while the outer or cylindric part of the valve is provided near its lower margin with a plurality of ports *k′ k′ k′*, adapted to act in connection with the ports *j′ j′* and corresponding in size and distance apart with the latter. The lower cylindric part of the valve-ring K in effect constitutes a valve controlling the exhaust-ports *j′ j′*, while the inwardly-extending part of the flange of the valve-ring constitutes in effect a valve controlling the inlet-ports *j j*, these parts, however, being made in one piece in the form of a single moving ring, which also constitutes a wall or partition dividing the steam chest or receiver from the exhaust-passage, the valve-ring for this purpose being arranged to fit against the exterior valve-seat J^2, so as to make a steam-tight joint therewith as well as with the seats J and J′. In order to avoid leakage past the outer surface of the valve-ring, I preferably provide a packing k^2 in the upper part of the outer cylindric surface of the ring.

The valve-seat J and the opposing surfaces of the valve-ring are shown as arranged obliquely to the side wall of the cylinder and as made of conical form, this construction being employed in order to prevent undue pressure of the valve-ring against its seat under the action of steam when the valve is closed, it being obvious that the steam will act with greatest effect when the valve-seat is made more inclined, and that if it is made cylindric, or nearly so, the steam will have no effect to force the valve against its seat, or, in other words, it will be practically balanced. For these reasons I prefer to make the valve-seat J oblique or inclined, and the inclination in practice will be made such as to afford sufficient pressure to keep the valve steam-tight without giving undue friction. The valve-seat J′ being cylindric, that part of the valve controlling the exhaust-ports will be perfectly balanced.

In order to secure the alternate admission and escape of steam from the cylinder by the use of a single valve-ring such as is described, it is obviously necessary that the steam inlet and exhaust ports of the cylinder and valve-ring should be so arranged that when the inlet-ports are closed the exhaust-ports will be open, and vice versa. This result may be accomplished by arranging the inlet-ports of either parts opposite the spaces between the exhaust-ports of the same parts, the drawings showing the inlet and exhaust ports of the valve-ring opposite each other, while the two sets of ports in the cylinder are alternated or staggered, as shown in Fig. 9.

The valve-ring arranged as described is obviously adapted to rise from its seat under an extraordinary pressure within the cylinder, such as would be produced by the action of the piston on water confined within the cylinder, thereby relieving the pressure by opening the inlet or exhaust port, or both. When the valve-ring is so moved, it is obviously held in place or guided by its engagement with the outer valve-seat J^2, which, being cylindric, allows the ring to slide vertically thereon.

As a further improvement I provide on the upper surface of the cylindric head a cylindric seat J^3, formed as shown on the outer surface of an upwardly-extending circular flange on the cylinder-head, and I so construct the valve-ring that it will closely fit at its inner edge against said seat J^3. This feature of construction obviates liability of the leakage of steam from the receiver to the in-

let-ports of the cylinder around the inner edge of the valve-ring. To still further provide against leakage of steam at this point, especially in case the parts become loose by wear, I extend the inner margin of the valve-ring upwardly in the form of a flange, or increase the thickness of the edge of the ring and insert in the cylindric inner face of the latter a packing-ring k^3, adapted to bear on the seat J^3. The packing-rings k^2 and k^3 on the outer and inner surfaces of the valve-ring obviously serve to insure steam-tight joints at both sides of the valve-ring, thereby avoiding liability of leakage of steam past the ring, while at the same time leaving it free to rise for the escape of water which may by accident be contained within the cylinder. When by reason of the presence of water in the cylinder the valve-ring is lifted, such water will escape into the exhaust-passage past the lower edge of the ring whenever the ring is raised sufficiently to bring such lower edge of the ring above the lower margins of the exhaust-ports.

While the lower or cylindric part of the valve-ring made as described is adapted to alternately open and close the exhaust-ports of the cylinder, and the valve-ring will be operative for this purpose if the annular exhaust-passage of the cylinder is extended upwardly to the upper edges of the ports or openings in the ring, so as to form an open space around the lower part of the ring, yet the drawings illustrate features of construction in these parts by which special advantages are obtained, as follows: The outer cylindric bearing-surface or valve-seat J^2, against which the valve-ring bears at its outer surface, is extended downwardly in the form of vertical ribs $j^2 j^2 j^2$, Figs. 13 and 14, forming a series of passages $j^3 j^3 j^3$, corresponding in number with and arranged opposite the exhaust-ports $j' j' j'$ of the cylinder, the said ribs being made integral with the exterior part of the cylinder. The advantage gained by extending the valve-seat J^2 downwardly below the ports of the valve-ring is that the seat thus constructed serves to withstand outward pressure tending to disrupt the valve-ring, it being obvious that, inasmuch as the valve-ring will in this construction rest against and slide on the seat J^2 and ribs forming downward extensions thereof, its tensile strength need not be relied upon to hold closed the exhaust-passages, and the ring may be made lighter or thinner than would otherwise be necessary, without danger of breakage. The particular construction shown in the passages $j^3 j^3 j^3$, while obviously advantageous and valuable where the cylinder is made of a single piece of cast metal, is not in all cases necessary for securing an external bearing-surface or seat for the lower part of the valve-ring, it being obvious that such bearing-surface may be formed by or upon a separate bushing provided with ports, as shown in Fig. 22, which illustrates a seat made in this manner.

In Fig. 21 is shown a construction in which the valve-seat J^2 is extended downwardly to the lower edge of the valve-ring, and a plurality of ports or openings $j^4 j^4$ are provided opposite the exhaust-ports of the cylinder, said ports $j^4 j^4$ being in communication with the exhaust-passage by suitable passages in the cylinder-wall. In the particular construction shown in said figure, wherein the cylinder consists of separate inner and outer shells, the ports are separated from each other by vertical ribs arranged in the same manner as the ribs $j^2 j^2$ of Figs. 13 and 14, said ribs forming vertical passages leading from the ports $j^4 j^4$ behind the lower annular part of the valve-seat to the annular steam-passage formed between the said shells.

In Fig. 22 the bearing-surface of the valve-seat J^2 is shown as formed by a separate cylindric shell or bushing j^7, inserted in the upper part of the outer shell of the cylinder, and in which the ports $j^4 j^4$ are formed. The cylinder is shown as provided with integral ribs $j^2 j^2$, located between the ports and serving to support the lower margin of the bushing; but such ribs are not necessary where the bushing is itself made of sufficient weight or strength to limit or prevent expansion or rupture of the valve-ring.

The valve controlling the inlet and exhaust ports of the high-pressure cylinder E is like that above described, with the exception of an added valve-ring L, which is interposed between that part of the valve-ring K which controls the inlet steam-ports $j\ j$ and the steam-space of the steam-chest, so as to afford a means of controlling the steam supply in accordance with the work to be done, thereby securing the results produced by what is ordinarily known as a "cut-off valve." The main valve illustrated in connection with the high-pressure cylinder is like the valve hereinbefore described, and the parts of said valve are lettered in the same manner, the only difference being that the valve-ring K in this instance, Fig. 6, is adapted to form a valve-seat for the said valve-ring L. For this purpose the upper surface of the flange K^2 of the valve-ring is shown as provided with a horizontal or flat top surface k^4, upon which rests the said valve-ring L or cut-off valve, and the cylindric valve-seat J^3 constitutes a guide-surface for the inner cylindric surface of the ring L, the packing k^3 on the inner edge of the valve-ring K being omitted. The said ring L when thus arranged is preferably fitted closely to the annular seat J^3, and to insure a steam-tight joint at this point a packing l' is preferably inserted in the vertical surface of the ring. The said ring L is provided with ports $l\ l$, corresponding in size and distance apart with the ports k of the valve-ring K.

It will of course be understood that the

valve-ring L is movable independently of the valve-ring K and that said valve-ring L may either be oscillated through a predetermined distance at each stroke of the piston to cut off the steam supply at a certain point in the stroke, as may be desired by the operator, or it may be moved through variable distances by means of an automatic regulating device or governor, so that the points of cut off may be varied to correspond with the amount of work being done by the engine. The engine herein shown is provided with an automatic regulating device of this character, as will hereinafter appear.

To now refer to the means shown for communicating oscillatory movement to the several valve-rings above described from a reciprocating part exterior to the cylinder, these parts are constructed as follows: In the wall of the cylinder, opposite the valve-ring K, (or that part hereinbefore designated as the annular valve-seat J^2,) at a point between the ports k' k' and the packing-rings k^2 thereof, is formed a horizontal groove or recess M, which is open at the inner surface of the cylinder and preferably extends through somewhat more than a third of the circumference of the valve-ring, as clearly seen in Figs. 3 and 8. Extending through the central part of this recess M is a horizontally-arranged transverse rod M', the ends of which are attached to pistons m m', which pistons slide in the horizontal cylinders N N', which are formed on or attached to the exterior wall of the cylinder and open at their inner ends into the recess M above referred to. Reciprocatory motion in the rod M is permitted by the sliding of the pistons m m' in the cylinders N N', while at the same time the said pistons, being provided with suitable packings, serve to prevent escape from the recess M of steam which may leak into the same from the receiver or cylinder.

For the purpose of transmitting motion from the reciprocating rod M' to the valve-ring K flexible metal strips M^2 M^3 are attached at their opposite ends, respectively, to the said rod and to the ring, each strip being attached to one end of the rod and at its opposite end to the ring, and the strips being arranged to extend past or overlap each other, so that movement of the rod in one direction will, by tension on the strap, turn the ring in the same direction and movement of the rod in the opposite direction will similarly act, by tension on the strap, to turn the ring in such opposite direction.

To secure smoothness and uniformity of movement, the rod M' is preferably made flat on its inner face or that adjacent to the ring K and is placed at a distance from the surface of the ring not materially greater than the thickness of the metal strips M^2 M^3, so that the parts of the strips resting in contact with the flat surface of the rod are practically tangent to the surface of the valve-ring, against which the strips rest. The valve-ring is shown as recessed, Fig. 6, to receive the strips M^2 M^3, so that the outer surface of the latter are flush with the outer surface of the ring. As a means of attaching the ends of said strips M^2 M^3 to the ring the latter is shown as provided with lugs k^7, which extend outwardly into the recess M and through which are inserted bolts m^2 m^2, provided with eyes which engage loops formed on the ends of the strips, said bolts m^2 being provided with nuts by which they can be moved to tighten the strips M^2 M^3. For adjustably attaching the ends of the strips M^2 M^3 to the rod M', the latter is provided with devices at each end, as follows: On a screw-threaded part of the rod adjacent to the end thereof is located a nut m^3 and adjacent to the same a sliding sleeve m^4, to which the end of the flexible strip is rigidly secured. Said nut and sleeve are provided at their adjacent ends with annular grooves which are engaged by flanges on a connecting-sleeve m^5, which sleeve is shown as made in two parts or sections, held together by a wrapping of wire, whereby it may be easily applied and detached. The nut m^3 is shown as provided with marginal holes for a wrench or spanner, so that it may be easily turned on the screw-threaded part of the rod, the effect of turning the nut outwardly on the rod being to draw the sleeve m^4 outwardly and to thereby tighten the strip which is attached to the sleeve. By means of adjusting devices on both the rod and the ring the straps M^2 M^3 may not only be tightened when desired, but the rod may be adjusted accurately into such position relatively to the valve-ring as is necessary for the perfect working of the valve.

As herein shown, the two opposite cylinders of the engine, or those which are side by side, are provided with valve-actuating rods M' M', arranged in alinement with each other, said rods being connected with the actuating devices by which they are moved by means of a single valve-stem M^4, which passes through the head n of that cylinder N which is nearest the actuating devices and is attached to the piston m within said cylinder. Motion is transmitted from the reciprocating rod M' of one cylinder to that of the other cylinder by connecting-rods m^6 m^6, which are united by a coupling m^7, and in order to avoid the necessity for heads on the adjacent cylinders N N' the latter are connected by a tubular connecting-piece N^2. The cylinder N' at the side of the main cylinder which is remote from the actuating devices is shown as provided with a closed head n'.

While in case of the lower cylinders, which are closely adjacent to each other, the adjacent cylinders N N' of the actuating devices are connected with each other by a tubular connecting-piece N^2, this construction is not usually desirable for the high-pressure cylinders, which by reason of their smaller diameter are relatively farther apart, and in case of these cylinders the rods M' M' of the

two cylinders are shown as connected by stems or rods m^8, passing through heads n^2 n^3 of the cylinders N N'.

The device shown for giving oscillatory movement to the cut-off-valve ring L is similar in all respects to that above described for operating the rings of the main valves, the same embracing reciprocating rods O, passing through the steam-chest adjacent to the cylindric part L' of the said valve-ring and connected with the same by straps O' O^2, arranged in the same manner as the straps M^2 M^3, hereinbefore described. At its ends the rod O is provided with pistons working in the cylinders P P', which are secured to or formed upon the outer wall of the high-pressure cylinder E and open at their inner ends into the steam-chest. The rods O O belonging to the two high-pressure cylinders are shown as arranged in alinement with each other, Fig. 5, and as connected with each other by means of a valve-stem *o*.

As a means of giving motion to the actuating-rods M' of the main valves devices are provided as follows: Q is a rock-shaft arranged vertically or parallel with the central axes of the steam-cylinders and mounted in brackets *q q q*, which are attached to the engine-base and cylinders, said rock-shaft being provided with rigid arms q' q', which are connected with the valve stems or rods M^4 M^4 by means of pivoted connecting-rods q^2 q^2 q^2. A second rock-shaft Q' is provided for actuating the cut-off valve, said rock-shaft being conveniently located within the rock-shaft Q, which is made hollow to receive it, and being provided at its upper end with a rigid arm q^3, which is connected with a valve-stem o', attached to the rod O by means of a pivoted connecting-rod q^4. Motion is given to the rock-shaft Q by means of an obliquely-arranged disk or cam-plate R, which is attached to the shaft B outside of the base of the machine and acts on a rigid arm q^5, which is attached to the lower end of said rock-shaft. Motion is similarly transmitted to the rock-shaft Q' by means of a second obliquely-arranged disk or cam-plate S, which is mounted on the shaft B and engages a rigid arm q^6 on the said rock-shaft Q'. The second cam-plate S is adapted to be turned or partially rotated on the shaft, and its movements are controlled and position determined by means of a governing device, herein shown as having the form of a fly-wheel governor, and which will be hereinafter described.

It is obviously necessary, in order to secure positive and uniform action of the valves, that the arm q^5 should be held at all times closely in contact with the cam-plate R, by means of which motion is given thereto. For so holding the said arm in contact with the said cam-plate I provide that the endwise pressure of the steam upon the pistons *m* of the several cylinders shall be greater than that on the pistons *m'*, by making said pistons *m* larger than the pistons *m'*, so that steam-pressure acting on the inner ends of said pistons *m* will tend to continually press or turn the rock-shaft Q in a direction to carry and hold the arm q^5 against the surface of the cam-plate R. Similarly, for maintaining the arm q^6 of the second rock-shaft Q' in contact with the cam-plate S, the piston within the cylinder P is made larger in diameter than the opposite piston P', the effect of the steam on these pistons being to force or carry the rod O in such direction as to throw said arm q^6 toward said cam-plate S. It follows from the above that as the crank is turned the several valves will be actuated once during each oscillatory movement of the piston.

The cam-plate S, which operates the cut-off valve, is mounted to turn on the shaft, and a governing device is applied to the fly-wheel or belt-pulley B^2 of the engine and serves to move or turn said cam on the shaft, said parts being constructed as follows: The cam-plate S, which operates the cut-off valve, is mounted to turn on the shaft, and a governing device is applied to the fly-wheel or belt-pulley B^2 of the engine and serves to move or turn said cam on the shaft, said parts being constructed as follows: Said cam-plate S is attached to or formed on a sleeve S', which is mounted on a shaft B, adjacent to the pulley B^2, and is provided with a rigidly-attached radial arm *s*. Pivotally mounted on one side of the pulley B^2 is a lever T, which carries at one end a weight T' and is connected at its opposite end by a rod *t* with the arm *s* of the cam-sleeve. A spring T^2, attached to the wheel-rim, is connected with the weighted end of the lever T by means of a strap or cord *t'*, and thereby holds the weight normally at the inward limit of its movement, the parts being so adjusted that when the weight is drawn inwardly by the spring the cam-plate S will be shifted so as to move the cut-off valve into a position to give a maximum admission of steam to the high-pressure cylinder. As the speed of the engine increases the centrifugal action of the weight T' will move the lever T in opposition to the action of the spring, and said lever, by pressing on the arm *s*, will turn the cam-plate and thereby change its relation to the cam-plate R, which operates the main valves, so as to cut off the steam supply at such point in the stroke of the piston as is determined by the speed of the engine.

The actuating device for the valve which is illustrated is only one of a number of devices which may be used for this purpose in connection with the form of valve described, such device being herein shown as one convenient and practical way of giving motion to the valves.

To refer to the specific features of construction shown in the several cylinders and the base on which they are supported, each of the several exterior shells *d e* of the cylinders D E are joined to the larger shell below the same by means of outward-extending flanges d^2 e^2, formed on the lower edges of

said outer shells and fitting the adjacent open ends of the outer shells *c d* below them, to which they are secured by bolts, as shown. In the case of the lowermost or larger cylinder C the outer shell *c* is provided at its lower margin with a similar flange c^2, which fits the margins of a circular opening in the top wall A^2 of said base A. The inner shells of the cylinders *c' d' e'* are shown as provided at their lower margins with outwardly-extending flanges c^3 d^3 e^3, the outer margins of which fit within rabbets in the lower ends of the outer shells, the inner shells being held in place within the outer ones by bolts inserted through the said flanges c^3 d^3 e^3 into the outer shells in the manner illustrated.

A plurality of segmental slots c^4 d^4 e^4, formed in the flanges c^3 d^3 e^3, opposite the spaces between the inner and outer shells, afford free passage for the exhaust-steam from said spaces. The cylinder-heads C' D', through which the piston-rod F passes, are provided with glands or packings c^5 d^5 to prevent the escape of steam past said heads or diaphragms.

The base-casting A is provided some distance below its top wall, to which the lower cylinders C C are attached, with a horizontal partition A^3, which forms the bottom wall of the chamber A', and which also serves to sustain the air-cylinders G G, which are bolted to the said partition, and the heads *g g* of which air-cylinders form part of the same. A second partition A^4, below the partition A^3, serves to give strength to the base and also to hold in position the lower ends of the air-cylinders. Said partitions A^3 A^4 are shown as provided with holes, through which the air-cylinders pass and within which they closely fit, the cylinders being provided at their upper ends with outwardly-extending flanges, which extend over and rest on the upper partition A^3, and through which are inserted the bolts which secure the air-cylinders in place and the top walls or heads *g* to the air-cylinders. This construction enables the air-cylinders to be easily inserted in place through openings in the top of the base-casting before the air-cylinders are placed on the latter.

As an improved means of attaching the several pistons with the piston-rods F F these parts are made as shown in Fig. 12. The piston-rod is made smaller at its upper than at its lower end, and at each piston is formed a shoulder *f*, above which is a cylindric part or bearing-surface *f'*, upon which the piston fits, the holes in the pistons being of varying size, and the parts *f' f'* are made of gradually-increasing diameter from the upper to the lower end of the piston-rod, so that the pistons may be slipped over the upper end of the rod one after the other, and each will engage its appropriate bearing-surface *f'* and will rest in contact with its shoulder *f*. Above each bearing-surface *f'* the rod is provided with a screw-threaded part f^2, on which is placed a screw-threaded nut or collar f^3, the screw-threaded part being made enough larger in diameter than the part of the rod above it to enable the nut or collar to be slipped downwardly over the rod until engaged with the screw-thread.

The nut or collar f^3 fits within a recess in the piston, so that the top surface of the nut or collar is practically flush with that of the piston when the parts are placed together. The nut may be held from turning or unscrewing by any suitable means, that shown consisting of a screw f^4, inserted through an outwardly-extending flange on the nut into the part of the piston which is overlapped by said flange. The nuts or collars arranged as described afford a simple and effective means of securing the pistons in place in a manner to allow convenient removal of the pistons.

In Figs. 15, 16, and 17 I have shown a construction in the valve-ring K differing somewhat from that shown in the other figures of the drawings and hereinbefore described— in this instance a single oblique or conical valve-seat J^4, located at the intersection of the side and end walls of the cylinder and containing a single set of ports or openings j^5 j^5, arranged annularly and forming both the inlet and outlet ports of the cylinder. The valve-ring K is in this instance generally triangular in form, having an oblique lower surface fitting the seat J^4 and an outer cylindric surface or seat J^2 on the outer wall of the cylinder. Inside the conical seat J^4 is an inner cylindric seat J^3, like that hereinbefore described, the valve-ring having a cylindric bearing-surface fitting against the same. The valve-ring in this instance is provided with inlet-ports k^5 k^5 and outlet-ports k^6 k^6, both of which open at the lower or conical face of the ring, with their open ends in annular order and with the inlet-ports alternating with the outlet ones. The inlet-ports lead downwardly through the top of the ring to the lower surface of the same, and the outlet-ports lead from said lower surface outwardly to the side or cylindric surface of the same. At the lower margin of the valve-seat J^4 is preferably located a flange j^6, which extends upwardly at the outer cylindric surface of the valve-ring to more certainly prevent the escape of steam at this point. In a valve thus constructed oscillatory movement of the valve-ring brings the inlet and outlet ports of the ring alternately opposite the ports in the cylinder, thereby securing the admission of live steam to and the exit of exhaust-steam from the cylinder in the usual manner. A valve made as last described has obviously many of the advantages possessed by that hereinbefore described, it being obvious that the valve-ring is in this case free to rise from its seat to allow the escape of water under compression, and that it is otherwise similar in its action to the valve-ring first above described.

Fig. 18 shows the exhaust-passages D^4 of

the steam-cylinder D as cast integral with the wall of the cylinder. The said passages, in a construction of this kind, will communicate at their upper ends with an annular exhaust-passage opposite or adjacent to the main valve and at their lower ends with the receiver between the cylinders C and D.

When the exhaust-passages are made outside of and separate from the cylinder, they will communicate at their upper ends with an exhaust-passage which receives the exhaust-steam from the main valve and will communicate at their lower ends with the receiver. Said receiver is shown in said Fig. 19 as extending upward a short distance at the sides of the cylinder, thereby affording a larger steam-space in the receiver without increasing the size of the engine.

In the operation of the engine illustrated it is obvious that the several valves of the three connected cylinders C, D, and E will be moved at the same time to admit the steam to and allow its escape from the several cylinders, so that while the steam or boiler pressure is acting on the piston of the low-pressure cylinder steam previously exhausted from the high-pressure cylinder and the intermediate cylinder and formed in part by the lower portion of said cylinders will be acting on the pistons in the intermediate and lower cylinders D and C. It will be observed, furthermore, that inasmuch as the steam-inlet ports lead directly through the cylinders, heads, or partitions which separate the receivers from the cylinders they permit the steam to pass from the receivers to the low-pressure cylinders by the shortest possible route and without bringing the steam into contact with any extended steam-passages in which it may lose its heat or become condensed. It will also be observed that the construction and relative location of the receivers and connecting-passages are highly favorable for preventing the condensation of the steam, which latter is kept at all times practically within the cylinders in which it is used from the time it enters the high-pressure cylinder until its exit from the low-pressure cylinder.

It will of course be understood that inasmuch as each set of connected cylinders are single acting and operate in one direction only on the crank, the piston-rod and connecting-rod are always in compression, the cranks being set opposite each other, so that in the downstroke of the piston-rod of one set of cylinders the piston-rod of the other set is forced or carried upwardly to effect the discharge of the steam from the several cylinders. An important advantage is gained by maintaining the piston-rod and connected parts always under compression for the reason that all jarring or pounding which might otherwise occur by reason of looseness of the joints from wear is thereby prevented. The employment of the air-cylinders is of great benefit in this connection because by gradually retarding the movement of the piston-rods and connected parts in their upstroke it prevents said parts from moving upwardly under the impetus given them by the upward stroke of the crank in a manner to exert an upward pull on the crank-pin, so that the crank-pin bearing and other joints are always in compression with the advantages above stated. It may be here stated that there is practically no loss of power occasioned by the compression of the air within the air-cylinders, because the return or down stroke of each piston-rod is aided by the expansion of the air to an extent practically equal to the power required for compressing the air in its upward stroke.

The valves constructed as described not only have the advantage of affording direct passage of the steam from the steam-chest and the intermediate receivers to the cylinders, but they also have the advantage of affording a very large area both for the inflow of steam to and its escape from the cylinders with a relatively small movement of the valve, thereby avoiding any wiredrawing of the steam and insuring the full pressure thereof on the pistons when admitted to the cylinders and the utmost freedom of escape while being exhausted therefrom.

While I have shown a single-acting compound engine having three cylinders it is obvious that the same principles of construction are applicable to compound engines having only two or a greater number than three cylinders. It is, furthermore, also obvious that certain features of construction of the valves and other parts herein illustrated may be applied as well to single or non-compound or to double-acting engines, or those wherein the steam acts on both sides of the piston, as to single-acting compound engines such as herein illustrated.

I claim as my invention—

1. The combination with a cylinder, and a steam chest or receiver, said cylinder being provided with an exhaust-passage adjacent to its side wall and with annularly-arranged steam inlet and exhaust ports, and a valve-ring separating the steam chest or receiver from the exhaust-passage and provided with two sets of ports operating in connection with the steam inlet and exhaust ports of the cylinder, said cylinder being provided with a cylindrical bearing-surface engaging the outer surface of the valve-ring between the two sets of ports in the said ring, substantially as described.

2. The combination with a cylinder provided with live-steam and exhaust passages and also provided with a conical valve-seat having ports therein, of a valve-ring separating the live-steam from the exhaust passage and provided with ports communicating with said live-steam and exhaust passages, said valve-ring having a conical bearing-surface which is held by the steam-pressure normally in contact with the conical valve-seat

and a cylindric bearing-surface engaging said valve-ring between the live-steam and exhaust ports, said ring being adapted to slide on said cylindric bearing-surface toward and from its seat, substantially as described.

3. The combination with a cylinder and a steam chest or receiver, said cylinder being provided with an annular exhaust-passage adjacent to its side wall and with annularly-arranged steam inlet and exhaust ports, a valve-ring separating the steam chest or receiver from the exhaust-ports and provided with two sets of ports operating in connection with the steam inlet and exhaust ports of the cylinder, said cylinder being provided with a cylindric bearing-surface engaging the outer surface of the valve-ring between the two sets of ports in the said ring and the valve-seat, the engaging surfaces of the ring and valve-seat adjacent to the steam-ports being of conical form, substantially as described.

4. The combination with a cylinder and a steam chest or receiver, said cylinder being provided with an exhaust-passage adjacent to its side wall and with annularly-arranged steam inlet and exhaust passages, a valve-ring separating the steam chest or receiver from the exhaust-passage and provided with two sets of ports operating in connection with the steam inlet and exhaust ports of the cylinder, said cylinder being provided with an annular bearing-surface engaging the valve-ring between the two sets of ports in said ring, and a second or cut-off-valve ring resting against the main-valve ring, and provided with ports controlling the passage of steam to the said inlet-ports, substantially as described.

5. The combination with a cylinder, a steam chest or receiver and an exhaust-passage, said cylinder being provided with annularly-arranged steam-ports leading from the receiver to the cylinder, annularly-arranged exhaust-ports leading from the cylinder to an exhaust-passage and a valve-ring separating the steam chest or receiver from the exhaust-passage and provided with two sets of ports adapted to severally operate in connection with the said steam inlet and exhaust ports, and a cylindric surface on the cylinder engaging the outer surface of the valve-ring between the two sets of ports in said ring, substantially as described.

6. The combination with a cylinder, a steam chest or receiver located adjacent to the end of the cylinder and separated from the same by a diaphragm or partition forming the cylinder-head, and an exhaust-passage adjacent to the side wall of the cylinder, said cylinder being provided with annularly-arranged ports extending through the cylinder-head from the receiver to said cylinder, and with annularly-arranged ports leading through the side wall of the cylinder from the interior thereof to the exhaust-passage, and a valve-ring which extends over the head and side walls of the cylinder and separates the steam chest or receiver from the exhaust-passage, and which is provided with two sets of valve-ports operating severally in connection with the steam inlet and exhaust ports of the cylinder, substantially as described.

7. The combination with a cylinder and a steam chest or receiver adjacent to one end of the same, said cylinder being provided with a diaphragm or partition forming the cylinder-head, with an exhaust-passage adjacent to its side wall, and with annularly-arranged inlet-ports extending through the cylinder-head and annularly-arranged exhaust-ports extending through the side wall of the cylinder to said exhaust-passage, of a valve-ring provided with an outer cylindric part provided with valve-ports which operate in connection with the exhaust-ports, and an inwardly-extending part or flange covering the steam-inlet ports and provided with valve-ports operating in connection with the same, substantially as described.

8. The combination with a cylinder and a steam chest or receiver adjacent to one end of the same, said cylinder being provided with a diaphragm or partition separating it from the receiver and forming the cylinder-head, and being also provided with an exhaust-passage adjacent to its side wall and with an oblique or conical valve-seat at the margin of its head provided with steam-inlet ports and with a cylindric annular valve-seat provided with exhaust-ports and a valve-ring provided with annularly-arranged valve-ports operating in connection with the said inlet and exhaust ports, substantially as described.

9. The combination with high and low pressure cylinders both of which are closed at one end and open at the other, of an intermediate receiver in communication with the open end of the high-pressure cylinder, pistons in said cylinders and a single piston-rod to which both pistons are attached, said cylinders being each provided with steam inlet and exhaust ports located at the junction of the cylinder-heads with the side walls thereof and the high-pressure cylinder being provided with an exhaust passage or passages located exterior to its side wall and extending lengthwise of the cylinder from the exhaust port or ports at its closed end to the receiver and means for controlling the inflow of steam to and its exhaust from the cylinders.

10. The combination with high and low pressure cylinders each of which is closed at one end and open at the other, of an intermediate receiver in communication with the open end of the high-pressure cylinder, said receiver being separated from the low-pressure cylinder by a partition or diaphragm which forms the head of said low-pressure cylinder, pistons in the said cylinders, a single piston-rod to which said pistons are secured and which passes through said diaphragm or partition, said cylinders being provided with steam inlet and exhaust ports located in the

walls of the cylinders adjacent to their closed ends and said high-pressure cylinder being provided with an exhaust passage or passages located exterior to its side wall and extending lengthwise of the cylinder from the exhaust port or ports thereof to the said receiver and means controlling the passage of steam through said steam inlet and exhaust ports.

11. A single-acting compound engine comprising high and low pressure cylinders each of which is open at one end and closed at the other, an intermediate receiver in communication with the open end of the high-pressure cylinder, pistons in the cylinders and a single piston-rod to which both pistons are attached, said high-pressure cylinder being provided at its closed end with a plurality of annularly-arranged steam-inlet ports and at the same end with a plurality of annularly-arranged exhaust-ports and having exhaust-passages exterior to its side wall and extending lengthwise of the cylinder from said exhaust-ports to the said receiver and valves controlling the flow of steam through said ports.

12. A single-acting compound engine comprising high and low pressure cylinders both of which are closed at one end and open at the other end, an intermediate receiver in communication with the open end of the high-pressure cylinder, pistons within the cylinders, a single piston-rod to which both pistons are attached, said high-pressure cylinder being provided with annularly-arranged steam-inlet ports and annularly-arranged exhaust-ports both located at the closed end of said high-pressure cylinder, exhaust-passages located exterior to the wall of the high-pressure cylinder and extending longitudinally of the same from said exhaust-ports to the receiver and a single annular valve-ring provided with ports which operate in connection with both the inlet and exhaust ports of the high-pressure cylinder.

13. A single-acting compound engine comprising a high-pressure cylinder which is open at one end and closed at the other, a low-pressure cylinder larger in diameter than the high-pressure cylinder and provided with a diaphragm or partition located at a distance from the end of the cylinder and forming with the adjacent end of the high-pressure cylinder a receiver for exhaust-steam which is in communication with the open end of the high-pressure cylinder, pistons in said cylinders and a single piston-rod to which said pistons are secured, said high-pressure cylinder being provided with an inlet port or ports and with an exhaust port or ports located at its closed end and with exhaust-passages located exterior to the wall of the cylinder and leading from said exhaust-ports longitudinally of the cylinder to the receiver and said low-pressure cylinder being provided with annularly-arranged steam-inlet ports which extend through said partition or diaphragm and a valve-ring which controls said steam-inlet ports of the low-pressure cylinder.

14. A single-acting compound engine comprising a high-pressure cylinder which is open at one end and closed at the other, a low-pressure cylinder larger in diameter than the high-pressure cylinder and provided with a diaphragm or partition located at a distance from the end of the cylinder and forming with the adjacent end of the high-pressure cylinder a receiver for exhaust-steam which is in communication with the open end of such high-pressure cylinder, pistons in said cylinders, and a single piston-rod to which said pistons are secured, said high-pressure cylinder being provided at its closed end with an inlet port or ports and an exhaust port or ports and having an exhaust passage or passages located exteriorly to the wall of the cylinder and leading from exhaust port or ports longitudinally of the cylinder to the receiver, and the low-pressure cylinder being provided with a plurality of annularly-arranged steam-inlet ports which extend through the said partition or diaphragm and valve-ring controlling said inlet-ports of the low-pressure cylinder, and means for giving oscillatory movement to said valve-ring.

15. A single-acting compound engine comprising a high-pressure cylinder which is open at one end and closed at the other, a low-pressure cylinder larger in diameter than the high-pressure cylinder and provided with a diaphragm or partition, located at a distance from the end of the cylinder and forming with the adjacent end of the high-pressure cylinder a receiver for exhaust-steam which is in communication with the open end of the high-pressure cylinder, pistons in such cylinders and a single piston-rod to which said pistons are secured, such high-pressure cylinder being provided with steam inlet and exhaust ports at its closed end and having an exhaust passage or passages located exterior to the side wall of the cylinder and leading from such exhaust-ports longitudinally of the cylinder to the receiver and the low-pressure cylinder being provided with annularly-arranged steam-inlet ports extending through said partition or diaphragm with an exhaust-passage in its side wall adjacent to the said diaphragm and with annularly-arranged exhaust-ports at its closed end leading to said exhaust-passages, and a single valve-ring provided with ports which operate in connection both with said steam inlet and exhaust ports.

16. An engine-cylinder comprising inner and outer cylindric shells forming an exhaust-passage between them, and a cylinder-head cast integral with the inner shell, said head being provided with annularly-arranged inlet-ports and the inner shell with annularly-arranged exhaust-ports, and a valve-ring fitting between the inner and outer shells and controlling said inlet and exhaust ports, substantially as described.

17. An engine-cylinder comprising an outer and inner shell, and a head cast integral with

the inner shell, said outer shell being longer than the inner shell and being extended beyond the head to form the side walls of the steam chest or receiver, said inner shell and head being provided with annularly-arranged steam inlet and exhaust ports, and a valve-ring for controlling the inlet and exhaust openings or ports, said valve-ring being provided with an external cylindric surface engaging the inner surface of the outer cylinder which extends beyond the cylinder-head, substantially as described.

18. An engine-cylinder comprising outer and inner shells, and a cylinder-head cast integral with the inner shell, said shells being adapted to form an exhaust-passage between them, and the inner shell being attached to the outer shell by means of an outwardly-extending flange on the open end of the inner shell, which flange is bolted to the adjacent end of the outer shell, and provided with slots or apertures forming a continuation of the exhaust-steam passage, substantially as described.

19. The combination with an engine-cylinder and a steam chest or receiver separated from the cylinder by a diaphragm or partition forming the cylinder-head, said head being provided with annularly-arranged steam-inlet ports, and the side wall of the cylinder being provided with an annular exhaust-passage and with annularly-arranged ports leading from the interior of the cylinder to said exhaust-passage, a valve-ring provided with two sets of valve-ports operating in connection with said steam inlet and exhaust ports, and a second or cut-off-valve ring resting in contact with the main-valve ring and provided with ports for controlling the passage of steam to the inlet-ports of the valve, substantially as described.

20. The combination with an engine-cylinder and a steam chest or receiver separated from the cylinder by a diaphragm or partition forming the cylinder-head, said head being provided with annularly-arranged steam-inlet ports, and the side wall of the cylinder being provided with an annular exhaust-passage and with annularly-arranged ports leading from the interior of the cylinder to said exhaust-passage, a valve-ring provided with two sets of valve-ports operating in connection with said steam inlet and exhaust ports, and a second or cut-off-valve ring resting in contact with the main-valve ring and provided with ports for controlling the passage of steam to the inlet-ports of the valve, the cylinder-head being provided with a cylindric bearing-surface engaging the said cut-off-valve ring, substantially as described.

21. The combination with an engine-cylinder, of a valve-chest or receiver separated from the cylinder by a diaphragm or partition forming the cylinder-head, said cylinder being provided with an annular exhaust-passage in its side wall and with annularly-arranged steam-inlet ports in the said head, and annularly-arranged exhaust-ports leading through the side wall of the cylinder to said exhaust-passage, a valve-ring having an outer cylindric part which operates in connection with the exhaust-ports, and an inwardly-extending part or flange operating in connection with the said inlet-port, and a second cut-off-valve ring resting on said inwardly-extending part or flange and provided with annularly-arranged ports operating in connection with the ports in said flange, substantially as described.

22. The combination with a cylinder, and a steam chest or receiver, said cylinder being provided with an exhaust-passage adjacent to its side wall, and with annularly-arranged steam inlet and exhaust ports, and a valve-ring separating the steam chest or receiver from the exhaust-passage and provided with ports operating in connection with the steam inlet and exhaust ports of the cylinder, said cylinder being provided outside of the valve-ring with an annular bearing-surface or valve-seat against which the valve-ring bears, and which contains annularly-arranged ports or passages corresponding with the exhaust-ports in the valve-ring, and communicating with the exhaust-passage of the cylinder, substantially as described.

23. The combination with a cylinder provided with an annular steam-space, of an annular valve-ring within said space, a longitudinally-reciprocating rod extending tangentially through a stuffing-box into said steam-space, and flexible strands attached at their opposite ends to the ring and rod, substantially as described.

24. The combination with a cylinder or steam-chest and a valve-ring, of means for actuating the valve-ring comprising a longitudinally-reciprocating rod located within the cylinder or steam-chest adjacent to the ring, pistons attached to each end of said rod, a cylinder communicating with the interior of the cylinder or steam-chest within which said pistons slide, and means for giving longitudinal reciprocatory motion to the rod, substantially as described.

25. The combination with a cylinder and steam chest or receiver which is separated from the cylinder by a diaphragm forming the cylinder-head, said cylinder being provided with an annular exhaust-passage in its side wall and with steam inlet and exhaust passages leading from the steam chest or receiver to the interior of the cylinder, and from the interior of the cylinder to said exhaust-passage, a valve-ring controlling said steam inlet and exhaust openings and engaging an annular bearing-surface formed on the side wall of said cylinder, said cylinder being provided with a transverse recess located opposite the outer surface of said ring, and means for actuating the said ring comprising a longitudinally-sliding rod located in said recess, and

two flexible strips attached at their ends to said valve-ring and rod, substantially as described.

26. The combination with an engine-cylinder and a steam chest or receiver, of a valve-ring and means for actuating the same comprising a longitudinally-movable rod located adjacent to the valve-ring and provided at its ends with pistons, cylinders opening into the steam chest or receiver within which said pistons are adapted to slide, flexible strips attached at their opposite ends to the valve-ring and said rod, and means for giving reciprocatory motion to said rod comprising a revolving cam-plate, and a movable arm in contact with the plate and connected with the said rod, one of said pistons and its cylinder being made larger than the other whereby the pressure of steam thereon holds the said movable part or arm in contact with the said cam-plate, substantially as described.

27. The combination with the cylinder or cylinders and crank-shaft of an engine and the valves thereof, of means for actuating said valves comprising a rock-shaft arranged parallel with the central axes of the cylinder, said rock-shaft being provided with arms connected with said valves, a cam-plate on the crank-shaft and an arm on the rock-shaft engaging the cam-plate, substantially as described.

28. The combination with the cylinder or cylinders and crank-shaft of an engine and the valves thereof, of means for actuating said valves comprising a rock-shaft arranged parallel with the central axis of the cylinders, arms on the rock-shaft connected with the valves and a cam-plate on the crank-shaft of the engine, an arm on said rock-shaft in contact with said cam-plate, and means for holding the said arm in engagement with the plate, comprising a cylinder subject to steam-pressure, and a piston therein connected with an arm on the rock-shaft, substantially as described.

29. The combination with the high and low pressure cylinders and crank-shaft of a compound engine and the main and cut-off valves thereof, of means for actuating said valves comprising two rock-shafts arranged parallel with the central axis of the cylinders, rigid arms on the rock-shaft connected with the several valves, two cam-plates on the said crank-shaft, arms on said rock-shafts engaging said cam-plates, the cam-plate which operates the cut-off valve being mounted to rotate on the shaft, and a speed-governor carried by the shaft and operating said cam-plate, substantially as described.

30. The combination with an engine-cylinder, a steam chest or receiver and crank-shaft, of a valve-ring and means for actuating the same comprising a longitudinally-movable rod, flexible strips attached at their opposite ends to said valve-ring and rod, a cam-plate on the crank-shaft and a rock-shaft arranged parallel with the axis of the cylinder and provided with an arm connected with the said rod, and with a second arm engaging the said cam-plate, substantially as described.

31. The combination with an engine-cylinder, a steam chest or receiver and a crank-shaft, of a valve-ring and means for actuating the same comprising a longitudinally-movable rod provided at its ends with pistons, cylinders communicating with the steam chest or receiver and within which said pistons slide, flexible strips attached at their opposite ends to the valve-ring and rod, a cam-plate on the crank-shaft and a rock-shaft provided with an arm which is connected with the said rod, and with a second arm which bears against said cam-plate, one of said pistons and its cylinder being made larger than the other, to hold the arm of the rock-shaft in contact with said cam-plate, substantially as described.

32. The combination with a piston-rod provided with a shoulder, a smooth conical bearing-surface adjacent to said shoulder and a screw-thread adjacent to said bearing-surface of a piston provided with a central opening which fits closely the said conical bearing-surface, and with a deep circular recess surrounding said opening, said recess having a shallow circular part of increased diameter adjacent to the surface of the piston, an interiorly-screw-threaded collar having a deep cylindric part which fits accurately within the deeper part of said recess and is provided with an enlarged flange which fits within the shallow recess, with its outer surface flush with the face of the piston and a dowel-screw engaging said flange of the collar to hold said collar from turning in the piston, substantially as described.

In testimony that I claim the foregoing as my invention I affix my signature in presence of two witnesses.

MILAN C. BULLOCK.

Witnesses:
C. CLARENCE POOLE,
H. M. CARTER.