No. 663,403.

Patented Dec. 11, 1900.

E. T. ADAMS.

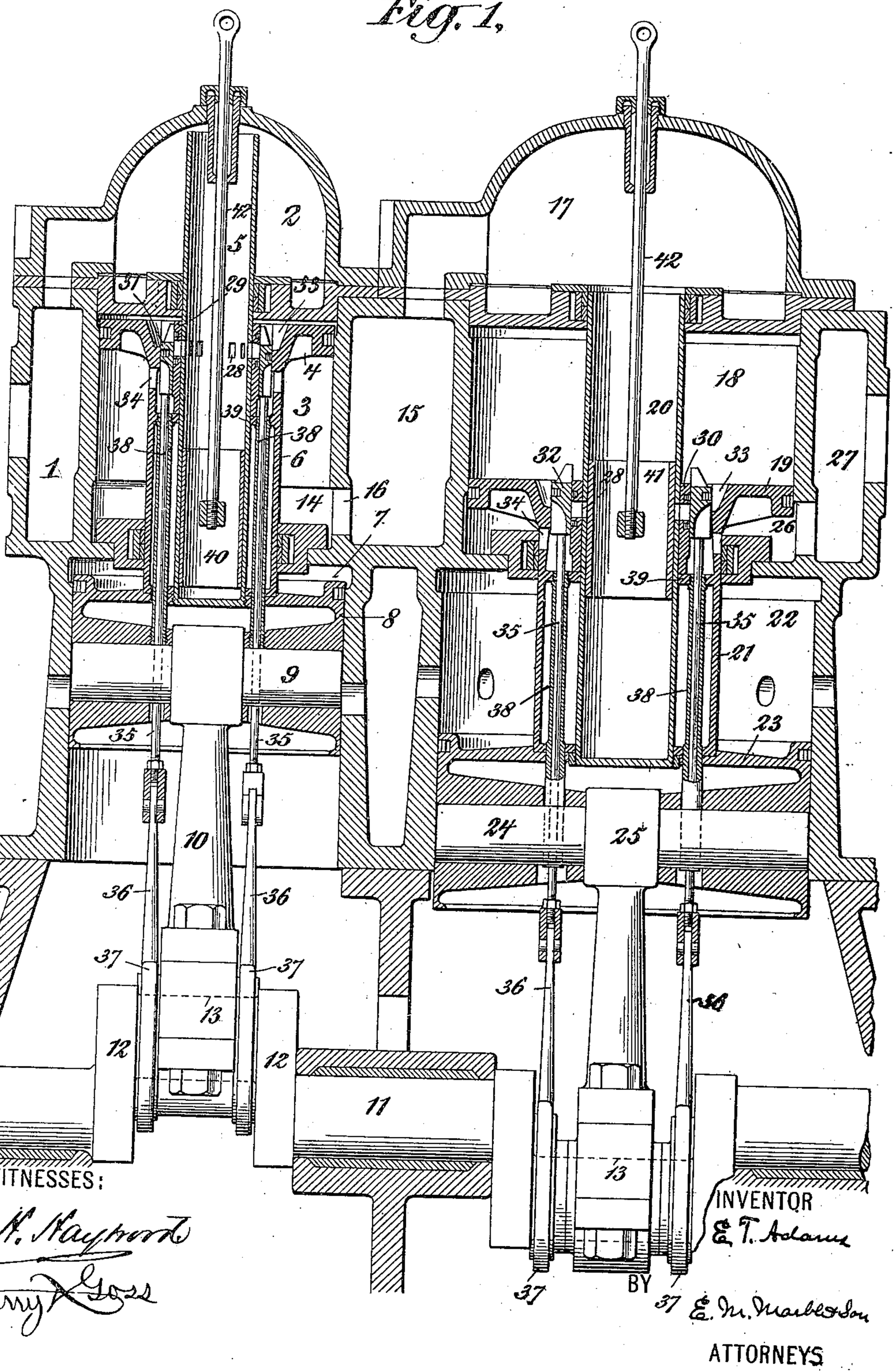
STEAM ENGINE.

(Application filed Apr. 7, 1899. Renewed May 1, 1900.)

(No Model.)

4 Sheets—Sheet 1.

Fig. 1.



WITNESSES:

D. N. Haywood

Harry A. Goss

INVENTOR

E. T. Adams

BY

E. M. Marble & Son

ATTORNEYS

No. 663,403.

Patented Dec. 11, 1900.

E. T. ADAMS.

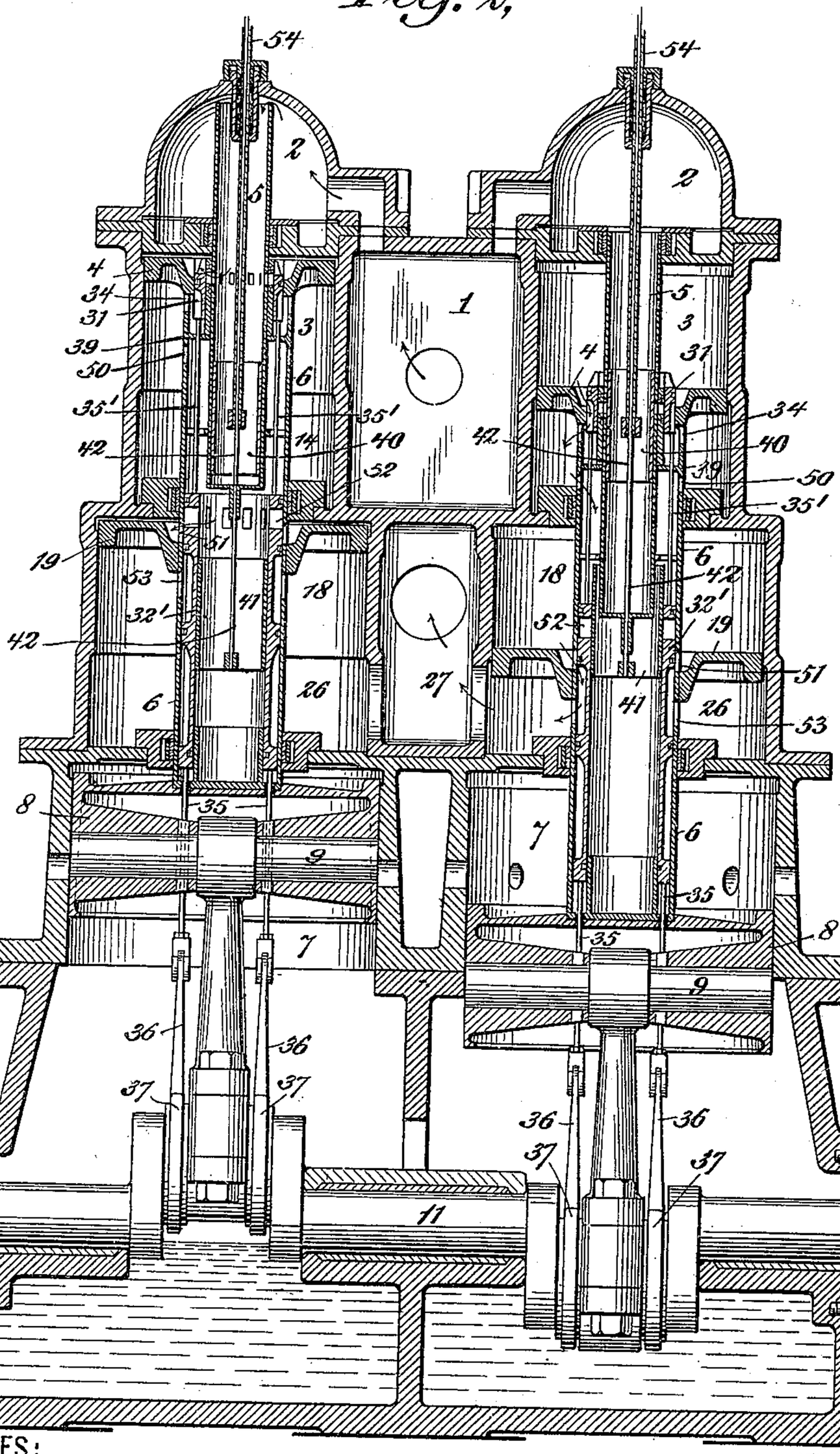
STEAM ENGINE.

(Application filed Apr. 7, 1899. Renewed May 1, 1900.)

(No Model.)

4 Sheets—Sheet 2.

Fig. 2.



WITNESSES:

D. F. Faybook

Harry F. Goss

INVENTOR

E. T. Adams

BY

E. M. Marble & Son

ATTORNEYS

No. 663,403.

Patented Dec. 11, 1900.

E. T. ADAMS.

STEAM ENGINE.

(Application filed Apr. 7, 1899. Renewed May 1, 1900.)

(No Model.)

4 Sheets—Sheet 3.

Fig. 3,

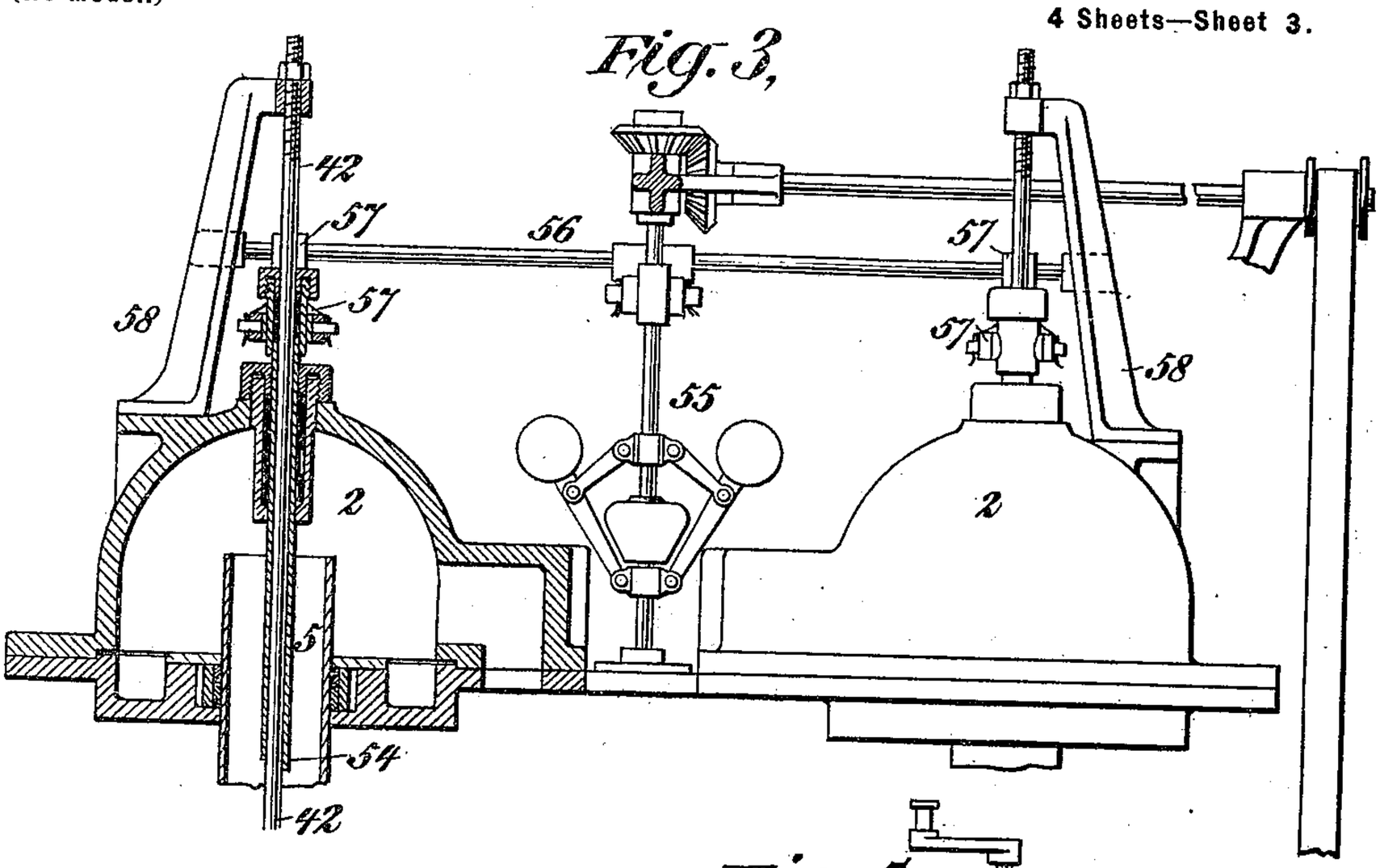


Fig. 5,

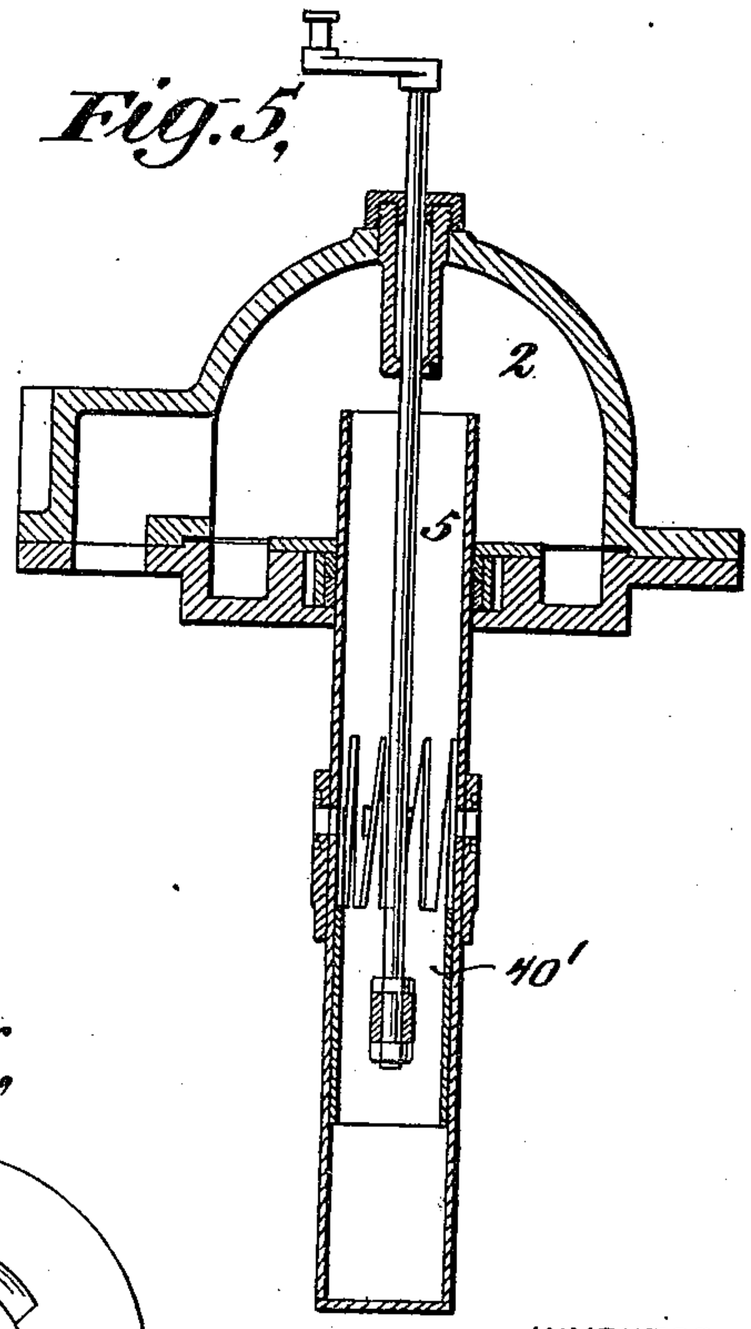


Fig. 4,

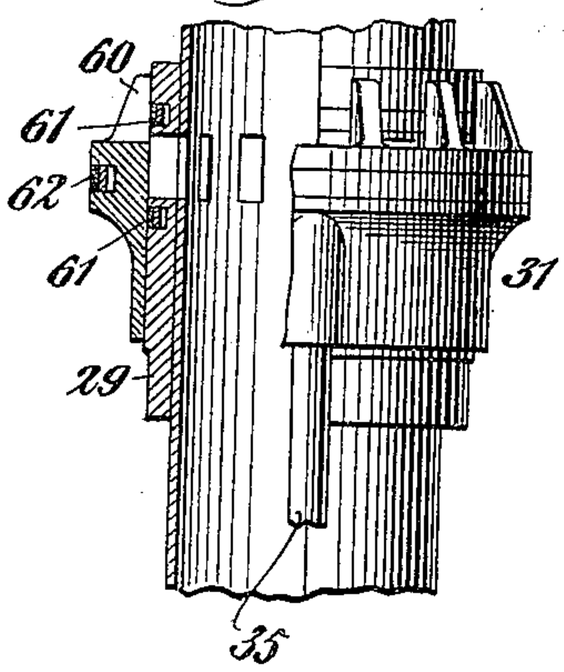
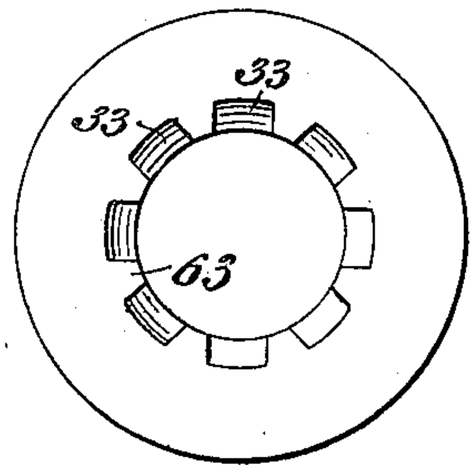


Fig. 6,



WITNESSES:

D. N. Haywood.

Harry A. Goss.

INVENTOR

E. T. Adams

BY

E. M. Marble & Son

ATTORNEYS

No. 663,403. Patented Dec. 11, 1900.

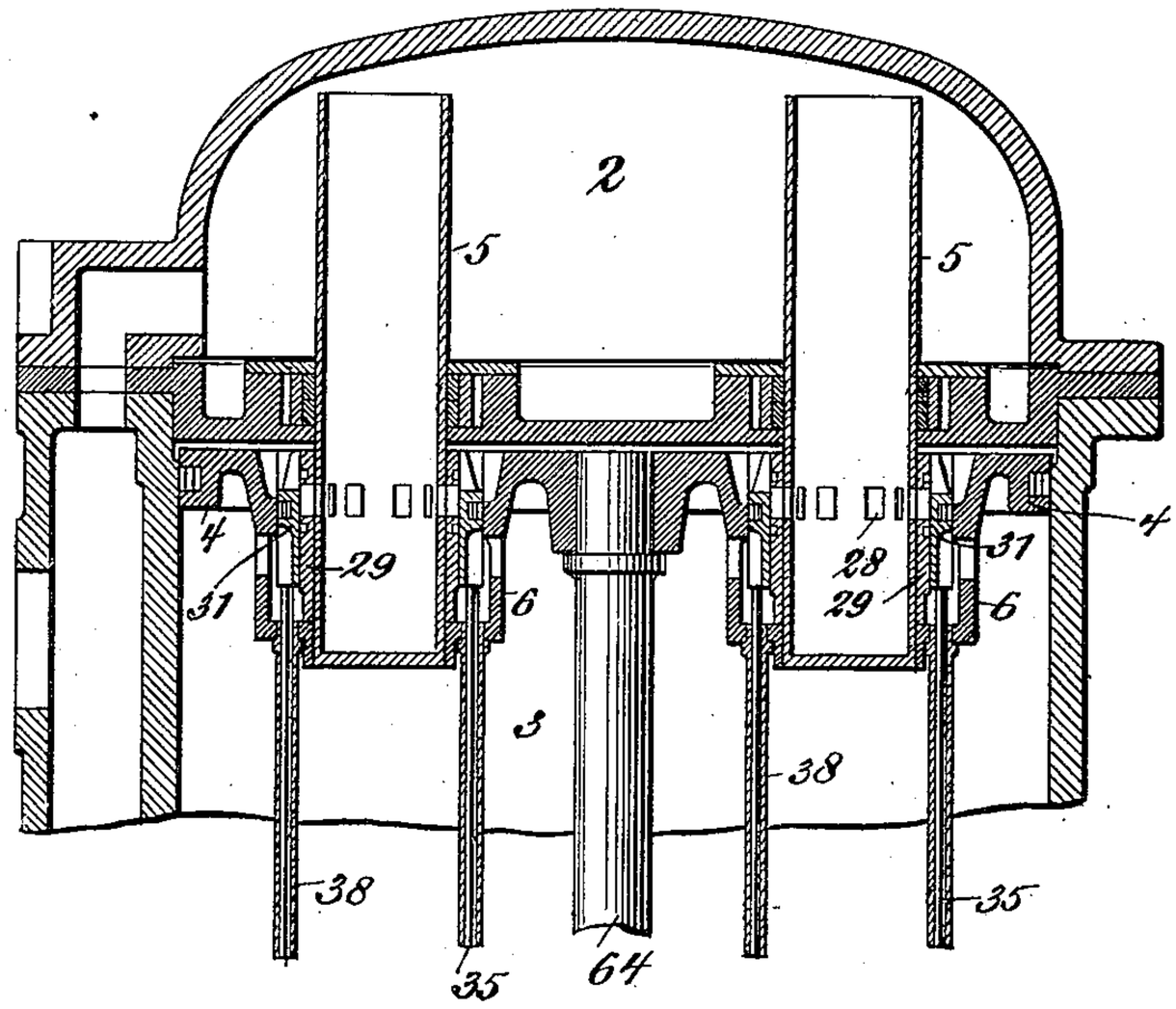
E. T. ADAMS.

STEAM ENGINE.

(Application filed Apr. 7, 1899. Renewed May 1, 1900.)

(No Model.) 4 Sheets—Sheet 4.

Fig. 7.



WITNESSES:

D. F. Raymond

Harry Gross

INVENTOR

E. T. Adams

BY

E. M. Marble & Son

ATTORNEYS.

UNITED STATES PATENT OFFICE.

EDWARD THOMAS ADAMS, OF MILWAUKEE, WISCONSIN.

STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 663,403, dated December 11, 1900.

Application filed April 7, 1899. Renewed May 1, 1900. Serial No. 15,132. (No model.)

To all whom it may concern:

Be it known that I, EDWARD THOMAS ADAMS, a citizen of the United States, residing at Milwaukee, in the county of Milwaukee and State of Wisconsin, have invented certain new and useful Improvements in Steam-Engines; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

My invention relates to steam-engines and other fluid-motors, and particularly to engines of what are known as the "central-valve" class, in which steam or other working fluid is introduced into the cylinders through a hollow piston-rod.

My invention consists in the novel construction and arrangement of the distribution-valves of such motors, in the novel cut-off valve employed, and generally in the novel combination, construction, and arrangement of the parts.

The objects of my invention are to increase the economy and efficiency of steam-engines and other fluid-motors, and particularly of motors of the central-valve class, to simplify the valve-gear of such motors, to reduce clearance-space, to provide large port-openings for the admission of the working fluid and for the exhaust thereof, to produce rapid cut-off, to improve and simplify the means employed for varying and adjusting automatically the point of cut-off, and to make the engine simple, compact, durable, and comparatively inexpensive. These objects are attained in the invention herein described, and illustrated in the drawings which accompany and form a part of this specification, in which the same reference-numerals indicate the same or corresponding parts, and in which—

Figure 1 is a central vertical section of a single-acting cross compound steam-engine constructed in accordance with my invention. Fig. 2 is a central vertical section of a double single-acting tandem compound engine constructed in accordance with my invention. Fig. 3 is a detail elevation and central vertical section of the upper ends of the cylinders of the engine shown in Fig. 2, showing means which may be employed for adjusting the high-pressure cut-off valves by means of an automatic governor and for supporting the low-pressure cut-off valves. Fig. 4 is a detail elevation and partial section of one of the distribution-valves and of the steam-admission tube upon which it is mounted. Fig. 5 is a transverse section of an engine cylinder and its hollow piston-rod and cut-off valve, showing a modified form of cut-off valve. Fig. 6 is a top view of one of the pistons; and Fig. 7 is a sectional view of an engine-cylinder, illustrating a modified form of valve-gear.

Referring first to Fig. 1, 1 is the steam-chest of the high-pressure cylinder, and 2 a steam-dome upon the upper end of that cylinder, connected with and forming substantially a continuation of the steam-chest.

3 is the high-pressure cylinder.

4 is the high-pressure piston, and 5 and 6 are concentric tubes which together form the piston-rod of the high-pressure cylinder.

7 is a guide and cushion cylinder beneath the high-pressure cylinder, such as are commonly employed in single-acting central-valve engines. 8 is the combined cross-head and piston within this cylinder; 9, the cross-head pin; 10, the connecting-rod; 11, the crank-shaft, and 12 12 the cranks for the high-pressure piston. The crank-pin 13 is shown in dotted lines.

14 is the exhaust-chamber beneath the cylinder 3, 15 the receiver in communication with 14 through a port 16, and 17 the steam-dome on the upper end of the low-pressure cylinder connected with and forming practically a part of the receiver 15.

18 is the low-pressure cylinder; 19, the low-pressure piston; 20 and 21, concentric tubes, together forming the low-pressure piston-rod; 22, the guide and cushion-cylinder beneath the low-pressure cylinder, and 23 the combined piston and cross-head of cylinder 22.

24 is the low-pressure cross-head pin, and 25 the low-pressure connecting-rod.

26 is the exhaust-space beneath the low-pressure cylinder, and 27 the exhaust-chest of the engine.

The cranks of the high-pressure and low-pressure cylinders are one hundred and eighty degrees apart. This is not essential, but is preferable in an engine of this class.

The tubes 5 and 20, which form parts of the high-pressure and low-pressure piston-rods, respectively, and through which steam is admitted to the high-pressure and low-pressure cylinders, are open at the top, communicating with the steam-domes 2 and 17, respectively. They pass through suitable stuffing-boxes in the upper cylinder-heads and at their lower ends are connected to the cross-heads 8 and 23, respectively. 28 28 are steam-ports in these tubes.

29 and 30 are valve-seat bushings surrounding tubes 5 and 20, respectively, and secured rigidly thereto, and 31 and 32 are the high-pressure and low-pressure distribution-valves, respectively. One of these valves is shown in elevation in Fig. 4. They are rings surrounding the valve-seat bushings 29 and 30 and adapted to move up and down with respect to the ports 28 in annular spaces separating the bushings 29 and 30 from the high-pressure and low-pressure pistons 4 and 19, respectively. These pistons are provided on their upper sides with recesses 33, surrounding the valves 31 and 32 and forming exhaust-ports.

The piston-rod tubes 6 and 21 are provided with ports 34 34 beneath their pistons, and the valves 31 and 32 are cut away on their under sides so as to permit the passage of steam, during the exhaust period in each cylinder, from above the piston, through the ports 33 and 34, into the space beneath the piston.

The tubes 6 and 21, which transmit the pressure upon the pistons to the cross-heads, pass through suitable stuffing-boxes in the lower cylinder-heads and are secured to the cross-heads in a suitable manner.

The valves 31 and 32 are reciprocated, with respect to the pistons and the valve-seat bushings 29 and 30, by valve-rods 35, connected by eccentric-rods 36 to eccentric-straps 37, the eccentrics of which are upon the crank-pins. These valve-rods are guided by bushings 38, which are secured to the cross-heads 8 and 23 and to internal flanges 39 of the tubes 6 and 21, which fit tightly against the internal piston-rod tubes 5 and 20, and thus prevent the passage of steam into the concentric chambers between the lower portions of the tubes 5 and 6 and 20 and 21, respectively. The long bushings 38 effectively prevent leakage of steam around the valve-rod.

Within the admission-tubes 5 and 20 of the piston-rods are cut-off sleeves 40 and 41, forming in effect riding cut-off valves and supported by valve-rods 42, passing through stuffing-boxes in the tops of the steam-domes 2 and 17. By means of these valve-rods the cut-off sleeves may be moved up and down. Such movement is necessary, however, only when the point of cut-off is to be changed. The ports 28 of admission-tubes 5 and 20 override these sleeves 40 and 41 as the pistons descend and so are closed. These cut-off valves operate close to their engine-cylinders and do not leave large clearance-spaces in which the steam expands while the pistons descend, as is the case when a cut-off valve is placed in the steam-dome at the top of the hollow piston-rod, as is frequently done. If desired, the positions of these cut-off sleeves may be adjusted by an automatic governor, as shown in Fig. 3.

The operation of this engine is as follows: In Fig. 1 the high-pressure piston is shown at the top of its stroke with the valve 31 just opening the steam-ports 28, and the low-pressure piston is shown at the bottom of this stroke with the exhaust-ports 33 open. Live steam may pass, therefore, from the steam-chest 1 and dome 2 into the tube 5 of the high-pressure piston-rod, and thence through the ports 28 into the upper part of the cylinder 3. Exhaust-steam may pass from the upper part of the low-pressure cylinder 18 through the ports 33 of the piston and the ports 34 of the hollow piston-rod into the exhaust-space 26 of the low-pressure cylinder, and thence into the exhaust-chest 27 and so to the air or to a condenser. As the high-pressure piston descends, the ports 28 override the cut-off sleeve 40, thus cutting off steam, so that during the remaining portion of the stroke the steam in cylinder 3 will work expansively. The cut-off sleeves are shown in Fig. 1 in positions corresponding to a very late cut-off; but they may be as much higher in the tubes 5 and 20 as may be desired, thus giving as early cut-off as desired. As the piston 4 descends, the low-pressure piston rises, the steam continuing to exhaust through the ports 33 and 34 into the exhaust-space 26. When the stroke is nearly completed, the distribution-valve 31 of the high-pressure piston, which valve has been moving upward with respect to its piston, has risen so far that steam may pass through the ports 33 into the exhaust-ports 34 of the hollow piston-rod and so into the exhaust-space 14 and receiver 15. Release is thus produced in the high-pressure cylinder. Meanwhile the distribution-valve 32 of the low-pressure cylinder has been moving downward with respect to its piston and in the latter portion of the stroke has closed the exhaust ports or passages 33 in said piston, and just as the end of the stroke is reached valve 32 opens the steam-ports 28 in the piston-rod. The cross-head piston 23 in rising compresses air against the lower head of the low-pressure cylinder, thus cushioning the reciprocating parts of the engine and serving to bring them to rest gently, and this cushioning action is assisted to some extent by a slight cushioning in the low-pressure cylinder after the exhaust-ports 33 are closed. In the next succeeding half-revolution of the crank-shaft the high-pressure cylinder exhausts and the low-pressure cylinder takes steam, the cut-off sleeve 41 cutting off this steam at the proper point in the stroke. Near the end of the stroke the exhaust-ports 33 in the low-pressure piston 19 are opened

and the steam in the low-pressure cylinder released, and correspondingly exhaust closure and compression take place in the high-pressure cylinder, the high-pressure cross-head 8 compressing air in the cylinder 7 and cushioning the reciprocating parts. The distribution-valves may be placed upon the inside of the piston-rod tubes which supply the steam to their cylinders instead of upon the outside. This arrangement is particularly convenient for the distribution-valves of the low-pressure cylinders of tandem compound engines, and the distribution-valves of the low-pressure cylinders of the tandem compound engine shown in Fig. 2 are so arranged. In such case the cut-off sleeves may work within the distribution-valves themselves, as shown in Fig. 2. The distribution-valves may be so proportioned and the eccentrics so set that said valves will themselves cut off steam early in the stroke, as is commonly the case in ordinary slide-valve engines. In such case the cut-off sleeves 40 and 41 may be omitted. These sleeves add very little to the complication of the engine, however, and their use is preferable.

Fig. 2 shows a double tandem compound engine having two high-pressure cylinders 3 placed over two low-pressure cylinders 18, the latter being located over two guide and cushion cylinders 7. The steam-chest 1 is located between the high-pressure cylinders, and the exhaust-chest 27 is located between the low-pressure cylinders. 4 4 are the high-pressure pistons; 19 19, the low-pressure pistons; 8 8, the cross-head pistons; 5 5 and 6 6, the inner and outer tubes forming the hollow piston-rods, and 31 31 the high-pressure distribution-valves. The valves of the high-pressure cylinders are arranged the same as the valve of the high-pressure cylinder in Fig. 1 and operate in the same way. The piston-rod tubes 6 pass from the high-pressure cylinders through stuffing-boxes into the low-pressure cylinders and thence through other stuffing-boxes into the guide-cylinders 7 and are secured to the cross-heads 8. The low-pressure pistons are secured directly to these tubes 6, which serve both as means for conveying the exhaust of the high-pressure cylinders into the receivers 14 and as means for conveying the steam from the receivers to the low-pressure cylinders. The distribution or steam valves 32′ of the low-pressure cylinders are within these tubes 6. The valve-rods 35, which communicate motion from the eccentrics to the low-pressure valves 32′, and other valve-rods 35′, which transmit the motion of valves 32′ to the valves 31 of the high-pressure cylinders, may be substantially in line therefore. Placing the low-pressure steam-valves within the tubes 6 promotes compactness, making it possible to employ piston-rod tubes 6 of minimum diameter, so that as little as possible of the area of cross-section of the low-pressure cylinders is absorbed by the piston-rods, and otherwise simplifies the valve-gear. The tubes 6 are provided with ports 50 beneath the high-pressure exhaust-ports 34 and the flanges 39, through which steam may pass from the receivers 14 into the interior of said rods. They are also provided with ports 51, which are the admission and exhaust ports of the low-pressure cylinders. The low-pressure valves 32′ are provided with corresponding admission-ports 52. Beneath the low-pressure pistons the tubes 6 are provided with exhaust-ports 53, communicating with the exhaust-spaces 26, and the sides of the valves 32′ are cut away to form passages by which ports 51 and 53 may be placed in communication during the time of exhaust. The low-pressure steam-valves 32′ are elongated sleeves, and within them are the low-pressure cut-off sleeves or valves 41. They operate by closing the ports 52 in the valves 32′ when said ports override the sleeves 41, thus in effect closing the ports 51. These cut-off valves 41 are supported by stems 42, passing upward through closely-fitting bearings in the lower ends of the high-pressure supply-tubes 5 and through the tops of the steam-domes 2. The cut-off valves 40 of the high-pressure cylinders are supported by hollow stems or tubes 54, through which the rods 42 pass. At their upper ends the stems 54 may be provided with stuffing-boxes through which the rods 42 pass, as shown in Fig. 3. This construction permits independent adjustment of the high-pressure and low-pressure cut-off valves. The cut-off valves may be fixed in position or may be adjusted automatically by a suitable centrifugal governor or by hand. In Fig. 3 I have shown a centrifugal governor 55, arranged to adjust the high-pressure cut-off valves, the low-pressure cut-off valves being stationary. The details of this governor are not shown. It is arranged to vibrate a rock-shaft 56 as the speed of the engine varies. Levers 57, carried by the shaft 56, are connected to the valve-stems 54, so that as the shaft 56 moves the high-pressure cut-off valves are raised or lowered, as the case may be. The valve-stems 42 of the low-pressure cut-off valves are provided at their upper ends with nuts resting upon brackets 58, secured to the steam-domes 2. These brackets support the low-pressure cut-off valves. The adjustment of these valves may be changed at will by turning the nuts on the stems 42.

Obviously the low-pressure cut-off valves may be adjusted by the governor in the same manner as the high-pressure cut-off valves, and, if desired, each pair of high-pressure and low-pressure cut-off valves may be secured to the same valve-stem instead of having separate concentrically-arranged valve-stems.

The cut-off-valve sleeves of the cross compound engine shown in Fig. 1 may both be adjusted automatically by a governor in the same manner as that indicated in Fig. 3 or the high-pressure cut-off valve only may be so adjusted, the low-pressure valve being sup-

ported by a bracket similar to the brackets 58 of Fig. 3.

The operation of the tandem compound engines shown in Fig. 2 is as follows: Steam from the steam-chest 1 enters the steam-domes 2, and when the pistons and valves are in the position shown in Fig. 2 enters the admission-tube 5 of the left-hand engine and passes through the ports in said tube and over the top of the distribution-valve 31 into the high-pressure cylinder. At the same time exhaust-steam of the high-pressure cylinder is passing from the receiver-space beneath the high-pressure piston through the ports 50 of the outer tube 6 of the piston-rod and through the ports of the low-pressure distribution-valve 32′ and the ports 51 of the tube 6 into the upper end of the low-pressure cylinder. Meanwhile in the right-hand engine both high-pressure and low-pressure cylinders are exhausting, the steam in the high-pressure cylinder passing through the exhaust-ports of the piston 4 into the receiver-space beneath said pistons and the steam in the low-pressure cylinder passing through the exhaust-ports in the piston 19 and the ports 51 and 53 of the tube 6 into the exhaust-space beneath said piston and so into the exhaust-chest 27. In the next half-revolution of the crank-shaft the left-hand engine exhausts and the right-hand engine takes steam.

The distribution-valves 31 are shown in detail in Fig. 4. As already stated, each of these valves consists of a sleeve cut away on its under side for the passage of the exhaust-steam. Upon its upper side the sleeve is provided with a series of fingers 60, the purpose of which is to retain in place the upper of two spring packing-rings 61, lying within recesses in the valve-seat bushings 29. Each valve 31 is also provided upon its outer face with a spring packing-ring 62. These rings 62 are retained in place by the ridges of metal 63, Fig. 6, which separate the exhaust-ports 33 in the pistons.

The distribution-valve 31 of the low-pressure cylinder of the cross compound engine shown in Fig. 1 is similar in construction to the valve shown in Fig. 4.

The cut-off sleeves may be so constructed that the point of cut-off may be varied by revolving the sleeves instead of by moving them longitudinally. Such a construction is illustrated in Fig. 5, in which the cut-off sleeve 40′ there shown is provided with inverted triangular openings corresponding to the ports in admission-tubes 5. By revolving the sleeve slightly about its axis the point in the stroke at which the ports in the admission-tube override the sleeve may be varied, and this movement of the sleeve may be effected by an automatic governor.

The admission-tubes 5 are not necessarily portions of the piston-rods. This is illustrated in Fig. 7, in which the piston there shown is provided with two admission-tubes 5 and with a solid piston-rod 64. The admission-tubes extend up into the steam-domes 2 and perform the same function as in the engine shown in Figs. 1 and 2. This construction is particularly suitable for large cylinders. The piston area of cylinders increases as the square of the radius of the cylinder, whereas the circumference of the admission-tube, and therefore the available surface for port-openings, increases directly as the radius of the admission-tubes. Therefore in large cylinders it is difficult to obtain sufficient port-opening, if but a single admission-tube be used, without employing a tube of excessive diameter; but if two admission-tubes be employed the difficulty is avoided.

The tubes 5, 6, 20, and 21, which together make up the hollow piston-rods of the engine shown in Fig. 1, and the corresponding tubes 5 and 6 of the engine shown in Fig. 2 are closed at the bottom. The steam-pressure upon their closed ends opposes the upward movement of the pistons and assists the downward movement thereof, this action being in harmony with that of the pressure upon the guide-pistons 8 and 23, therefore, and helping to overcome the inertia of the reciprocating parts and to keep the pressure on the wrist-pin and crank-pin bearings in the same direction always. It is obvious, therefore, that by properly proportioning the diameter of tubes 5, 6, 20, and 21 the cushion-cylinders 7 and 22 may be omitted.

In stating in certain of the following claims that the main-valve sleeve is mounted upon the admission-tube or upon the hollow piston-rod I do not mean to limit said claims to the construction in which the main-valve sleeve surrounds the admission-tube, but regard the valve as mounted upon the admission-tube or piston-rod whether it be on the inside or on the outside thereof, since in either case it is guided by said tube or rod.

Having thus completely described my invention, what I claim, and desire to secure by Letters Patent, is—

1. The combination, with a cylinder, a piston, a steam-chest, and an admission-tube, moving with the piston, communicating with the steam-chest and provided with ports communicating with the cylinder, of a valve-sleeve separate from and movable longitudinally with respect to the piston, and mounted upon the admission-tube, and adapted to open and close said ports, and means for vibrating said sleeve as the piston reciprocates.

2. The combination, with a cylinder, a piston, a steam-chest, and an admission-tube, moving with the piston, communicating with the steam-chest, and provided with ports communicating with the cylinder, of a valve-sleeve separate from and movable longitudinally with respect to the piston, and adapted to open and close said ports, means for vibrating said sleeve as the piston reciprocates, and a cut-off valve adapted to close said ports prior to the closure thereof by the main valve, substantially as described.

3. The combination, with a cylinder, a piston, a steam-chest, and an admission-tube, moving with the piston, communicating with the steam-chest, and provided with ports communicating with the cylinder, of a valve-sleeve separate from the piston, mounted upon the admission-tube and longitudinally movable with respect to said ports and adapted to open and close the same, and means for vibrating said sleeve as the piston reciprocates.

4. The combination, with a cylinder, a piston, a steam-chest, and an admission-tube, moving with the piston, communicating with the steam-chest, and provided with ports communicating with the cylinder, of a valve-sleeve, separate from the piston, mounted upon the admission-tube, and movable longitudinally with respect to said ports and the cylinder, and adapted to regulate admission to and exhaust from said cylinder, and means for vibrating said sleeve as the piston reciprocates.

5. The combination, with a cylinder, a piston, a steam-chest, and an admission-tube, moving with the piston, communicating with the steam-chest, and provided with ports communicating with the cylinder, of a valve-sleeve separate from the piston, surrounding the admission-tube and located in a recess between said tube and the piston, movable longitudinally with respect to the piston, and adapted to regulate admission to and exhaust from said cylinder, and means for operating said valve.

6. The combination, with a cylinder, a piston, a steam-chest, and an admission-tube, communicating with the steam-chest, and provided with ports communicating with the cylinder, of a main valve consisting of a sleeve, separate from the piston, movable longitudinally with respect to said ports and the cylinder, and adapted to regulate admission to and exhaust from said cylinder, means for operating said valve, and a cut-off-valve sleeve adapted to close said ports prior to the closure thereof by the main valve.

7. The combination, with a cylinder, a steam-chest, a piston, and a hollow piston-rod communicating with said steam-chest and having ports communicating with said cylinder, of a valve-sleeve separate from and movable longitudinally with respect to the piston, and mounted upon the piston-rod, and adapted to open and close said ports, and means for vibrating said sleeve as the piston reciprocates.

8. The combination, with a cylinder, a steam-chest, a piston, and a hollow piston-rod communicating with said steam-chest and having ports communicating with said cylinder, of a valve-sleeve, separate from and movable longitudinally with respect to said ports and the cylinder, and adapted to regulate admission to and exhaust from said cylinder, and means for vibrating said sleeve with respect to said ports with each stroke of the piston.

9. The combination, with a cylinder, a steam-chest, a piston, and a hollow piston-rod communicating with said steam-chest and having ports communicating with said cylinder, of a valve-sleeve separate from and movable longitudinally with respect to the piston, and mounted upon the piston-rod, and adapted to open and close said ports, and means for vibrating said sleeve with respect to said ports with each stroke of the piston.

10. The combination, with a cylinder, a steam-chest, a piston, and a hollow piston-rod communicating with said steam-chest and having ports communicating with said cylinder, of a valve-sleeve, separate from the piston, and mounted upon the piston-rod, which is longitudinally movable with respect to said ports and is adapted to open and close the same and means for imparting to said sleeve longitudinal movement with respect to said ports and the cylinder, with each stroke of the piston.

11. The combination, with a cylinder, a piston, and a hollow piston-rod having ports communicating with said cylinder, of a valve-sleeve, separate from the piston, surrounding said piston-rod, and movable longitudinally with respect to the piston, and means for imparting to said sleeve longitudinal movement with respect to said ports and the cylinder with each stroke of the piston.

12. The combination, with a cylinder, a steam-chest, a piston, and a hollow piston-rod communicating with said steam-chest and having ports communicating with said cylinder, of a distribution-valve, separate from the piston, consisting of a sleeve mounted upon the piston-rod, movable longitudinally with respect to said ports and the cylinder, and adapted to regulate admission to and exhaust from said cylinder, and means for vibrating said sleeve as the piston reciprocates.

13. The combination, with a cylinder, a piston, and a hollow piston-rod having ports communicating with said cylinder, of a valve, separate from the piston, located in a recess between said piston-rod and the piston, longitudinally movable with respect to the piston, and controlling admission to and exhaust from said cylinder, and means for operating said valve.

14. The combination, with a cylinder, a piston, and a hollow piston-rod having ports communicating with said cylinder, of a valve-sleeve, separate from the piston, located in a recess between said piston-rod and the piston, longitudinally movable with respect to the piston, and arranged to admit working fluid through said piston-rod ports into the cylinder and to permit such fluid to exhaust between said sleeve and the piston, and means for operating said valve.

15. The combination, with a cylinder, a hollow piston-rod having admission-ports communicating with said cylinder, and a piston, having exhaust-ports, of a valve-sleeve, separate from the piston, located in a recess between said piston and piston-rod, longitudi-

nally movable with respect to the piston, and arranged to open and close said admission and exhaust ports alternately, and means for operating said valve.

16. The combination, with a cylinder, a piston, and a hollow piston-rod, composed of inner and outer tubes, the inner tube having admission-ports communicating with the space on one side of the piston and the outer tube having exhaust-ports communicating with the space on the other side of said piston, of a valve-sleeve surrounding the inner tube and arranged to permit working fluid to enter the cylinder through the ports in said inner tube, and then to permit such fluid to exhaust into the outer tube and through the ports thereof, and means for operating said valve.

17. The combination, with a cylinder, a piston, and a hollow piston-rod composed of inner and outer tubes, the inner tubes having admission-ports communicating with the space on one side of the piston and the outer tube having exhaust-ports communicating with the space on the other side of said piston, of a valve-sleeve surrounding the inner tube and arranged to permit working fluid to enter the cylinder through the ports in said inner tube, said sleeve being cut away on its outer side to permit such fluid to exhaust between said sleeve and the piston into the outer tube, and means for operating said valve.

18. The combination, with a cylinder, a steam-chest, a piston, and a hollow piston-rod communicating with said steam-chest and having ports communicating with said cylinder, of a valve-sleeve, separate from the piston, and mounted upon the piston-rod, which is longitudinally movable with respect to said piston and ports and is adapted to open and close the same, valve-rods for vibrating said sleeve, and means for communicating motion thereto.

19. The combination, with a cylinder, a steam-chest, a piston, a hollow piston-rod communicating with said steam-chest and having ports communicating with said cylinder, a crank, and means for connecting the piston-rod thereto, of a valve-sleeve, separate from the piston, and mounted upon the piston-rod, which is longitudinally movable with respect to said piston and ports and is adapted to open and close the same, eccentrics on the crank-pin, and means for transmitting motion of said eccentrics to the valve.

20. The combination, with a cylinder, a steam-chest, a piston, and a hollow piston-rod communicating with said steam-chest and having ports communicating with said cylinder, of a valve-sleeve, separate from the piston, and mounted upon the piston-rod, which is longitudinally movable with respect to said piston and ports and is adapted to open and close the same, valve-rods, within said hollow piston-rod, connected to said valve, and means for imparting motion to said valve-rods and the valve.

21. The combination, with a cylinder, a piston, and a hollow piston-rod having ports communicating with said cylinder, of a valve-sleeve which is longitudinally movable with respect to said ports and is adapted to open and close the same, valve-rods within said piston-rod and projecting from one end thereof, and tubes surrounding said valve-rods and adapted to prevent the escape of working fluid around said rods.

22. The combination, with a cylinder, a piston, and a hollow piston-rod having ports communicating with said cylinders, of a main valve, separate from the piston, arranged to open and close said ports, means for operating the same, and a cut-off valve adapted to close said ports prior to the closure thereof by the main valve.

23. The combination, with a cylinder, a piston, and a hollow piston-rod having ports communicating with said cylinder, of a main valve, separate from the piston, adapted to open and close said ports, and a cut-off valve, normally stationary with respect to said ports, and so located that said ports are closed by said cut-off valve prior to the closure thereof by the main valve.

24. The combination, with a cylinder, a piston, and a hollow piston-rod having ports communicating with said cylinder, of a main valve, separate from the piston, adapted to open and close said ports, and a cut-off valve, within the piston-rod, over which said ports pass, so as to be closed thereby, prior to the closure of said ports by the main valve.

25. The combination, with a cylinder, a piston, and a hollow piston having ports communicating with said cylinder, of a valve-sleeve, separate from the piston, forming the main valve and adapted to open and close said ports, and a cut-off-valve sleeve within the piston-rod, arranged to close said ports prior to the closure thereof by the main valve.

26. The combination, with a cylinder, a piston, and a hollow piston-rod having ports communicating with said cylinder, of a valve-sleeve, separate from the piston, forming the main valve, and adapted to open and close said ports, means for vibrating said sleeve, a separate cut-off valve within the piston-rod and adapted to close said ports prior to the closure thereof by the main valve, and means for adjusting said cut-off valve.

27. The combination, with a cylinder, a piston, and a hollow piston-rod having ports communicating with said cylinder, of a valve-sleeve, separate from the piston, forming the main valve, surrounding the piston-rod, and adapted to open and close said ports, means for vibrating said sleeve, and a separate cut-off-valve sleeve within the piston-rod and adapted to close said ports prior to the closure thereof by the main valve.

28. The combination, with a cylinder, a pis-

ton, and a hollow piston-rod having ports communicating with said cylinder, of a main valve, separate from the piston, adapted to close and open said ports, a cut-off valve normally stationary with respect to said cylinder, and so located that said ports are closed by said cut-off valve prior to the closure thereof by the main valve, and an automatic governor connected with and adapted to adjust said cut-off valve.

29. The combination, with a cylinder, a piston, and a hollow piston-rod having ports communicating with said cylinder, of a valve-sleeve, separate from the piston, forming the main valve, a second sleeve, forming a cut-off valve, one sleeve being on the inside of the piston-rod and the other sleeve upon the outside thereof, the main valve being adapted to open and close said ports, and the cut-off valve being arranged to close said ports prior to the closure thereof by the main valve.

30. The combination, with tandem high-pressure and low-pressure cylinders, pistons therefor, and a hollow piston-rod for said pistons, having admission-ports communicating with each of said cylinders on one side of the pistons thereof, and exhaust-ports communicating with each of said cylinders on the other side of the pistons thereof, of a high-pressure distribution-valve sleeve surrounding the piston-rod, a low-pressure distribution-valve sleeve, within the piston-rod, and means for vibrating said valves.

31. The combination, with tandem high-pressure and low-pressure cylinders, pistons therefor, and a hollow piston-rod for said pistons, having admission-ports communicating with each of said cylinders on one side of the pistons thereof, and exhaust-ports communicating with each of said cylinders on the other side of the pistons thereof, of a high-pressure distribution-valve surrounding the piston-rod, a low-pressure distribution-valve sleeve, within the piston-rod, having ports adapted to register with the low-pressure ports of said piston-rod communicating with the working side of the low-pressure cylinder, and cut-off valves for said cylinders, the low-pressure cut-off valve working within the low-pressure distribution-valve sleeve.

32. The combination, with tandem high-pressure and low-pressure cylinders, pistons therefor, and a hollow piston-rod for said pistons, consisting of inner and outer tubes, the inner of said tubes having admission-ports for the high-pressure cylinder and the outer of said tubes having exhaust-ports for the high-pressure and low-pressure cylinders and admission-ports for the low-pressure cylinder, of valve-sleeves forming distribution-valves for the high-pressure and low-pressure cylinders, the high-pressure valve surrounding the inner tube of the piston-rod and the low-pressure valve lying within the outer tube of said piston-rod, and means for vibrating said valves.

33. The combination, with tandem high-pressure and low-pressure cylinders, pistons therefor, and a hollow piston-rod for said pistons, having admission and exhaust ports for said cylinders, of main distribution-valves, separate from and movable longitudinally with respect to the pistons, and adapted to open and close said ports, and cut-off valves within the piston-rod adapted to close the admission-ports thereof prior to the closure of said ports by the main valves.

34. The combination, with tandem high-pressure and low-pressure cylinders, pistons therefor, and a hollow piston-rod for said pistons, having supply and exhaust ports for said cylinders, of main distribution-valves adapted to open and close said ports, and cut-off valves for each of said cylinders, within the piston-rod, having concentric valve-stems projecting from one end of the piston-rod, by which said cut-off valves are held in position.

35. The combination, with tandem high-pressure and low-pressure cylinders, pistons therefor, and a hollow piston-rod for said pistons, consisting of inner and outer tubes, the inner of said tubes having admission-ports for the high-pressure cylinder and the outer of said tubes having exhaust-ports for the high-pressure and low-pressure cylinders and admission-ports for the low-pressure cylinder, of distribution-valves for said cylinders, the low-pressure valve being a sleeve within the piston-rod, and cut-off valves for said cylinders, located within the piston-rod, the low-pressure cut-off valve working within the low-pressure distribution-valve.

36. The combination, with an admission-tube, of a valve consisting of a sleeve mounted thereon and movable longitudinally with respect thereto, and a packing-ring carried by said tube and pressing against said sleeve, said sleeve being provided with fingers for retaining said packing-ring in place.

37. The combination, with a piston, having a valve-opening the axis of which is parallel to the axis of the piston, of a valve in said opening, and a packing-ring carried by said valve and bearing against said piston, said piston being provided with ridges to hold the packing-ring in place.

38. The combination, with a cylinder, a piston, a steam-chest, a crank, means for connecting the same to a piston-rod, and a piston-rod having an admission-tube communicating with the steam-chest, provided with ports communicating with the cylinder, and open at its outer end and closed at a point beyond its ports, whereby a constant pressure is exerted upon the admission-tube tending to prevent reversal of pressure at the bearings, of a valve movable longitudinally with respect to the piston-rod and adapted to open and close said ports, and means for operating said valve.

39. The combination with a cylinder, a piston, a steam-chest, a crank, means for con-

necting the same to a piston-rod, and a hollow piston-rod communicating with the steam-chest, provided with ports communicating with the cylinder, and open at its outer end and closed at a point beyond its ports, whereby a constant pressure is exerted upon the piston-rod, tending to prevent reversal of pressure at the bearings, of a valve movable longitudinally with respect to the piston-rod, and adapted to open and close said ports, and means for operating said valve.

In testimony whereof I have hereunto affixed my signature in the presence of two witnesses.

EDWARD THOMAS ADAMS.

Witnesses:

B. T. LEUZARDER,

B. A. BRENNAN.