No. 713,675. Patented Nov. 18, 1902.

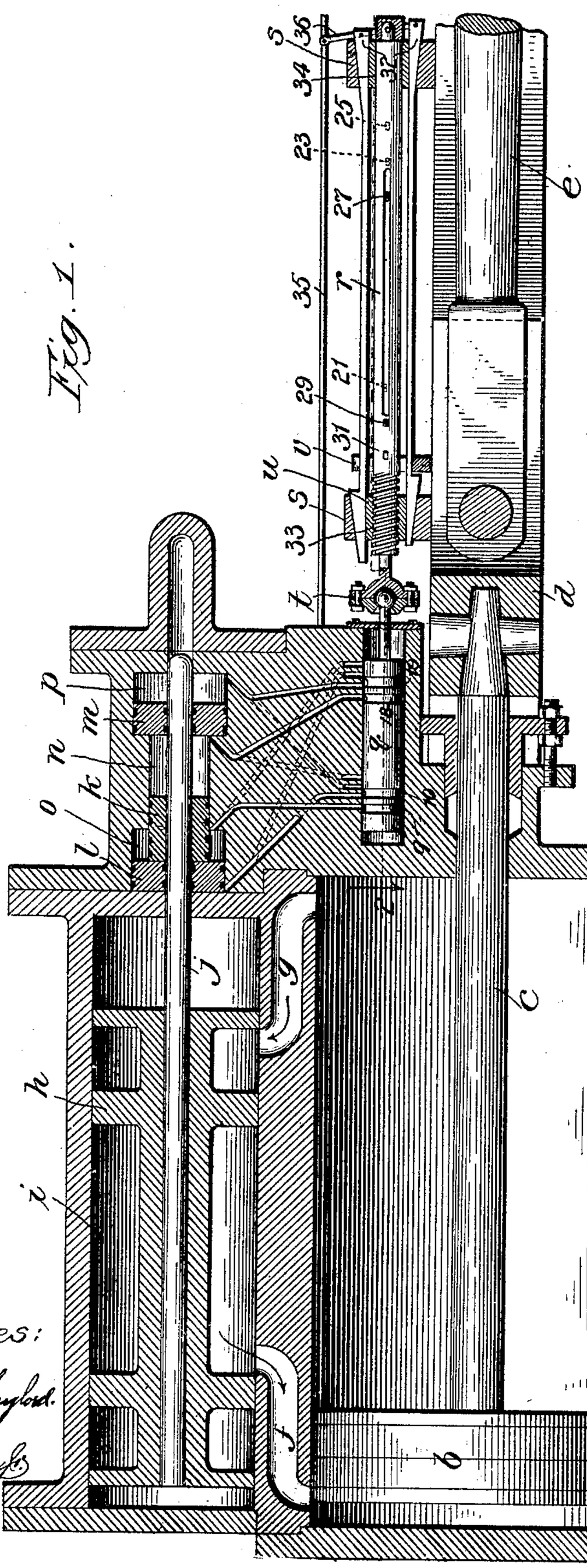
S. OTIS.

FLUID PRESSURE ENGINE.

(Application filed Nov. 7, 1901.)

(No Model.) 4 Sheets—Sheet 1.

Fig. 1.



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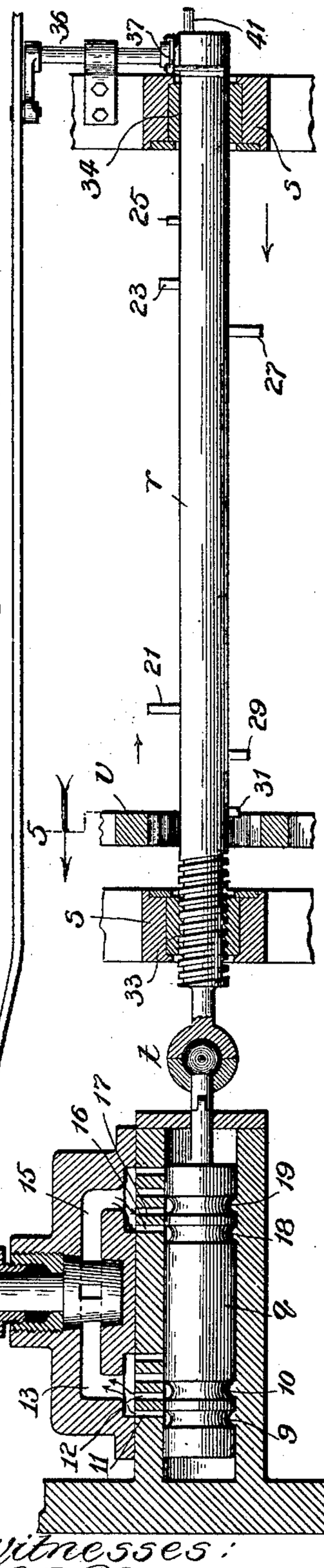

Fig. 2.

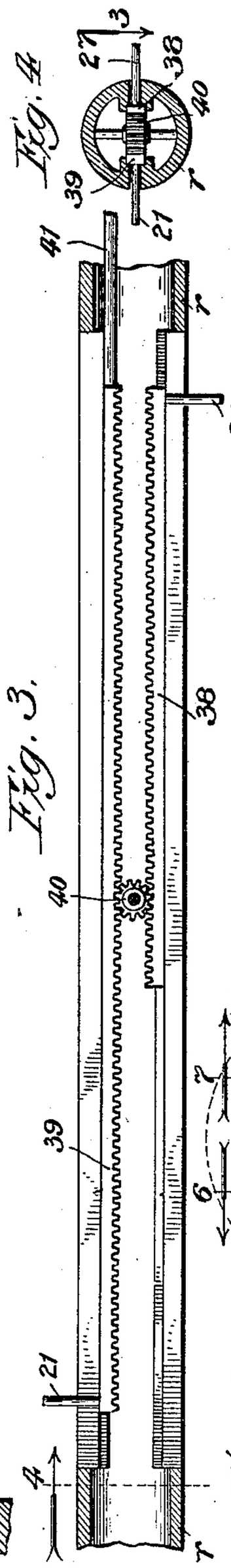

Fig. 3.

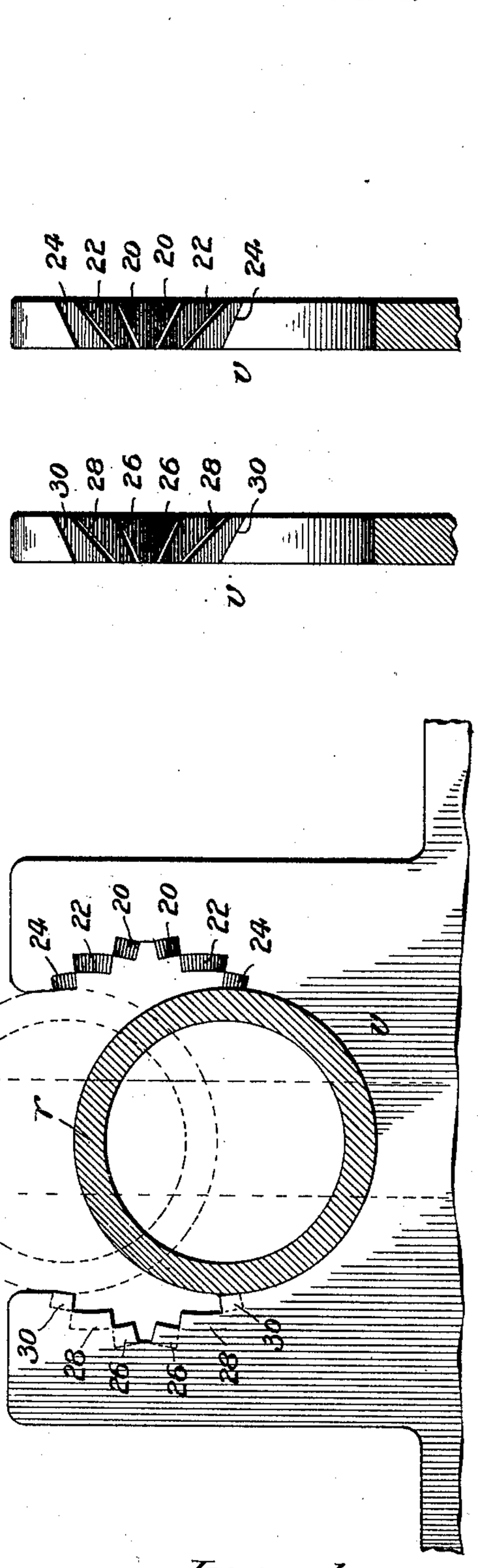

Fig. 4.

Fig. 6.

Fig. 5.

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Fig. 8.

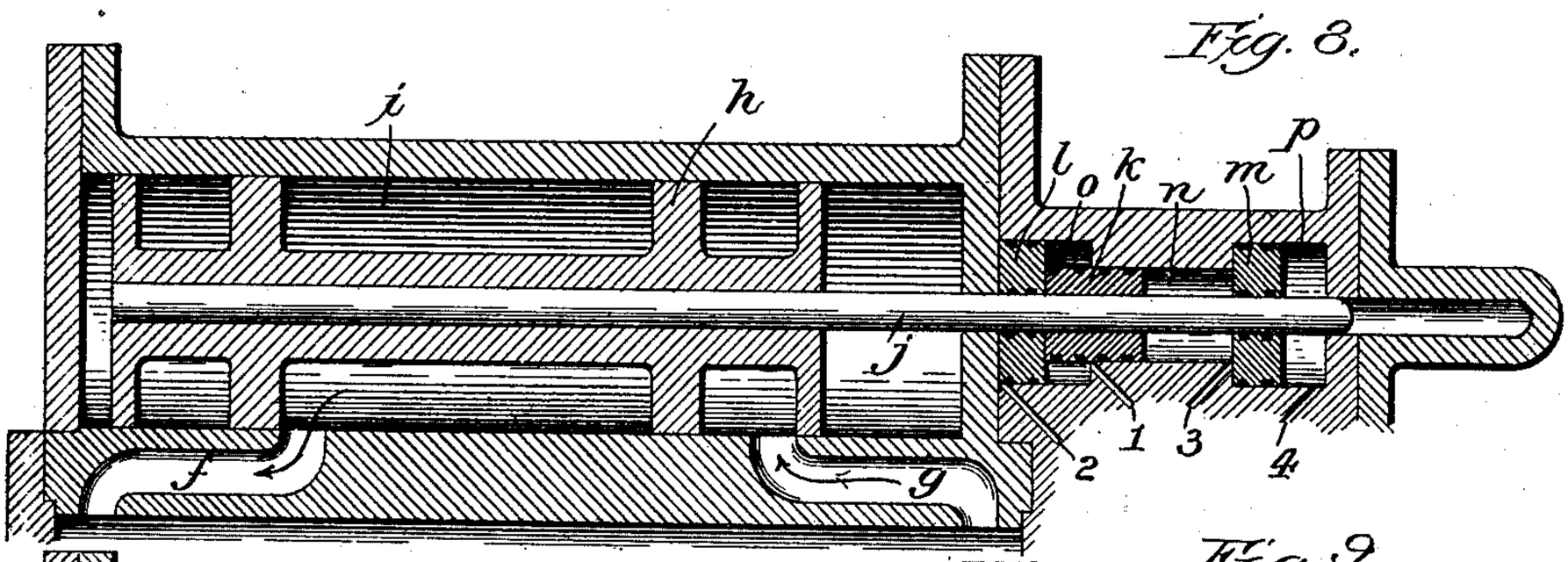


Fig. 9.

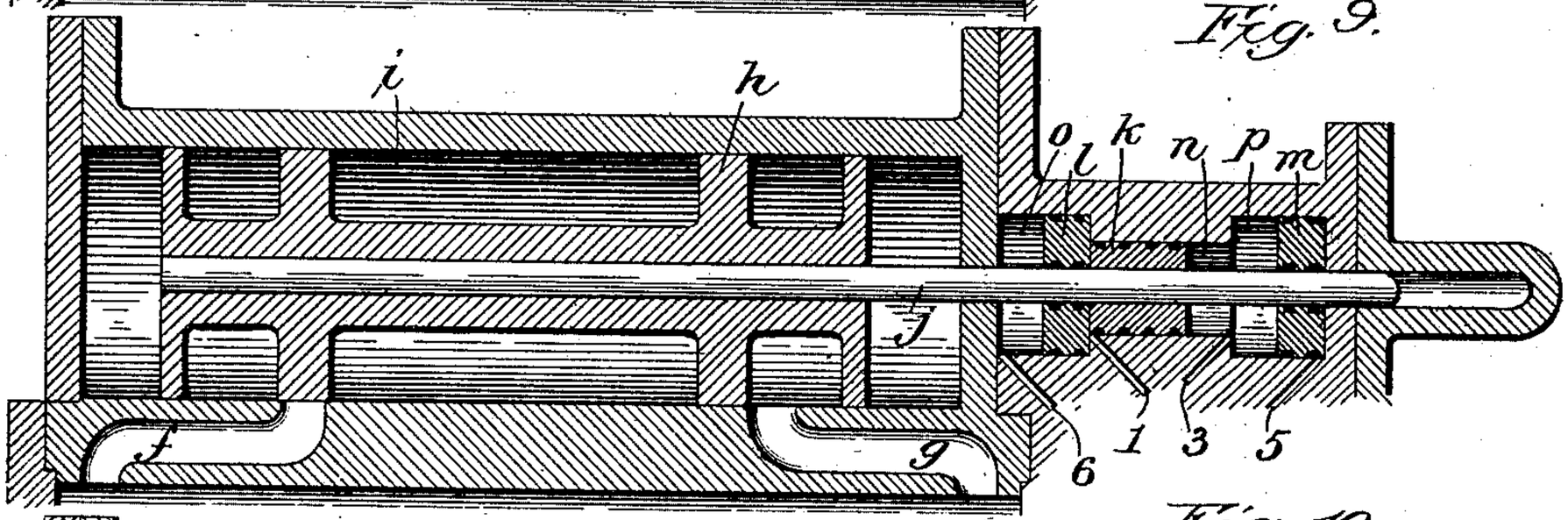


Fig. 10.

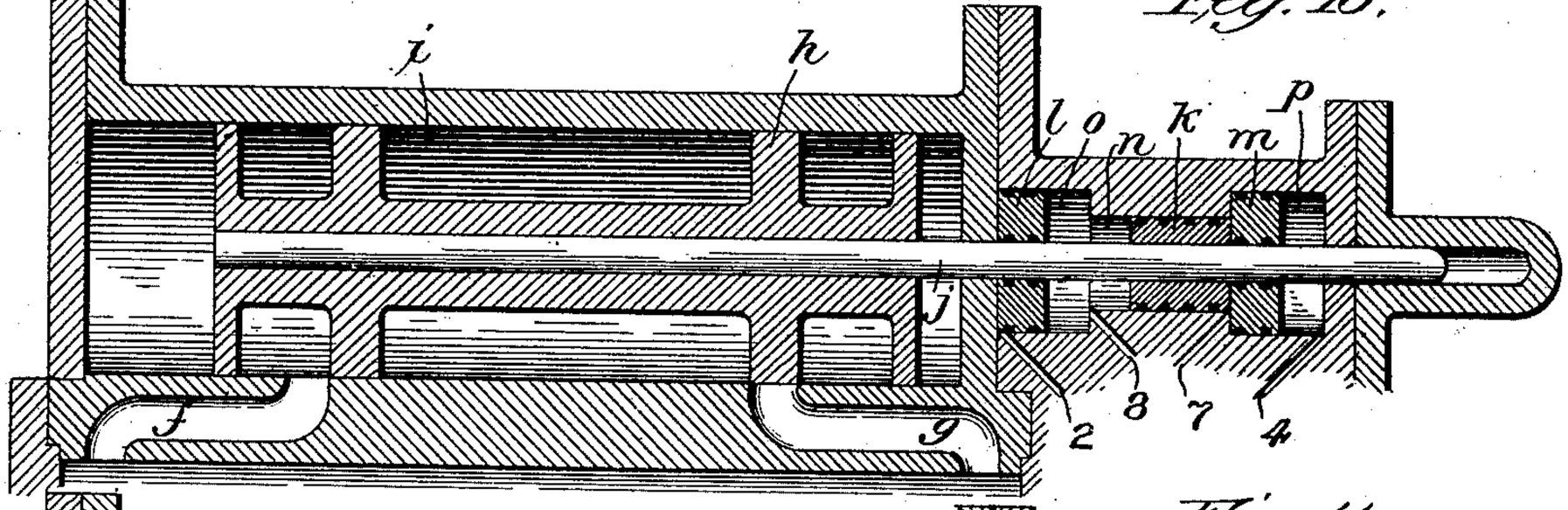
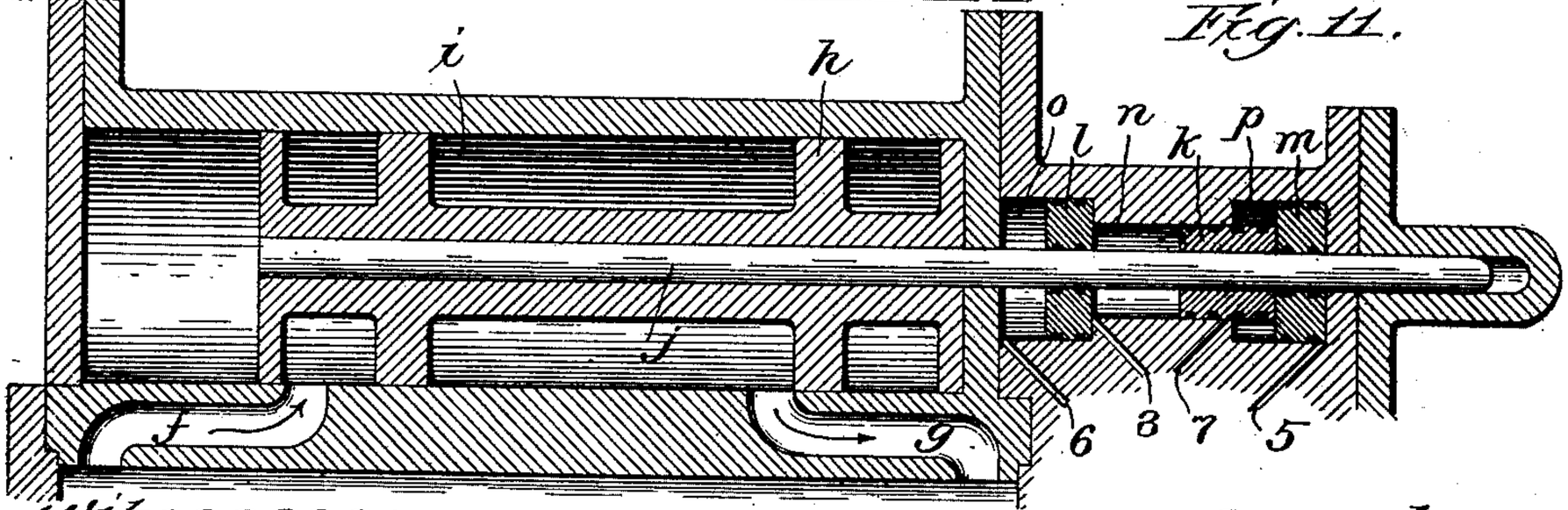


Fig. 11.



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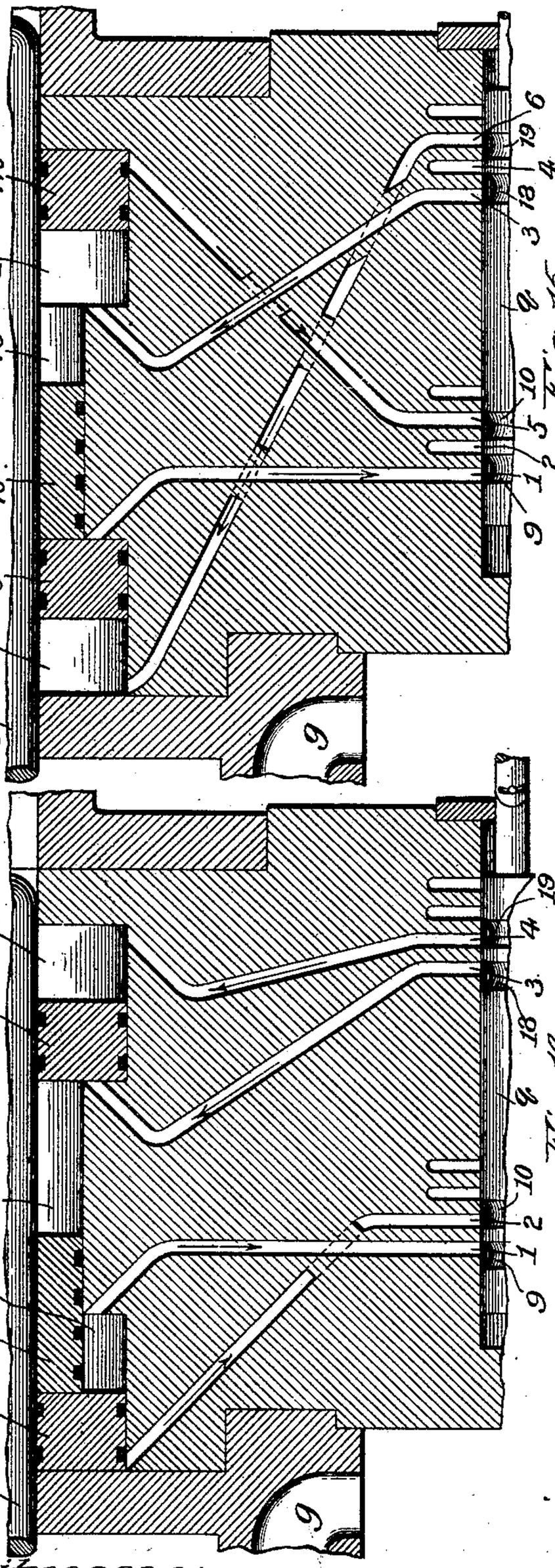

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UNITED STATES PATENT OFFICE.

SPENCER OTIS, OF CHICAGO, ILLINOIS.

FLUID-PRESSURE ENGINE.

SPECIFICATION forming part of Letters Patent No. 713,675, dated November 18, 1902.

Application filed November 7, 1901. Serial No. 81,388. (No model.)

To all whom it may concern:

Be it known that I, SPENCER OTIS, a citizen of the United States, residing at Chicago, in the county of Cook and State of Illinois, have invented certain new and useful Improvements in Fluid-Pressure Engines, of which the following is a specification.

This invention relates to fluid-pressure engines that are operated by steam, compressed air, or other motive fluid, and particularly to the means and methods employed for operating the controlling-valves therefor, all of which will more fully hereinafter appear.

The principal object of the invention is to provide a steam or other fluid-pressure engine with simple, economical, and controlling-valve mechanism by which the admission and exhaust of steam from the operating-cylinder are governed or controlled.

Further objects of the invention will appear from an examination of the drawings and the following description and claims.

The invention consists principally in the combination of a fluid-pressure engine provided with a main cylinder having a piston movably mounted therein, valve mechanism for controlling the admission, cut-off, and exhaust of motive fluid to and from the main cylinder, and supplementary-piston mechanism arranged to be operated by fluid under pressure to move the controlling-valve.

The invention consists, further, in the combination of a fluid-pressure engine provided with a main cylinder and a piston movably mounted therein, valve mechanism for controlling the admission, cut-off, and exhaust of motive fluid to and from the main cylinder, and a plurality of supplementary pistons connected with the controlling-valve mechanism and arranged to be operated by fluid under pressure.

The invention consists, further, in the combination of a fluid-pressure engine in which there is combined a main cylinder having a piston movably mounted therein, a reciprocating valve for controlling the admission, cut-off, and exhaust of the motive fluid to and from the main cylinder, a valve-stem connected with such reciprocating controlling-valve, and a plurality of supplementary pistons mounted on such valve-stem and arranged to be operated by fluid under pressure for moving the same with its controlling-valve.

The invention consists, further, in the combination of a fluid-pressure engine in which there is combined a main cylinder provided with a movable piston, a reciprocating valve for controlling the admission, cut-off, and exhaust of the motive fluid to and from the main cylinder, a valve-rod connected with such controlling-valve, a fixed piston attached to the valve-rod, and two floating pistons slidingly mounted on such rod and arranged to be operated by fluid under pressure to move the controlling-valve.

The invention consists, further and finally, in the features, combinations, and details of construction hereinafter described and claimed.

In the accompanying drawings, Figure 1 is a sectional elevation taken longitudinally through the cylinder and valve-chest of a fluid-pressure engine, showing my improvements as they appear when used in connection therewith; Fig. 2, an enlarged sectional view of a portion of the mechanism, taken on line 2 of Fig. 1, looking in the direction of the arrow; Fig. 3, a longitudinal sectional view taken through the supplementary-valve rod on line 3 of Fig. 4; Fig. 4, a cross-sectional view taken on line 4 of Fig. 3; Fig. 5, an enlarged cross-sectional view of the tripping cam-block, taken on line 5 of Fig. 2, looking in the direction of the arrow; Fig. 6, a sectional elevation taken on line 6 of Fig. 5; Fig. 7, a sectional elevation taken on line 7 of Fig. 5 looking in the direction of the arrow; Fig. 8, a sectional view of the controlling-valve with its operating mechanism shown in initial position or the position to admit motive fluid to the main cylinder and at the left of the movable piston; Fig. 9, a similar view with the parts moved to position to cut off the fluid under pressure; Fig. 10, a similar view showing the parts moved into such position as to permit the compression of the remaining portion of the motive fluid in the left-hand end of the operating-cylinder; Fig. 11, a similar view showing the parts moved to position to permit the introduction or inlet of steam to the right hand of the main cylinder and the exhaust of the motive fluid from

the other end; Fig. 12, a diagrammatic view showing the construction and arrangement of pistons that operate the controlling-valve and in one position; Fig. 13, a similar view showing such pistons in a second position; Fig. 14, a similar view showing such pistons in a third position; and Fig. 15, a similar view showing such pistons in a fourth position, that which they assume before being moved back to the initial position shown in Fig. 12.

As above suggested, this invention relates particularly and is intended to be used in connection with fluid-pressure engines, engines in which steam is used as the motive fluid, though it will be seen that compressed air will also be used. It is also designed with particular reference to use in connection with locomotives, all of which will be understood by those skilled in the art.

In the art to which this invention relates, and particularly when considering locomotives, it is well known that link mechanism is used and interposed between the eccentrics and slide-valve of the engine for the purpose of operating the same and which is capable of being moved from one position to another in order to "reverse" the locomotive that is arranged to run it forwardly or backwardly. This link mechanism is expensive to manufacture, assemble, and repair, as well as being liable to get out of order or be injured during the use of the engine, all of which renders its use in a measure objectionable. It is further well known that the regulation of the cut-off of the steam cannot always be made with the same degree of accuracy as is required in other fluid-pressure engines. This invention therefore is intended principally to provide a simple and economical valve motion or means for operating the controlling-valve of a fluid-pressure engine, particularly a locomotive, so as to dispense with link mechanism, eccentrics, &c., all of which will more fully hereinafter appear.

In illustrating and describing these improvements I have only illustrated and described that which I consider to be new, taken in connection with so much that is old as will properly disclose the invention to others and enable those skilled in the art to practice the same, leaving out of consideration other and well-known mechanisms, which if illustrated and described herein would only tend to confusion, prolixity and ambiguity.

In constructing a fluid-pressure engine and fitting it with these improvements I provide what I term a "main" cylinder *a* of the desired size, shape, and strength and having a reciprocating piston *b* movably mounted therein, the piston-rod *c* of which projects therefrom and is connected with the usual cross-head *d*, in turn provided with the usual connecting-rod *e*, all arranged to be operated in the ordinary and well-known manner. To control the inlet, cut-off, and exhaust of motive fluid to and from the main cylinder, I provide the walls thereof with passages *f* and *g*, arranged to be used alternately as inlet and exhaust passages. Immediately above or adjacent to these ports or passages and on the outside of the cylinder-walls is arranged a reciprocating controlling piston-valve *h*, adapted to be reciprocated—that is, moved backward and forward across said openings—in such manner that when the parts are in the position shown in Fig. 1 the fluid under pressure is permitted to pass from the valve-chest *i* and through the passage *f* between the rear cylinder-head and the movable piston to force such piston forwardly, while the motive fluid at the other end is permitted to be exhausted or forced out through the passage *g* in the usual manner. I have not shown or described the connection of the valve-chest with the supply and exhaust passages by which the steam is admitted to the valve-chest and exhausted therefrom, as such arrangement is well known and needs no detailed description herein. To provide simple, economical, and efficient mechanism for operating or moving this controlling-valve the desired time or times, I provide it with a stem or rod portion *j*, rigidly connected therewith and projecting out through the walls at one end of the valve-chamber, as shown in Fig. 1. This valve-stem is provided at or near its free end with a plurality of supplementary compound pistons—viz., a fixed piston *k*, rigidly or immovably secured thereto, and two floating pistons *l* and *m*, slidingly mounted thereon. These pistons are arranged in what I prefer to term for the sake of convenience a "compound-supplementary-piston" chamber made in stepped portions—a central small chamber *n*, an enlarged end chamber *o* at one end, and a second enlarged chamber *p* at the other end. An examination of the drawings will show that the fixed piston is smaller in diameter—that is, its end surfaces have a smaller superficial area than the end surfaces of the two floating or end pistons, the purpose of which will be more fully hereinafter set forth.

It is necessary to provide means for the introduction and exhaust of motive fluid to and from the exact points of the supplementary-piston chamber and at the correct time or times in such a manner as to move the fixed and floating pistons, and thus the controlling-valve, at the proper times or whenever it is necessary. In order to accomplish this result, a supplementary-piston valve *q* is provided and interposed in the channels that connect the supplementary-piston chamber with the source of fluid-pressure supply and its exhaust, as more fully hereinafter set forth. During the movements of the main piston of the engine this supplementary-piston valve is moved forward and backward in a step-by-step manner by means hereinafter described, so as to govern the inlet and exhaust of the motive fluid to and from the supplementary-piston chamber. When the parts are in the

position shown in Figs. 1, 8, and 12, the supplementary-piston valve is so arranged that it permits the exhaust of the motive fluid from the supplementary-piston chamber through the passages 1 and 2, thence around the annular passages 9 and 10 of the supplementary-piston valve, and out through the openings 11 and 12 in the casing into the supplementary-valve chest 13, from whence it passes out through the reversing-valve 14 to the open air. At the same time motive fluid is permitted to pass through the reversing-valve into the supplementary valve-chest and into the chamber 15 of such chest, thence through the passages 16 and 17, thence around the annular passages 18 and 19 of the supplementary-piston valve, and then through passages 3 and 4 to the supplementary-piston chamber, where it enters at the right-hand side of the fixed piston *k* and the floating piston *m*. This action forces the fixed piston, with the valve-stem and controlling-valve, to the left, as shown in Figs. 1, 8, and 12, and the floating piston *m* also to the left and against the shoulder, as shown in the same figures. During the movement of the main piston which is now taking place the supplementary-piston valve is moved to the position shown in Fig. 13, so that motive fluid is permitted to exhaust from the supplementary-piston chamber (see also Fig. 9) through the passages 1 and 5 from the right-hand side of both of the floating pistons *l* and *m*, while motive fluid is permitted to enter the supplementary chambers through the passages 3 and 6 to the left of both of such floating pistons. In this way the pressure acting on the superior area of such pistons moves them both to their extreme limit of motion and to the left, one against the shoulder and the other against the end of the supplementary-piston chamber, thus forcing the fixed piston, with the controlling-valve, to the position shown in Fig. 9, thereby cutting off fluid under pressure from further entering the main cylinder, so that the pressure that has already passed into such cylinder may be used expansively. The next movement of the supplementary-piston valve brings it to the position shown in Fig. 14, where it covers and uncovers the passages shown in such figure, as well as those shown in Fig. 10, in such manner that motive fluid is exhausted from the supplementary-piston chamber through the passages 2 and 7 from the left-hand side of both floating pistons and is permitted to enter such chamber through passages 4 and 8 to the right-hand side of such floating pistons. By this action both floating (or loose) pistons are moved to the left, one against the end wall and the other against the shoulder, while at the same time the motive fluid moves the "fixed" piston to the right against the floating piston *m*, which forms a stop to limit its further movement. This motion of the fixed piston moves the controlling-valve to the position shown in Fig. 10, so that the exhaust at the right end of the operating-cylinder is cut off and the motive fluid remaining in such end is compressed. The supplementary-piston valve is now moved to the position shown in Fig. 15, where it covers and uncovers the passages shown in such figures and also in Fig. 11. The motive fluid is now exhausted from the supplementary-piston chamber through passages 5 and 7 at both sides of the floating piston *m* and admitted through passages 6 and 8 to both sides of the floating piston *l*, so that the fixed piston is now moved to the extreme right and the floating piston is also moved to the extreme right. This action moves the controlling-valve to the position shown in Fig. 11, where it uncovers the exhaust at the left and opens the inlet at the right end of the operating-cylinder.

So far I have described the movements of the controlling-valve and its operating mechanisms in one direction and the inlet of steam to the right-hand end of the operating-cylinder. The supplemetary piston-valve is now moved in a reverse manner step by step, so that the passages 1, 2, 3, 4, 5, 6, 7, and 8 are covered and uncovered in pairs to operate the fixed and floating pistons, and thereby the controlling-valve, to cut off the motive fluid from the operating-cylinder first, as shown in Figs. 10 and 14, then to compress the balance in the left end of the main cylinder, as shown in Figs. 9 and 13, and next, as shown in Figs. 8 and 12, to again admit the motive fluid to the left-hand end of the operating-cylinder and exhaust it from the opposite end. These operations are repeated over and over again as long as the motive fluid is supplied to the supplementary-piston valve and to the controlling-valve or until the motive fluid is shut off from both of such valves.

It becomes necessary to provide means for operating the supplementary-piston valve in its step-by-step movements, and in order to accomplish this result a supplementary-valve rod *r* is provided and mounted in suitable movable bearing-blocks 33 and 34, in turn mounted in lugs *s*, secured to some immovable part of the engine, preferably the cross-head guides. This supplementary-valve rod is made in a compound manner—that is, it is provided with a ball-joint, as shown at *t* in Fig. 1—to permit lateral movements of one part and so that the same part may have a rotary as well as rectilinear motion—that is, a helical motion—without in any way injuring the other part. The supplementary-valve rod is also provided with a threaded portion *u*, engaging a threaded opening in one of the bearing-blocks 33, so that it may be given the desired helical movement by means of this thread—that is, when rotated in one direction it also pulls the rod outwardly and when rotated in the other direction it forces the rod, and consequently the supplementary-piston valve, inwardly. To accomplish these movements of the supplementary-piston valve, I provide a U-shaped cam-block *v*, as

shown particularly in Figs. 1, 5, 6, and 7, and hollow it out, as above suggested, so that it may span such valve-rod, as shown particularly in Fig. 5. The recess of this cam-block is provided with a plurality of inclined cams, so that when the parts are in the position shown in Figs. 1, 2, and 5 and during the forward movement of the cam-block, which is secured to the cross-head of the engine, the inclined cam 20 contacts the pin 21, as shown in Fig. 2, and rotates the supplementary-valve rod to the left against the movements of the hands of a watch, and thereby draws such valve-rod, with the supplementary-piston valve, out one step. This moves the supplementary-piston valve to the position shown in Fig. 13, so that the parts operate as described in connection with such figure. The continued movement of the cross-head carries the cam-block to such a position that its inclined cam 22 contacts the pin 23 to rotate the supplementary-valve rod another step, which also gives it another step in its rectilinear movement and carries the supplementary-piston valve into the position shown in Fig. 14, and thereby the controlling-valve into the position shown in Fig. 10—viz., the compressing position. The continued movement of the cross-head carries the cam-block to such position that its inclined cam 24 contacts the pin 25 and rotates the supplementary-piston valve the final step in this direction. This action moves the supplementary-piston valve into the position shown in Fig. 15, which, as above described, moves the controlling-valve to the position shown in Fig. 11 to admit motive fluid to the right-hand and exhaust it from the left-hand end of the operating-cylinder. The cross-head having reached its limit of motion in one direction—viz., to the right—is moved backwardly, so that the inclined cam 26 of the cam-block contacts the pin 27 to rotate the supplementary-valve rod to the right or in a reverse direction, consequently forcing the supplementary-piston valve to return one step and back to the position shown in Fig. 14, with the resultant action that motive fluid is cut off from the right-hand end of the operating-cylinder. The continued retreat of the cross-head carries the cam-block to such position that its inclined cam 28 contacts the pin 29 to further rotate the supplementary-valve rod another step to the right and force the supplementary-piston valve to the position shown in Fig. 13 and the controlling-piston to the position shown in Fig. 9—that is, where the compressing action takes place at the left-hand end of the operating-cylinder. The continued movement of the cross-head carries the cam-block so that its inclined cam 30 contacts the pin 31 to rotate the supplementary-valve rod into the initial position above described, the result being that the parts are in the position shown in Figs. 1, 8, and 12, with the inlet of the main operating-cylinder open at the left-hand end and the exhaust open at the opposite end.

In order to dispense with the link-motion, it is desirable that some means be provided for the reversal of the engine—that is, to exhaust the motive fluid from the supplementary-piston valve, where it has hitherto been admitted, and admit it where it has hitherto been exhausted. In order to accomplish this result, the reversing-valve 14, which is constructed and arranged as a "three-way" valve, is rotated ninety degrees in such manner that the motive fluid is supplied to the passage 13 and exhausted from passage 15. At the same time it is necessary to change the position and rotations of the supplementary-valve rod *r*, so as to obtain the correct phases of cut-off and compression to harmonize with the reversal. To accomplish this latter result, the lugs 3 are provided with a pair of parallel bars 32, that are in turn provided with inclined surfaces or wedges engaging corresponding inclines on the lugs. The plane surfaces of these parallel bars engage with the bearing-blocks 33 and 34, that hold, guide, and govern in a large measure the supplementary-valve rod and movements thereof. In the position shown in Fig. 1 these parallel bars are in such position as to hold the supplementary-valve rod, with its pins, in the position shown in full lines in Fig. 5, so that the pins above referred to on such valve-rod will contact the desired cams at the lower part of the cam-block. It is desirable, as above suggested, that the position and rotation of this supplementary-valve rod be changed, and, further, that it be changed immediately the position of the reversing-valve 14 is changed. To assist in obtaining this movement, the cam-block *v* is made double—that is, is provided with a set of inclined cams at its lower portion and a second set, the counterpart of the first, arranged in a reverse manner at the upper portion thereof. When the valve 14 is reversed, it is reversed through the action or movements of a rod 35, with which it is connected, (see Fig. 2,) which rod is also connected with a bell-crank 36, in turn connected with the parallel bars by means of a double crank 37, (see Figs 1 and 2,) so that as the valve is changed into the position shown in Fig. 1 the upper parallel bar is moved to the right and the lower to the left, thus raising the bearing-blocks 33 and 34, and thereby laterally moving the supplementary-valve rod. During the raising or lateral movement of this supplementary-valve rod the pin 39, which is the last one to be contacted by the cam-block in the description of the cycles above given, contacts the upper inclined cam 30 in such manner as to impart a rotation to the supplementary-valve rod equivalent to the entire number of its step rotations which it receives during one entire rectilinear movement of such cam-block. This rotates the supplementary-valve rod to the left, and consequently moves the supplementary-piston valve to the position shown in Fig. 15. In this position (and with the

understanding that the exhaust is now to the right of such Fig. 15 and the inlet to the left) the fixed and floating pistons are immediately moved, with the controlling-valve, to the position shown in Figs. 8 and 12, thereby permitting the steam to enter at the left-hand side of the main operating-cylinder and exhaust from the right-hand side of the same, while at the same time permitting the correct phases of cut-off, compression, and inlet and obtaining the reversal of the engine. It will be understood, however, by those skilled in the art that in the case of locomotives there is always a pair of these engines bearing a quarter or ninety-degrees relation to each other. The engine shown in Fig. 1 has the parts shown in dead-center, which would not be the case with the engine coupled on the other side, and such engine would therefore be the one which would give the rotation in a reverse manner. It will be unnecessary to describe or show diagrammatically the further cycles of the supplementary-piston valve, the fixed and floating pistons, the controlling-valve, or the main operating-piston, for the reason that it can be readily followed and understood with the aid of the diagrams heretofore given, all of which act to prevent confusion and ambiguity, as would be the case if further described herein. It is also desirable that some means be provided to vary the point of cut-off—that is, to permit the engine to take steam at as remote a point of the stroke as is necessary to handle a heavy load or cut it off early enough to carry the minimum load. To accomplish this result, the cut-off pins 21 and 27 are secured to sliding racks 38 and 39, movably mounted within the supplementary-piston rod and engaged with each other by means of a spur-pinion 40. (See Fig. 3.) One of these sliding racks is provided with a rod 41, extending out therefrom and which may be led back to any desired point in the engine (stationary or locomotive) so as to be adjusted readily and easily by a connecting-governor (not shown) or by the engineer in charge. When it is desired to lengthen the point of cut-off and take steam as long as possible, all that is neccessary is to pull out the rod 41 to the limit of its movement, which will actuate the spur-pinion 40 and move the other rack 38 in the opposite but desired manner, as will be readily understood from an examination of the drawings.

I claim—

1. In a fluid-pressure engine, the combination of a main cylinder having a piston movably mounted therein, valve mechanism for controlling the admission cut-off and exhaust of the motive fluid to and from the main cylinder, and supplementary-piston mechanism arranged to be operated by fluid under pressure to move the controlling-valve, substantially as described.

2. In a fluid-pressure engine, the combination of a main cylinder having a piston movably mounted therein, valve mechanism for controlling the admission cut-off and exhaust of motive fluid to and from the main cylinder, and a plurality of supplementary pistons connected with the controlling-valve for operating the same and arranged to be operated by fluid under pressure, substantially as described.

3. In a fluid-pressure engine, the combination of a main cylinder provided with a piston movably mounted therein, a reciprocating valve controlling the admission cut-off and exhaust of motive fluid to and from the main cylinder, a valve-stem connected with the reciprocating and controlling valve, and a plurality of supplementary pistons mounted on such stem arranged to be operated by fluid under pressure for moving the controlling-valve, substantially as described.

4. In a fluid-pressure engine, the combination of a main cylinder having a piston movably mounted therein, a valve for controlling the admission cut-off and exhaust of motive fluid to and from the main cylinder, a valve-rod connected with such controlling-valve, and a plurality of supplementary pistons connected with such valve-rod, one at least of which is fixed thereto and all of which are arranged to be operated by fluid-pressure and move the controlling-valve, substantially as described.

5. In a fluid-pressure engine, the combination of a main cylinder having a piston movably mounted therein, a controlling-valve for governing the admission cut-off and exhaust of motive fluid to and from the main cylinder, a valve-rod connected with such controlling-valve, and a fixed piston and two floating pistons on such valve-rod arranged to be operated by fluid under pressure and move the controlling-valve, substantially as described.

6. In a fluid-pressure engine, the combination of a main cylinder provided with a piston movably mounted therein, a reciprocating piston-valve governing the inlet cut-off and exhaust of motive fluid to and from the main cylinder, a valve-rod connected with a controlling-valve, a fixed piston on such valve-rod, and two floating pistons slidingly mounted on such valve-rod, one adjacent to each end of the fixed piston—all arranged to be operated by fluid-pressure, substantially as described.

7. In a fluid-pressure engine, the combination of a main cylinder provided with a piston movably mounted therein, a piston-valve for governing and controlling the inlet cut-off and exhaust of motive fluid to and from the main cylinder, a valve-rod connected with such controlling-valve, a fixed piston secured to such valve-rod, and two floating pistons of larger diameter slidingly mounted on the valve-rod, one at each end of the fixed piston—all arranged to be operated by motive fluid and govern the movements of the controlling-valve, substantially as described.

8. In a fluid-pressure engine, the combina-

tion of a main cylinder provided with a piston movably mounted therein, a piston-valve for governing and controlling the inlet cut-off and exhaust of motive fluid to and from the main cylinder, a valve-rod connected with such controlling-valve, a fixed piston secured to such valve-rod, two floating pistons of larger diameter slidingly mounted on the valve-rod, one at each end of the fixed piston—all arranged to be operated by motive fluid and govern the movements of the controlling-valve, and a supplementary-piston valve arranged to be operated by a movable part of the engine and govern the inlet and exhaust of motive fluid to the fixed and floating pistons, substantially as described.

9. In a fluid-pressure engine, the combination of a main cylinder provided with a piston movably mounted therein, a piston-controlling valve for governing and controlling the inlet cut-off and exhaust of motive fluid to and from the main cylinder, a valve-rod connected with such controlling-valve, a fixed piston secured to such valve-rod, two floating pistons of larger diameter slidingly mounted on the valve-rod, one at each end of the fixed piston—all arranged to be operated by motive fluid and govern the movements of the controlling-valve, and a supplementary reciprocating piston-valve arranged to be operated by a movable part of the engine and control the inlet and exhaust of motive fluid to and from the fixed and floating pistons, substantially as described.

10. In a fluid-pressure engine, the combination of a main cylinder provided with a piston movably mounted therein, a reciprocating valve governing or controlling the inlet cut-off and exhaust of motive fluid to and from the main cylinder, a fixed and two floating pistons connected with the controlling-valve and arranged to be operated by fluid-pressure to move such controlling-valve, a reciprocating supplementary-piston valve arranged to govern and control the inlet and exhaust of motive fluid to and from the chamber in which the fixed and floating pistons operate, and means for operating the supplementary-piston valve in a step-by-step manner during the reciprocations of the main piston, substantially as described.

11. In a fluid-pressure engine, the combination of a main cylinder provided with a piston movably mounted therein, a reciprocating valve governing and controlling the inlet cut-off and exhaust of motive fluid to and from the main cylinder, a valve-stem connected with such controlling-valve, a casing providing a supplementary-piston chamber secured adjacent to the chamber in which the controlling-valve operates, a fixed piston secured to the controlling-valve rod in such supplementary-piston chamber, two floating pistons slidingly mounted on such valve-rod, one at each end of the fixed piston, means providing a plurality of passages to each end of the supplementary-piston chamber, a supplementary-piston valve for opening and closing such passages and governing the inlet and exhaust of motive fluid from each end of such supplementary-piston chamber, substantially as described.

12. In a fluid-pressure engine, the combination of a main cylinder provided with a piston movably mounted therein, a reciprocating valve governing and controlling the inlet cut-off and exhaust of motive fluid to and from the main cylinder, a valve-rod on such controlling-valve, a casing providing a compound supplementary-piston chamber of large diameter at each end and small diameter in the center, a small piston fixed to the valve-rod and arranged in the small supplementary-piston chamber, two larger floating pistons slidingly mounted on such valve-rod, one at each end of the fixed piston and in the large supplementary-piston chambers, means providing a plurality of passages to each end of the supplementary-piston chamber and at each side of the large pistons therein, a supplementary-piston valve for covering and uncovering the last-named passages to govern the inlet and exhaust of motive fluid to the compound piston-chamber and thereby the actions of the fixed and floating pistons, and means for operating the supplementary-piston valve in a step-by-step manner during the reciprocations of the main piston, substantially as described.

13. In a fluid-pressure engine, the combination of a main cylinder provided with a piston movably mounted therein, a reciprocating piston-valve governing and controlling the inlet cut-off and exhaust of motive fluid to and from the main cylinder, a valve-rod on such controlling-valve, a casing providing a compound supplementary-piston chamber of large diameter at each end and small diameter in the center, a piston fixed to the valve-rod and arranged in the small supplementary-piston chamber, two floating pistons slidingly mounted on such valve-rod—one at each end of the fixed piston and in the large supplementary-piston chambers, means providing a plurality of passages to each end of the supplementary-piston chamber and at each side of the large pistons therein, a supplementary-piston valve for covering and uncovering the last-named passages to govern the inlet and exhaust of motive fluid to the supplementary-piston chamber and thereby the actions of the fixed and floating pistons, a supplementary-valve rod connected with the supplementary-piston valve and provided with a helical or threaded portion, and means arranged on a movable part of the engine to give the supplementary-valve rod a rotary and rectilinear motion, substantially as described.

14. In a fluid-pressure engine, the combination of a main cylinder provided with a reciprocating piston, a reciprocating valve governing or controlling the inlet cut-off and exhaust of motive fluid to and from the main piston, a valve-rod on such controlling-valve,

a fixed piston on such valve-rod, two floating pistons slidingly mounted on such valve-rod, one at each end of the fixed piston—all arranged to be operated by fluid-pressure, a supplementary-piston valve for covering and uncovering a plurality of passages—one being a set of inlet and the other a set of exhaust passages leading to and from said valve to and from the fixed and floating pistons, and a valve for admitting a supply of motive fluid to and from the supplementary-piston valve and arranged in connection therewith to supply or exhaust the motive fluid to and from each set of passages leading to and from the supplementary-piston valve to obtain a movement of the engine in either direction as desired, substantially as described.

15. In a fluid-pressure engine, the combination of a main cylinder provided with a reciprocating piston, a reciprocating valve governing or controlling the inlet cut-off and exhaust of motive fluid to and from the main piston, a valve-rod on such controlling-valve, a fixed piston on such valve-rod, two floating pistons slidingly mounted on such valve-rod, one at each end of the fixed piston—all arranged to be operated by fluid pressure, a supplementary-piston valve for covering and uncovering a plurality of passages—one being a set of inlet and the other a set of exhaust passages leading to and from said valve to and from the fixed and floating pistons, a valve for admitting a supply of motive fluid to and from the supplementary-piston valve and arranged in connection therewith to supply or exhaust the motive fluid to and from each set of passages leading to and from the supplementary-piston valve to obtain a movement of the engine in either direction as desired, substantially as described.

16. In a fluid-pressure engine, the combination of a main cylinder provided with a reciprocating piston, a reciprocating valve governing or controlling the inlet cut-off and exhaust of motive fluid to and from the main cylinder, a valve-rod on such controlling-valve, a fixed piston on such valve-rod, two floating pistons slidingly mounted on such valve-rod, one at each end of the fixed piston—all arranged to be operated by fluid-pressure, a supplementary-piston valve for covering and uncovering a plurality of passages—one being a set of inlet and the other a set of exhaust passages leading to and from said valve to and from the chamber in which the fixed and floating pistons operate, a valve for admitting a supply of motive fluid to and from the supplementary-piston valve and arranged in connection therewith to supply or exhaust the motive fluid to and from each set of passages leading to and from the supplementary-piston valve to obtain a movement of the engine in either direction as desired, a threaded valve-rod connected with the supplementary-piston valve, a plurality of pins on said rod, a cam-block provided with a plurality of cams mounted on a movable part of the engine to contact the pins and give the supplementary-valve rod its helical motion, and means for moving the supplementary-piston-valve rod laterally to bring its pins into contact with different cams on the cam-block and provide the desired phases for a reversal of the engine, substantially as described.

17. In a fluid-pressure engine, the combination of a main cylinder provided with a reciprocating piston, a reciprocating valve governing or controlling the inlet cut-off and exhaust of motive fluid to and from the main cylinder, a valve-rod on such controlling-valve, a casing providing a compound supplementary-piston chamber of different diameters, a fixed piston in the smaller diameter of such chamber and secured to the valve-rod, two floating pistons loosely mounted on such valve-rod and in the supplementary compound piston-chambers of larger diameter—one at each end of the fixed piston, means providing a plurality of exhaust and inlet passages to and from said compound supplementary-piston chamber, a supplementary-piston valve for covering and uncovering the last-named passages, a reversing-valve 14 for admitting the supply of motive fluid to and from the supplementary-piston valve and arranged to reverse the inlet and exhaust thereto and therefrom, a threaded supplementary-valve rod pivotally connected with the supplementary-piston valve and mounted in movable bearing-blocks, a plurality of radial pins secured to said supplementary-piston-valve rod, a block mounted on a reciprocating part of the engine and provided with a plurality of inclined cams spanning said valve-rod so as to contact the pins thereon in two positions and impart a helical motion to said valve-rod, and a pair of wedge-shaped parallel bars for moving the bearing-blocks and thereby the supplementary-piston valve laterally, substantially as described.

18. In a fluid-pressure engine, the combination of a main cylinder provided with a reciprocating piston, a reciprocating valve governing or controlling the inlet cut-off and exhaust of motive fluid to and from the main cylinder, a valve-rod on such controlling-valve, a casing providing a compound supplementary-piston chamber of different diameters, a fixed piston in the smaller diameter of such chamber and secured to the valve-rod, two larger floating pistons loosely mounted on such valve-rod and in the larger supplementary compound piston-chambers—one at each end of the fixed piston, means providing a plurality of exhaust and inlet passages to and from said compound supplementary-piston chamber, a supplementary-piston valve for

covering and uncovering the last-named passages, a reversing-valve 14 for admitting the supply of motive fluid to and from the supplementary-piston valve arranged to reverse the inlet and exhaust thereto and therefrom, a threaded valve-rod pivotally connected with the supplementary-piston valve and mounted in movable bearing-blocks, a plurality of radial pins secured to said supplementary-valve rod, a cam-block mounted on a reciprocating part of the engine and provided with a plurality of inclined cams spanning said valve-rod so as to contact the pins thereon in two positions and impart a helical motion to said valve-rod, a pair of wedge-shaped parallel bars for moving the bearing-blocks and thereby the supplementary-piston valve laterally, and rod-and-lever mechanism connecting the reversing-valve and the parallel wedge-shaped blocks together so as to impart a simultaneous movement thereto, substantially as described.

SPENCER OTIS.

Witnesses:
THOMAS FRANCIS SHERIDAN,
HARRY IRWIN CROMER.