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C. C. WORTHINGTON.

VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,533. Patented June 15, 1897.

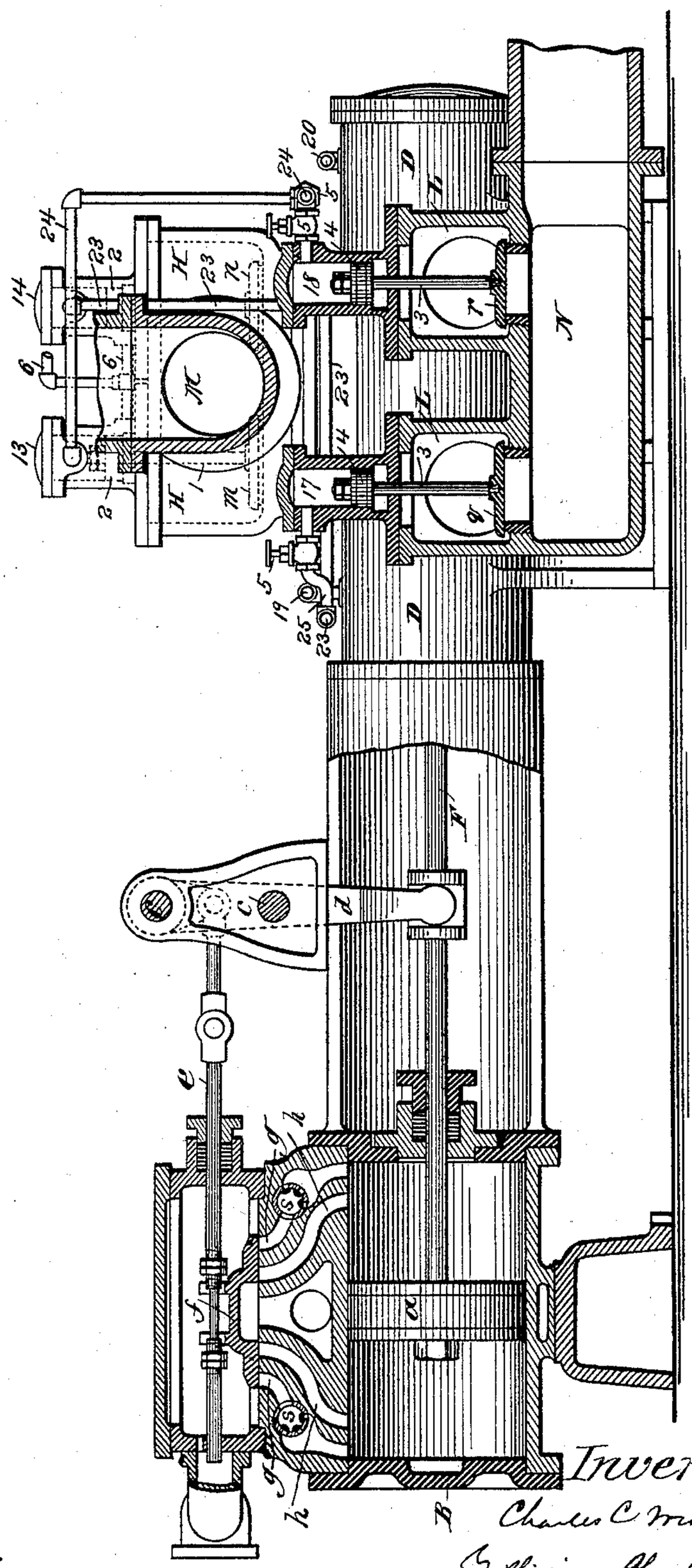

Fig. 1.

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(No Model.) 10 Sheets—Sheet 2.

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VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,533. Patented June 15, 1897.

Fig. 2.

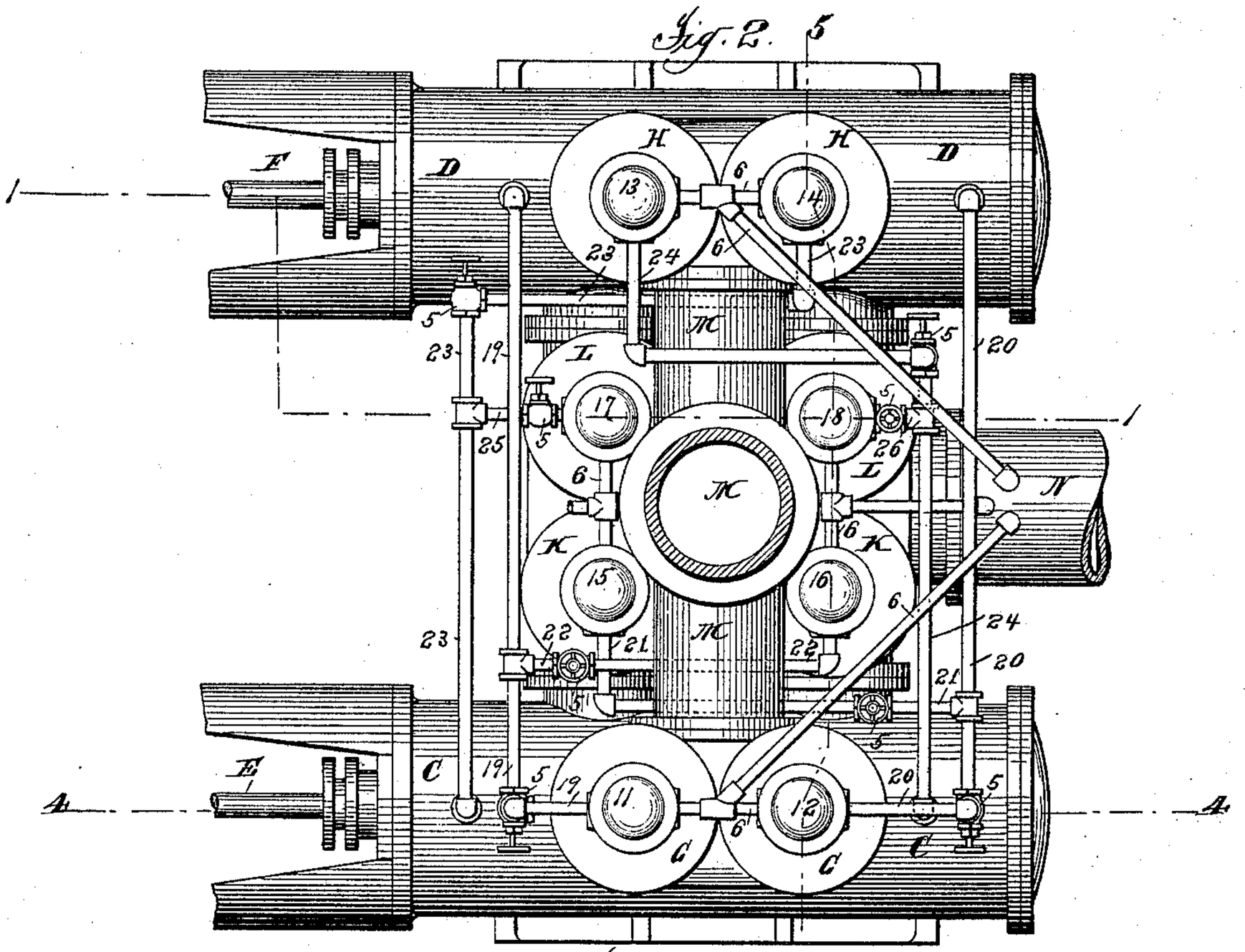
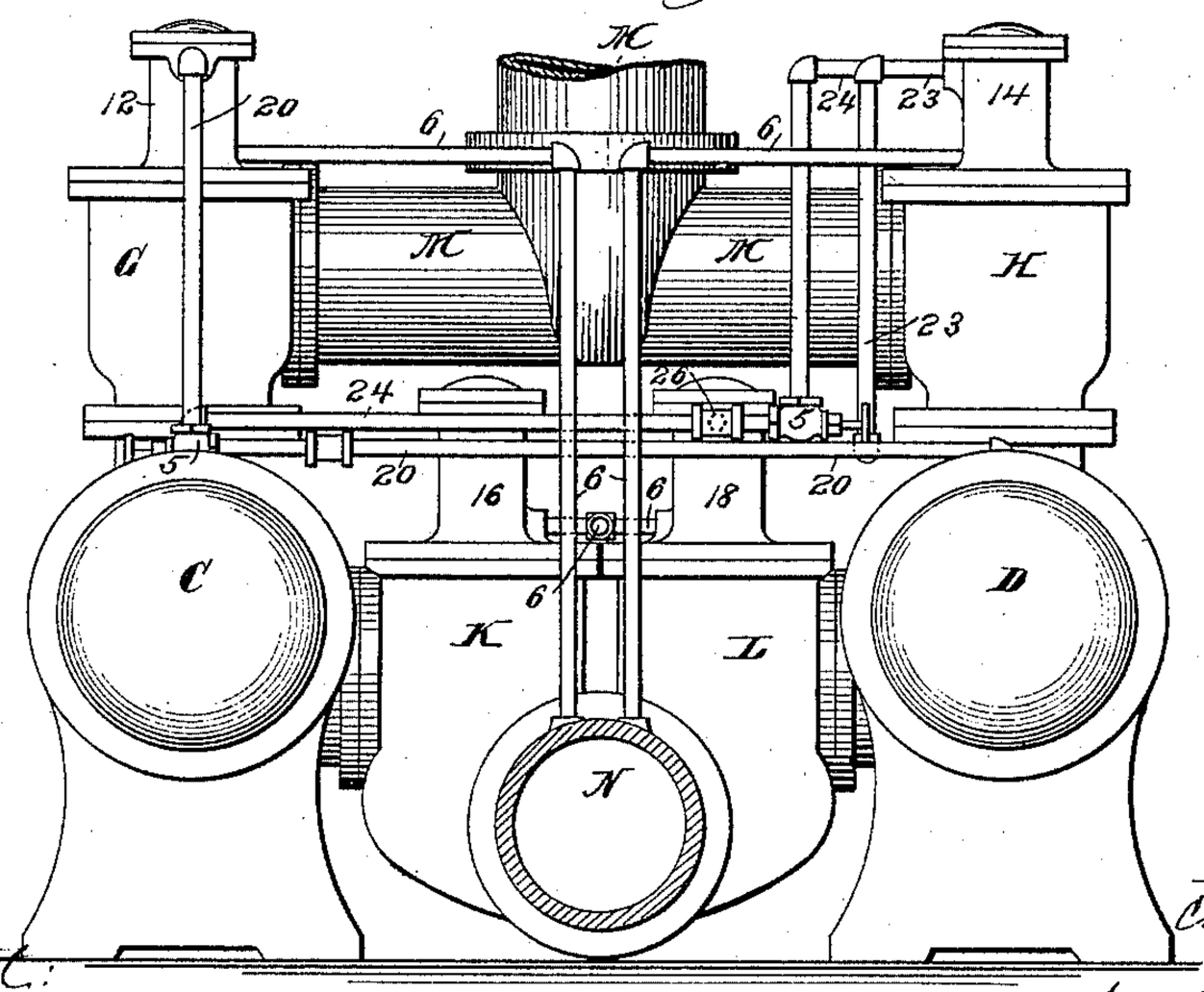


Fig. 3.



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VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,533. Patented June 15, 1897.

Fig. 4.

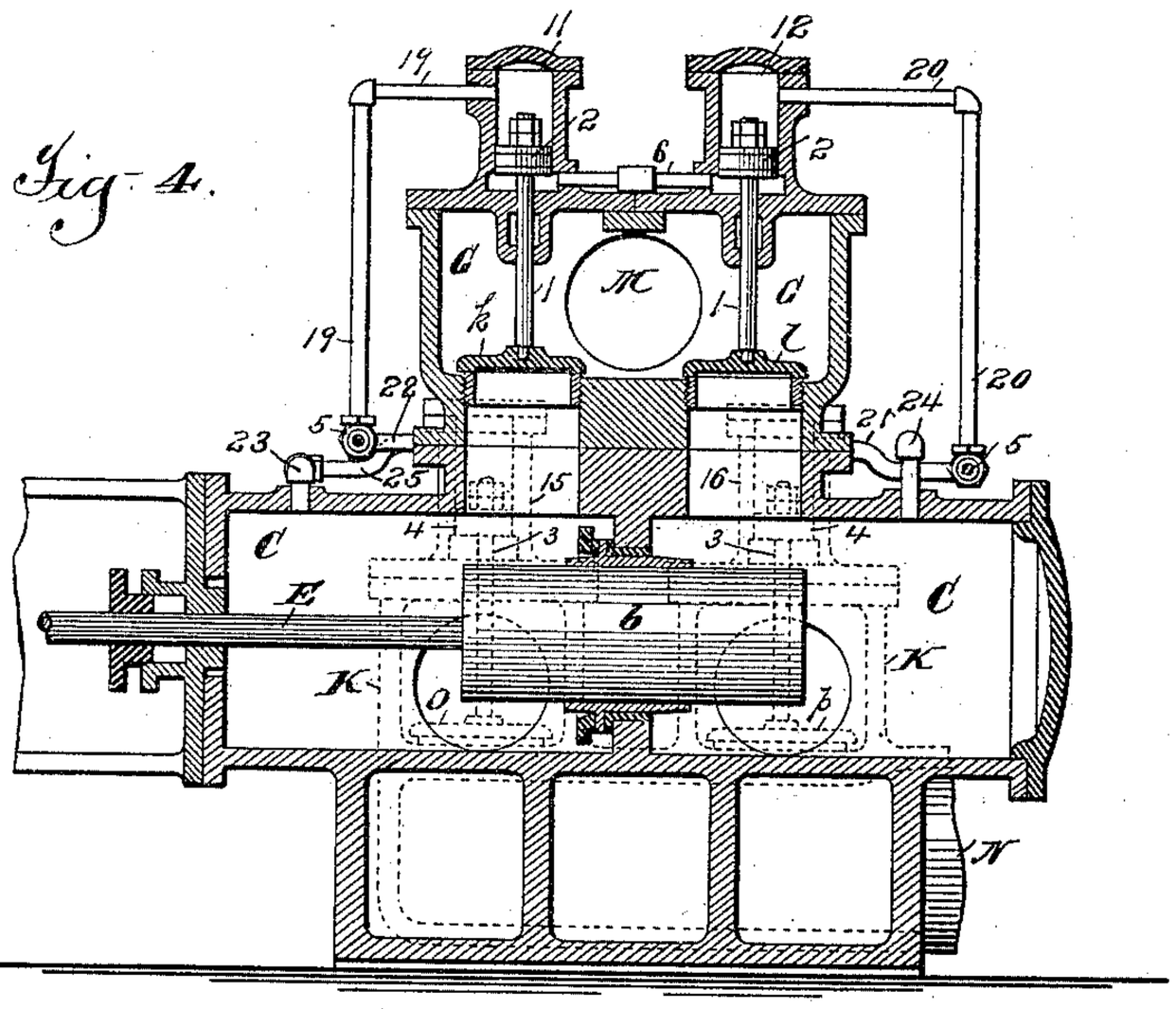


Fig. 17.

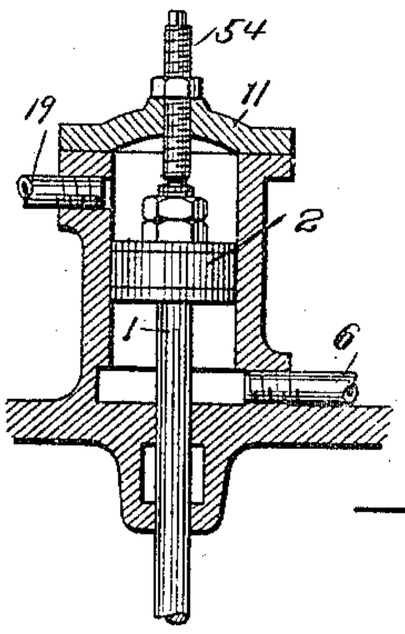
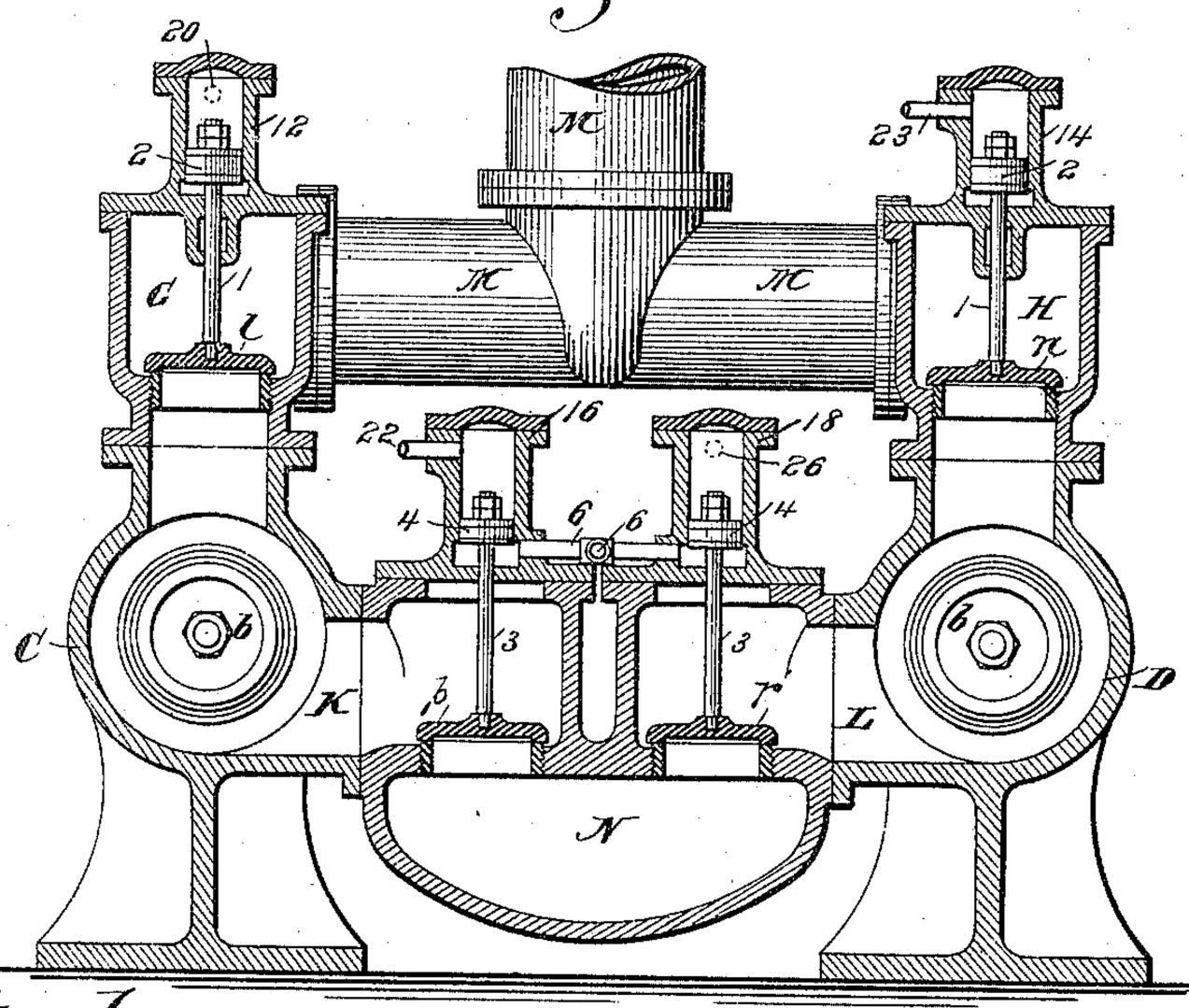


Fig. 5.



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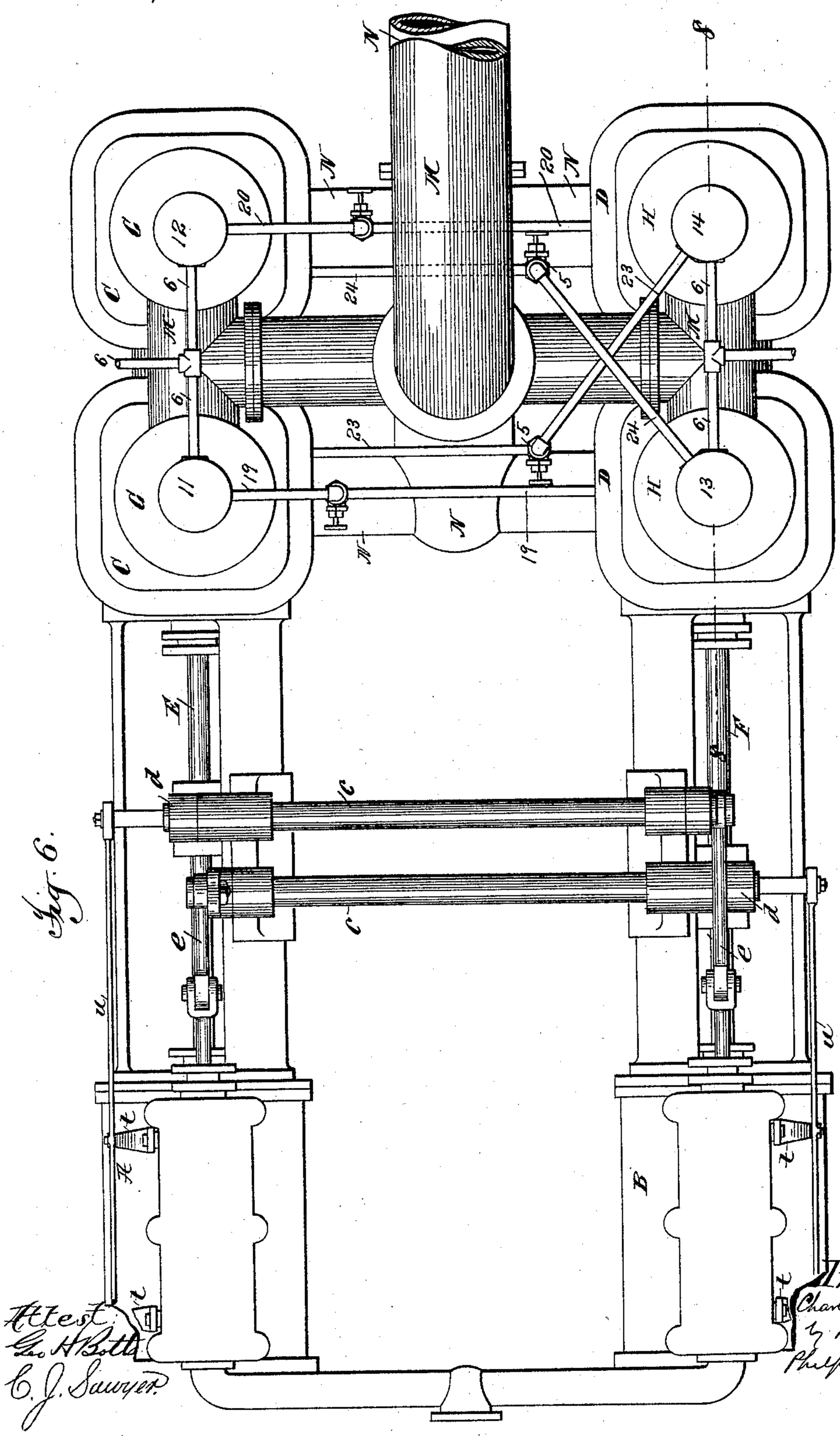
VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,533. Patented June 15, 1897.



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VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,533. Patented June 15, 1897.

Fig. 7.

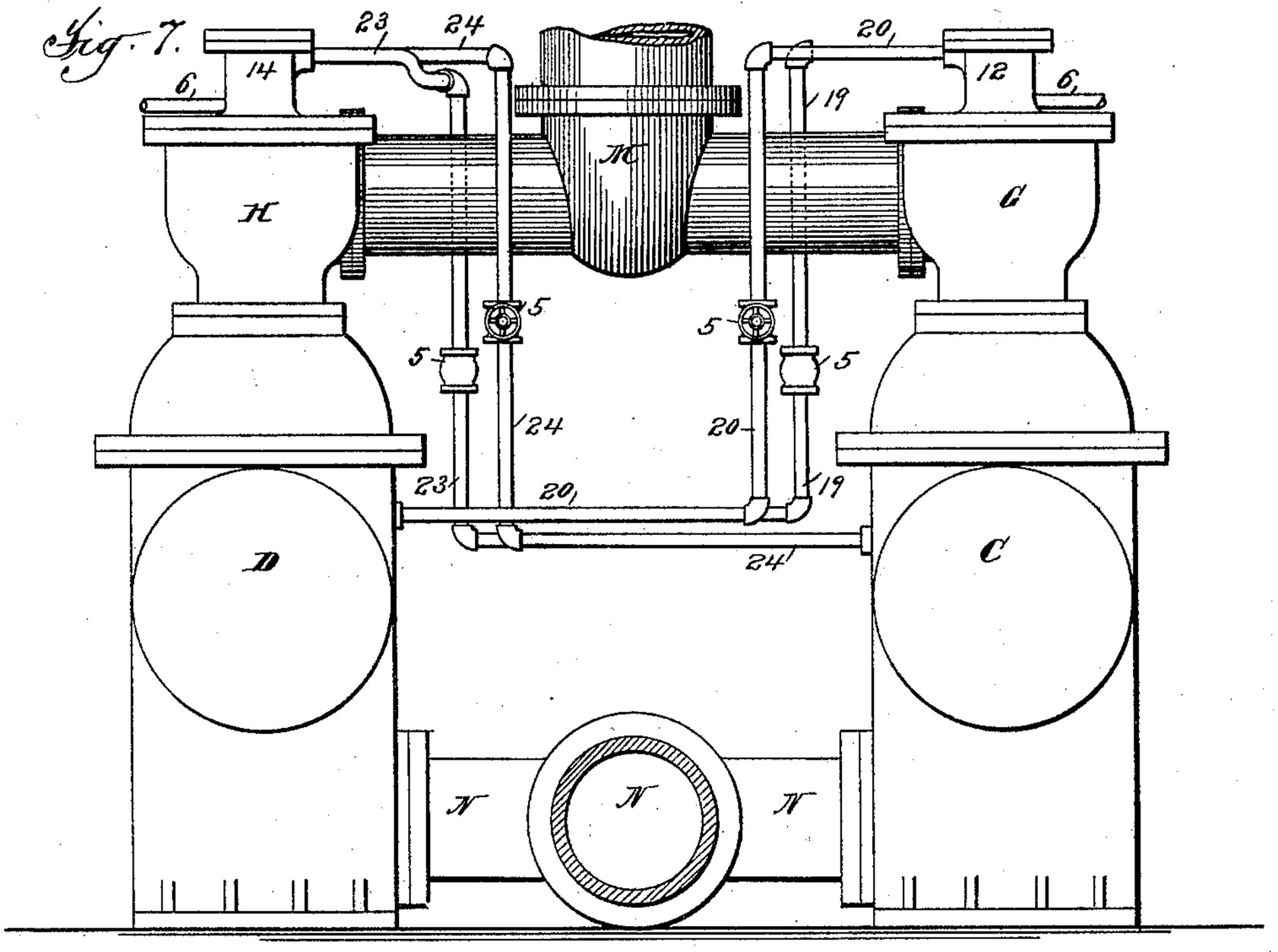
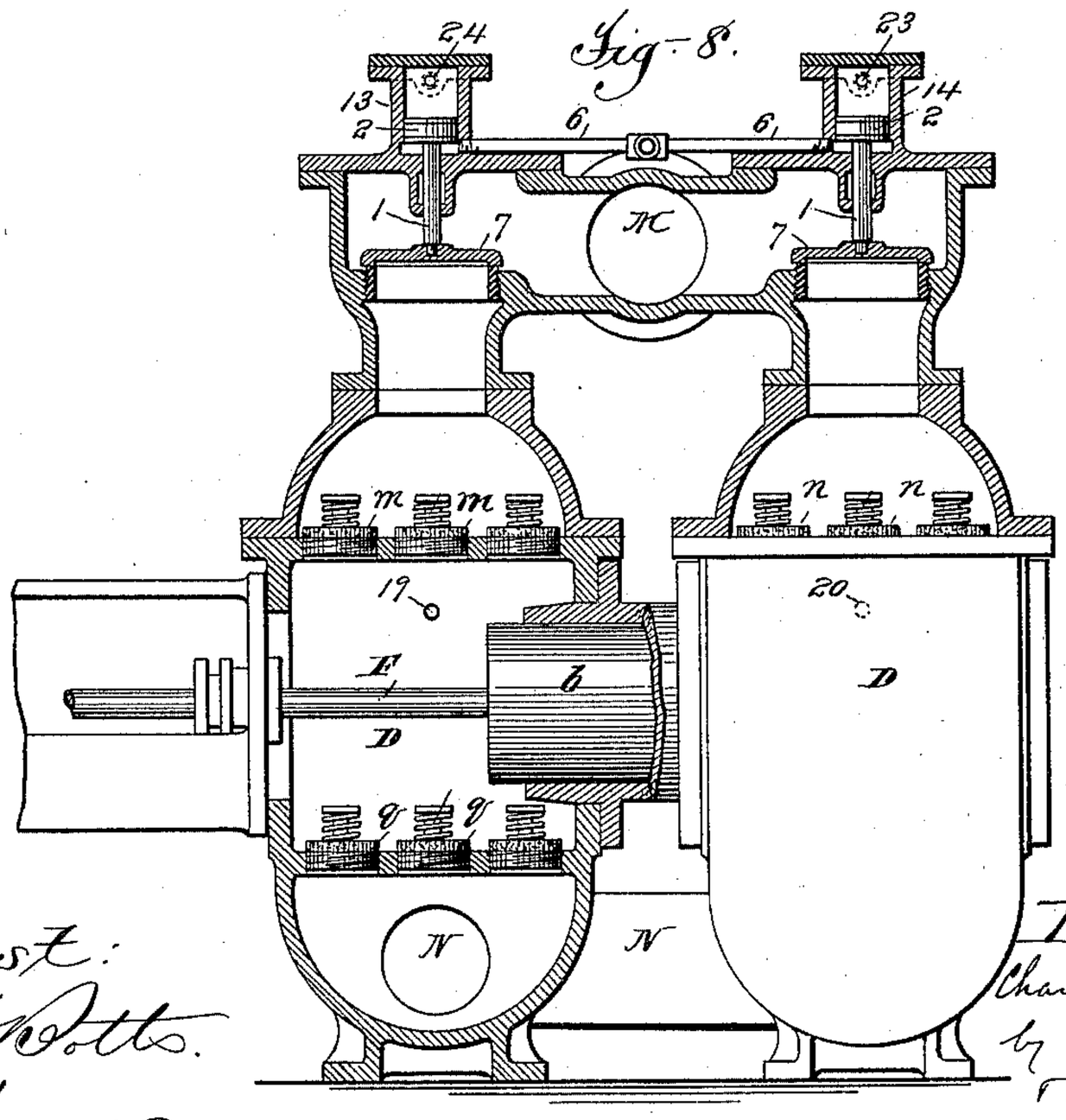


Fig. 8.



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VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,533. Patented June 15, 1897.

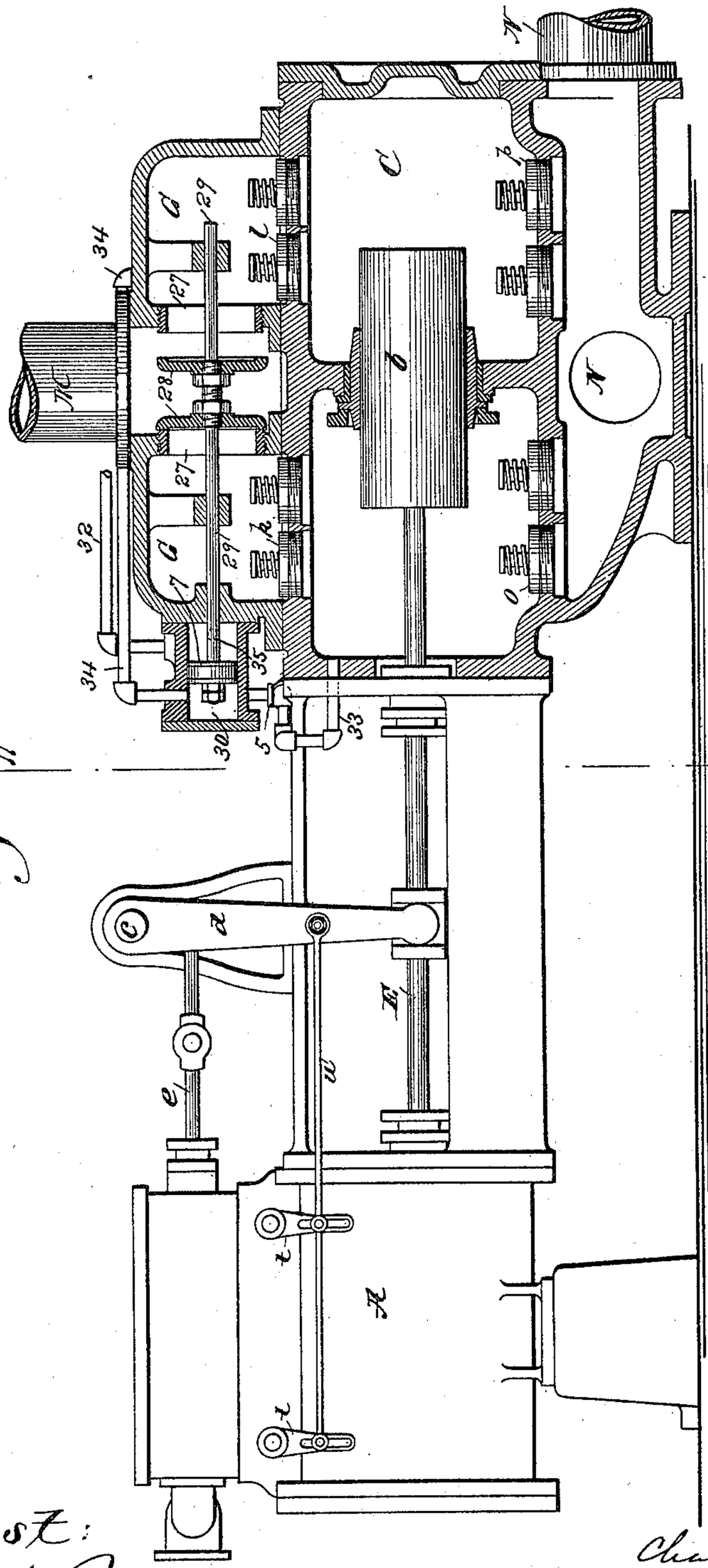

Fig. 9.

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VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,533. Patented June 15, 1897.

Fig. 10.

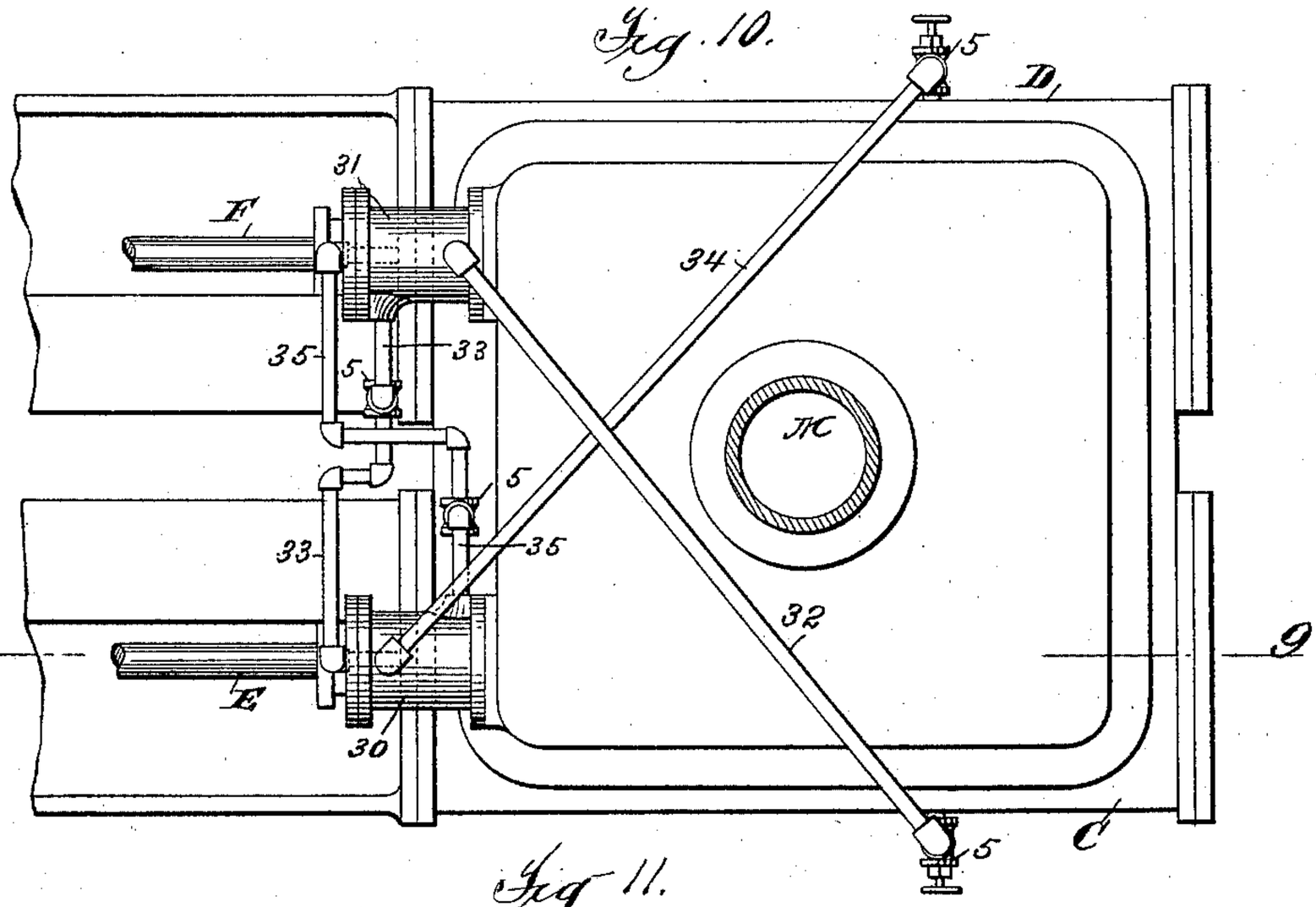
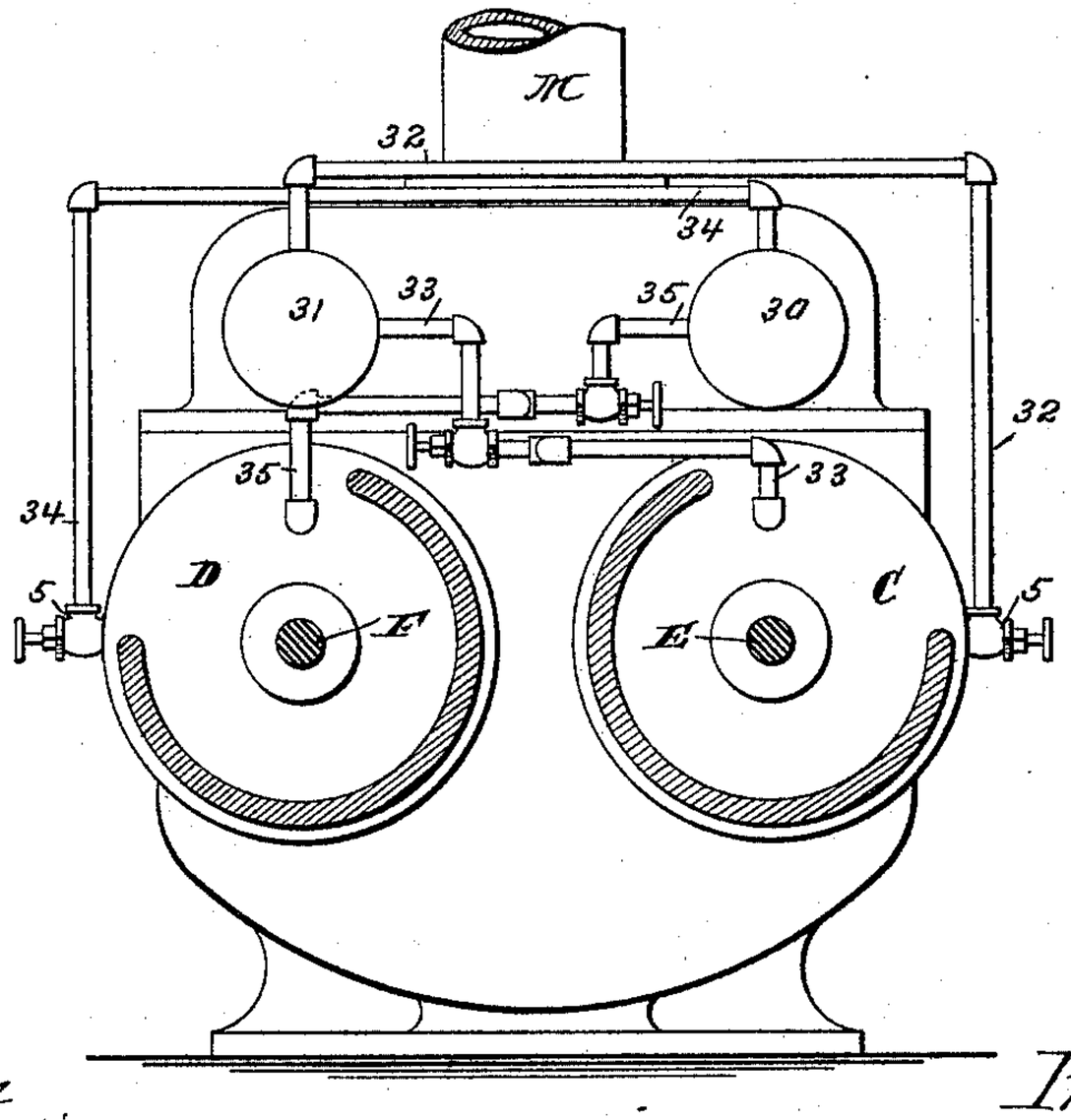


Fig 11.



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VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,533. Patented June 15, 1897.

Fig. 12.

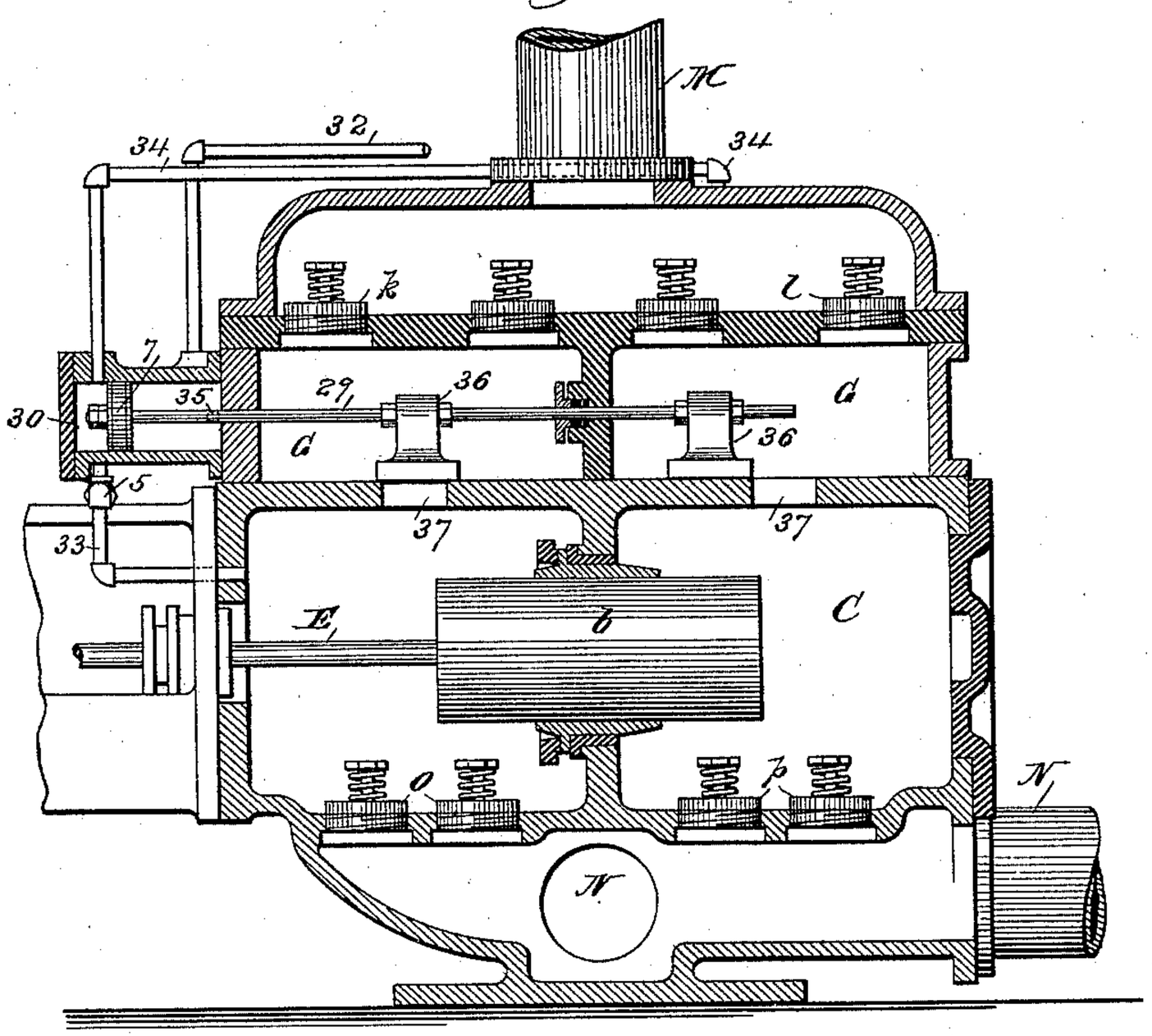
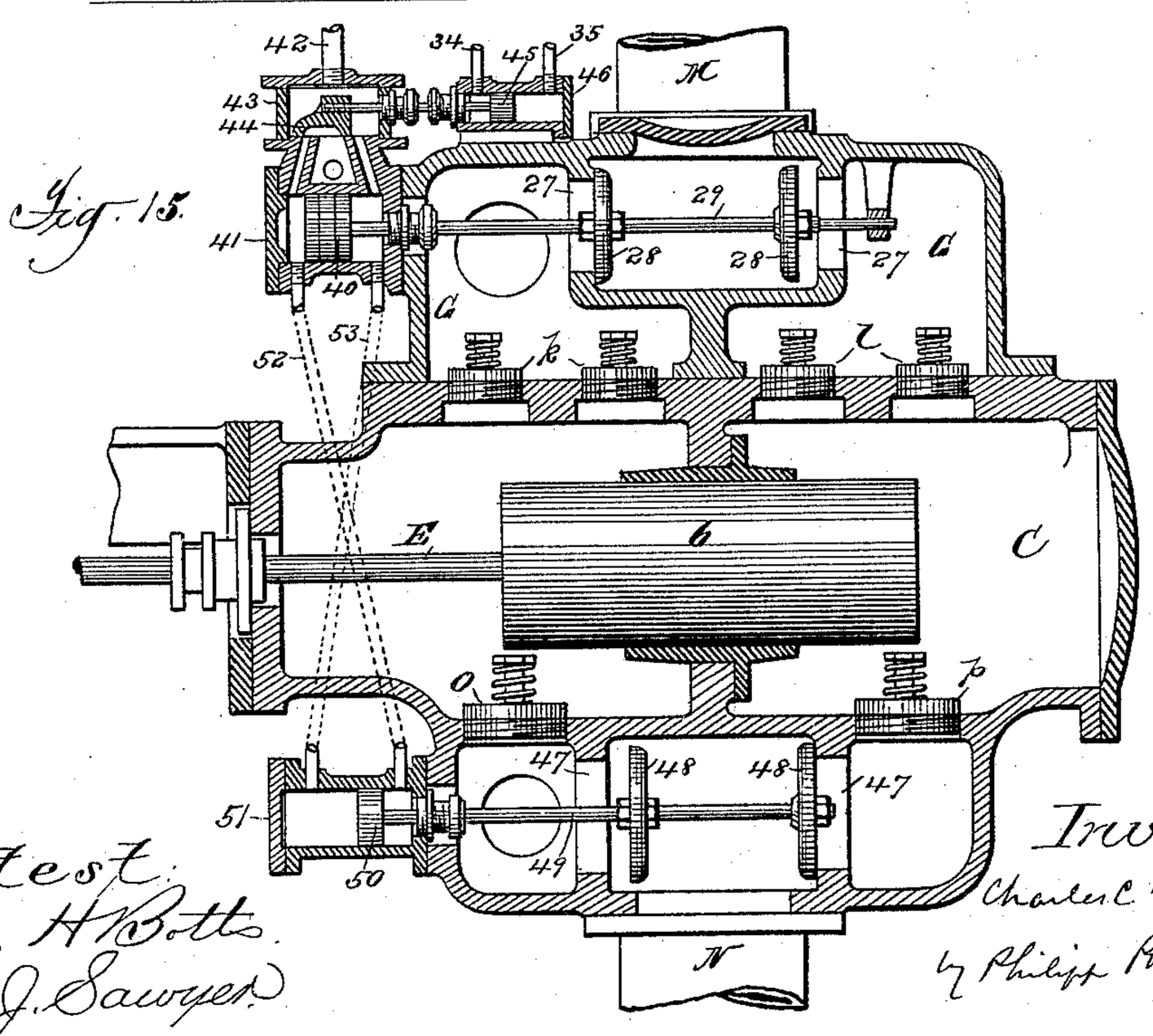


Fig. 15.



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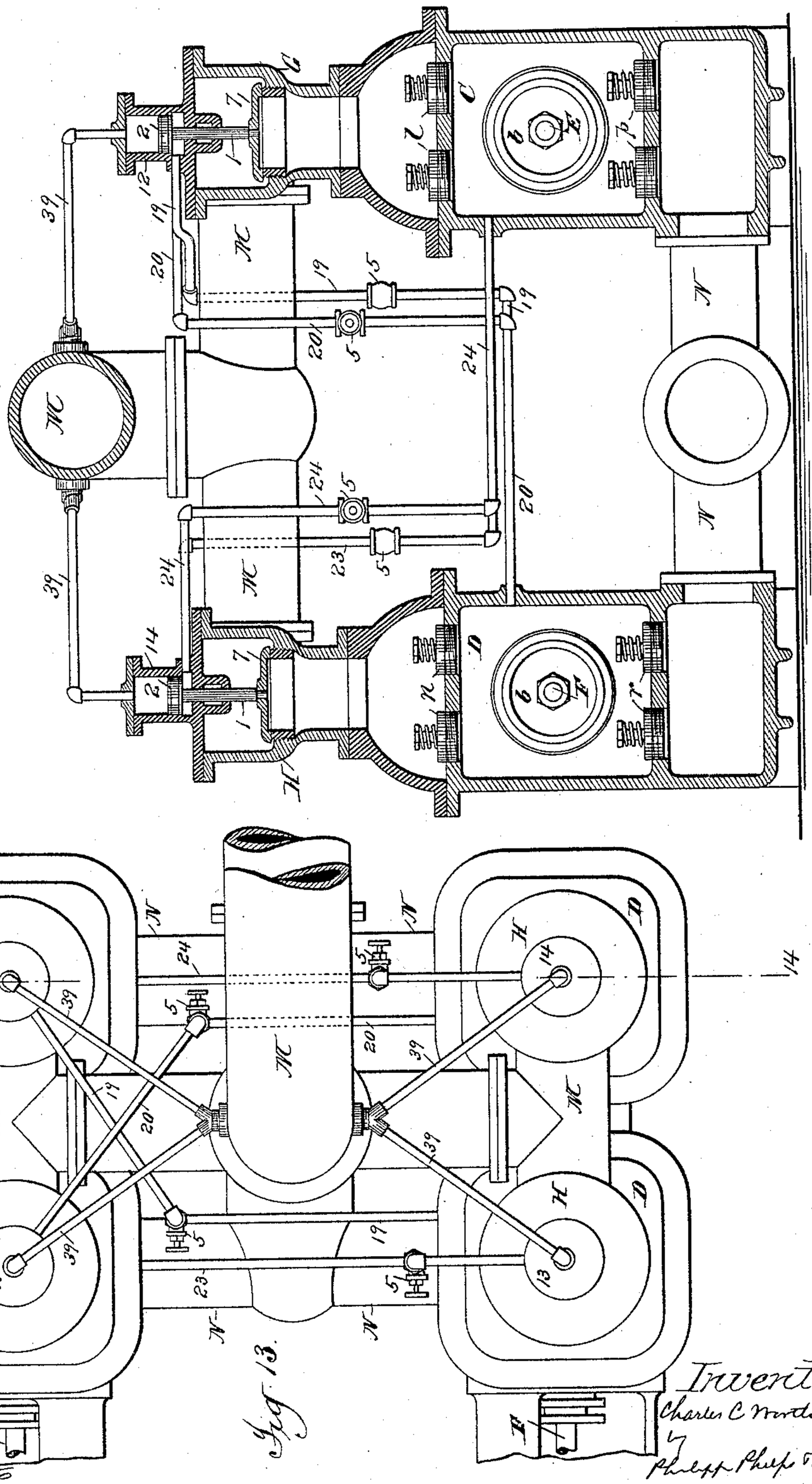

Fig. 14.

Fig. 13.

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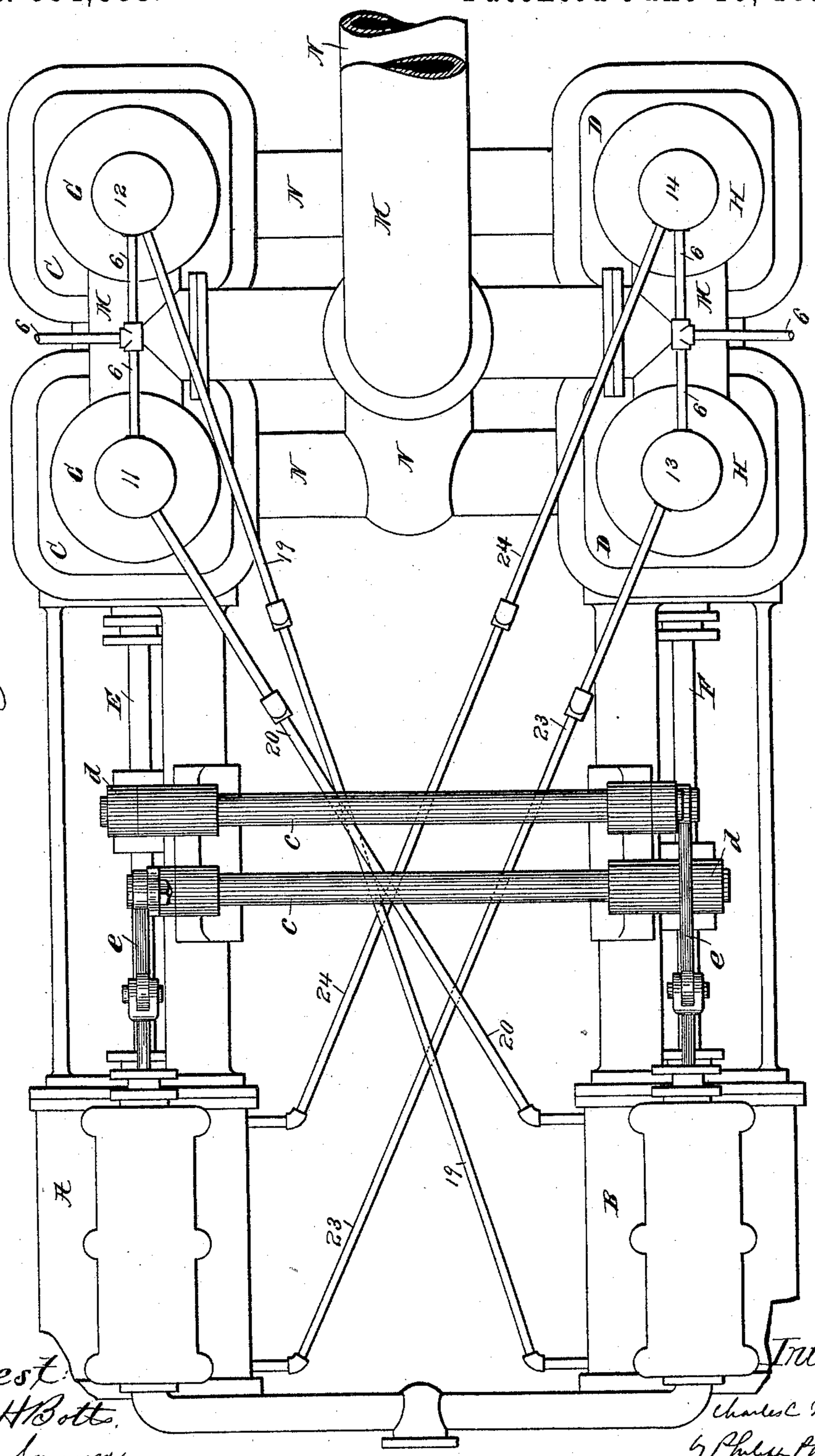

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UNITED STATES PATENT OFFICE.

CHARLES C. WORTHINGTON, OF IRVINGTON, NEW YORK.

VALVE-MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP-VALVES.

SPECIFICATION forming part of Letters Patent No. 584,533, dated June 15, 1897.

Application filed February 27, 1891. Serial No. 383,088. (No model.)

To all whom it may concern:

Be it known that I, CHARLES C. WORTHINGTON, a citizen of the United States, residing at Irvington, county of Westchester, and State of New York, have invented certain new and useful Improvements in Valve-Movements for Pumps and Methods of Closing Pump-Valves, fully described and represented in the following specification and the accompanying drawings, forming a part of the same.

The object of the present invention is to provide an improved valve-movement for pumps and an improved method of closing pump-valves, and especially to secure a more uniform action of steam or power pumps and to increase the speed at which they can be operated successfully.

While the main features of the invention are of general application in pumps of all classes, the invention is of special application to direct-acting steam-pumps or pumping-engines in which the improvements constituting the invention coöperate with other features of the construction to secure certain special results not attained in other pumps, and the invention will therefore be described and illustrated as applied to steam-pumps or pumping-engines of this class. In this class of pumps, as is well known, the motor-pistons are connected to the rods which carry the corresponding pump-plungers in such manner that the piston and plunger are free to move in either direction, according to the side of the piston upon which the pressure is greater. It has been customary to provide pumps of this class with some means by which the piston and plunger are gradually arrested at the end of the stroke in either direction, thus avoiding the danger of damage to the pump by more or less violent contact of the piston with the heads of the cylinder. Numerous devices have been proposed for this purpose, but that most generally adopted in practice consists of double steam-ports in the cylinder so arranged that the exhaust-port is closed by the piston just before it reaches the end of its stroke in either direction, thus causing the piston to be arrested gently by cushioning upon a small portion of the exhaust-steam remaining in the cylinder. This method has been found satisfactory at the speeds at which pumps of this class are usually run. Wherever this speed is increased, however, the momentum of the moving parts becomes sufficient to compress the steam thus imprisoned between the exhaust-port and the cylinder-head to a pressure which causes a rebound or recoil of the moving parts of the pump. This recoil is due to the pressure in the cushion acting upon the piston plus the pressure in the force-main acting upon the plunger, the pressure in the force-main being communicated to the plunger through the force-valves, which at that moment of the stroke have not had time to close. The effect of this recoil is to cause the water in the force-chamber to flow rapidly through the force-valves into the pump-chamber, producing a current which tends to slam the force-valves violently to their seats. The suction-valves at the opposite end of the plunger also are slammed by the pressure produced by the recoil movement of the plunger. The violence of this slam increases with the speed of the pump and soon becomes an element of danger. One of the specific objects of the present invention is to provide means whereby when the plunger arrives at the end of the stroke this recoil is avoided and all backward movement of the plunger prevented until it begins its return stroke. With this pump, in which the piston is stopped entirely by the cushion, it is evident as the momentum of the moving parts increases with the velocity that the cushioning pressure upon the ends of the steam-cylinder is very great at high speeds and that the danger of damage above referred to can be prevented only by employing a high steam-cushion at all times or providing some means by which the amount of cushion can be regulated and increased or decreased with the speed of the pump.

In the use of steam-cushions, therefore, it is customary to provide some means by which the amount of steam retained is varied in accordance with the speed of the pump, and for this purpose a small outlet is generally provided at the end of the cylinder, and this outlet controlled by a "relief-valve." By the adjustment of this relief-valve the amount of steam retained can be varied, as desired, so as to secure the filling up of the clearance-spaces and the exact adjustment of the length

of stroke, with the proper cushioning of the piston at different speeds without the employment of a permanently large cushion.

A further object of my invention is to provide means by which the piston and plunger may be stopped wholly or partially by pressure acting against the plunger in the water-cylinder toward the end of the stroke, thus avoiding the necessity for adjustment of the steam-cushion in accordance with the speed of the pump and rendering it possible to employ only a moderate steam-cushion at all speeds.

The piston and plunger may be stopped entirely by applying increased pressure upon the plunger at the end of the stroke, but I prefer to use a moderate amount of cushion in the steam-cylinder in connection therewith in order to divide up the stopping force and because the cushion is desirable in order to fill up the clearance-spaces in the steam-cylinder and secure the immediate action of the piston when the live steam is admitted upon the reversal of the valves.

A further object of my invention is to provide means for positively controlling the water-valves and especially to provide means by which these valves shall be gradually and positively closed by pressure during the latter part of the stroke of the plunger, the closing of these valves thereby exerting a gradually-increased stopping pressure upon the plungers.

I provide an improved method of closing a pump-valve, either suction or force, which consists in applying to said valve against the pumping pressure a fluid-pressure in excess of the pumping pressure, and I prefer to vary the pressure thus applied gradually during the stroke of the pump-plunger, so as to secure the gradual closing of the valve against the pumping pressure, and I attain the special objects pointed out above by thus closing the force-valves or an auxiliary valve or valves between the plunger and force-main, so that the pressure in the force-main is cut off from the plunger of the pump at the end of its stroke, with the result that no recoil of the plunger takes place, and the plunger is stopped wholly or partially by the pressure of the water within the pump-cylinder. By the term "pumping pressure" I mean the excess of pressure upon the pump-cylinder side of the valve tending to open or hold the valve open during the action of the pump. This fluid-pressure may be supplied from any suitable source in single or duplex pumps, and any suitable means may be used to control it in accordance with the action of the plunger, so as to secure the results desired; but in duplex pumps I preferably transmit a fluid-pressure varying with the movement on one side of the pump to the valve or valves on the opposite side, so as to control the valve or valves in such a manner as to secure their closing in the manner desired.

It is evident that the total pressure or force required to close the valves will vary with the line of movement of the valve relatively to the water-current, and it will be understood that by the expressions "against the pumping pressure" and "in excess of the pumping pressure" I do not mean the valve must be moved in a direction directly opposed to that of the current, but intend to cover, broadly, all constructions in which the valves are closed by a fluid-pressure acting in opposition to the pumping pressure and of sufficient amount to close the valve, whatever be the line of movement of the valve relatively to the water-current. I prefer to transmit this pressure directly in the force-valves, so as to secure their gradual and positive closing in front of the plunger as the latter reaches the end of its stroke, and I prefer to transmit the pressure also to the suction-valves to secure their closing behind the plunger at or about the same time, but the varying pressure may be transmitted only to the force-valves or to an auxiliary valve or valves controlling communication between the force-main and the water-cylinder, so as to secure the results desired, and similar auxiliary valves may be used also with the suction-valves.

The varying pressure may be so applied as to close the auxiliary or main valves, or the valves may be closed by a constant pressure from the main or other suitable source and the varying pressure employed to control the operation of the valves by such constant pressure. The varying pressure, moreover, may control the operation of the valves either by opposing the constant pressure, so that the closing pressure upon the valves varies with the ratio of the varying to the constant pressure, or the varying pressure may operate a valve by which the constant pressure is controlled as desired to secure the closing of the valves, as above described.

In attaining the highest speeds with a steam-pump provided with positive water-valves acting as described to cause a gradual increasing pressure to act against the plunger it may be found in some cases that the available pressure is not sufficient to thus close the valve, because as it begins to close the speed of the plunger is lessened, which is immediately followed by a packing of the steam behind the steam-piston, causing an increase of steam-pressure. The increase of steam-pressure thus caused may exceed the available power for operating the water-valves and thus prevent their closing. When a very high speed is desired, therefore, it is advisable to provide the steam-cylinder or cylinders with cut-off valves, which shall operate to cut off the admission of steam to the cylinder late in the stroke, so that the water-valves can be positively closed and the plunger and piston stopped without the packing of the steam in the steam-cylinder.

In the ordinary low-duty pumps now in use the cut-off valves operate at about five-sixths stroke, it being found necessary to continue

the admission of the steam to this late point in the stroke at the speeds at which these pumps are generally run. A higher economy would be attained by cutting off earlier in the stroke, and with the positive water-valve and high speed rendered possible thereby this is practicable, as the high piston speed and momentum acquired by the piston and plungers will be sufficient to carry them to the end of their stroke without the steam following as late in the stroke as with lower speeds.

As the invention is especially adapted for use in duplex direct-acting steam-pumps, in which the valves on one side may be controlled from the opposite side, as above described, and my invention consists in part of the construction and arrangement of connections by which the valves are controlled in such pumps, the invention will be illustrated in connection with duplex pumps, and a full description of constructions embodying the invention in the preferred form will now be given in connection with such an illustration and the method and features of construction forming my invention specifically pointed out in the claims.

Figure 1 is a longitudinal section of a duplex direct-acting steam-pump, showing the present invention in its preferred form, the section of the water end being taken on the line 1 1 of Fig. 2 and of the steam end centrally through the steam-cylinder on the following side of the pump. Fig. 2 is a plan view of the water end. Fig. 3 is a rear elevation of the water end. Fig. 4 is a longitudinal section on the line 4 4 of Fig. 2. Fig. 5 is a cross-section on the line 5 5 of Fig. 2. Fig. 6 is a plan view of a pump, showing a construction employing auxiliary force-valves. Fig. 7 is a rear elevation of the water end of the same. Fig. 8 is a section on the line 8 8 of Fig. 6. Fig. 9 is a sectional elevation of a pump, showing a construction employing a single valve-controlling motor-cylinder for each side of the pump. Fig. 10 is a plan view of the water end of the same. Fig. 11 is a sectional elevation looking to the right from line 11 11 in Fig. 9. Fig. 12 is a section similar to Fig. 9 except that the auxiliary valves are placed inside the force-valves. Fig. 13 is a plan view of the water end, showing a construction in which the valves are closed by a constant pressure opposed by the varying pressure. Fig. 14 is a section looking to the left on the line 14 14 of Fig. 13. Fig. 15 is a section of the water end, showing a construction in which the varying pressure operates a valve to control a constant pressure closing auxiliary force and suction valves. Fig. 16 is a plan view similar to Fig. 6 except that the varying pressure is transmitted from the steam-cylinders, and Fig. 17 is a detail of a modification hereinafter referred to.

Referring to said drawings, the pumps shown in the different views are as to their general construction substantially identical and ordinary forms of duplex pumps. A single description will suffice for all, therefore, except in respect to the parts embodying the invention, which are varied in the different forms.

In the operation of duplex pumps the pistons move in opposite directions during a part of the stroke and in the same direction during the rest of the stroke. When moving in the same direction, the same piston is always in advance in whichever direction the two pistons are moving, and in accordance with established practice the terms "leading" and "following" herein refer, respectively, to the sides of the pump, the pistons of which lead or follow when both are moving in the same direction.

Each of the pumps shown consists of two steam-cylinders A B and two water-cylinders C D, the cylinders A C and B D forming, respectively, the leading and following sides of the pump. The pistons *a* and the water-plungers *b* for each side of the pump are connected to single piston-rods E F in the usual manner.

In the construction shown in some of the figures the water-cylinders on the same side are formed in a single casting and divided into two water-chambers on opposite ends of the plunger by means of a central wall or diaphragm, while in the construction shown in other figures the two water-cylinders are formed of independent castings, the plunger alternating between them; but it will be understood that these constructions are substantial equivalents and the operation of the pump in either case the same, there being a common force-main for both ends of the plunger in all the constructions.

The steam-cylinders are provided with the usual main-valve gear consisting of rock-shafts *c*, levers *d*, and valve-rods *e*, by which the main valves *f* for each side of the pump are operated from the piston-rods of the other side in the manner common in duplex pumps. The steam-cylinders are preferably provided with separate induction and exhaust ports *g h*, so that as the pistons *a* near the end of their strokes in either direction they cover the exhaust-ports *h* and confine a small amount of exhaust-steam in front of them in the ends of the cylinders by which the pistons are cushioned and arrested. This is the common method of cushioning, but it will be understood that any other form of apparatus may be used for this purpose, and that, as stated above, all cushioning of the steam-pistons may be omitted and the pistons and plungers be stopped by water-pressure only. The induction-ports *g* are controlled by cut-off valves *s*, operating to cut off the steam, as above described, and actuated from the levers *d* on the same side of the pump by cranks *t* and connecting-rods *u*. The construction of rotary cut-off valves and operating connec-

tions is that shown in my prior patent, No. 292,525, and is a simple and efficient form, but any other may be used.

The water-cylinders are provided with the usual force-valves *k l m n* and suction-valves *o p q r*, the force-valves *k l* and suction-valves *o p* communicating, respectively, with the water-cylinder at the end next to and farthest from the steam end on the leading side of the pump, and the force-valves *m n* and suction-valves *q r* corresponding thereto on the following side of the pump. The force-valves communicate with the force-chambers G H on the opposite sides of the pump and the suction-valves with corresponding suction-chambers K L, these force and suction chambers communicating, respectively, with the force and suction mains M N.

In the organization shown in Figs. 1 to 6 but one force-valve and one suction-valve for each end of the plunger is provided, while in the other organizations shown a plurality of valves for each end of the plunger are used. These constructions, however, as will be seen, are substantially the same.

Referring now particularly to Figs. 1 to 5, the parts in which the invention is embodied in its preferred form as applied to the pump shown in these figures will be described. Each of the force-valves *k l m n* is connected to the piston-rod 1 of a piston 2, these pistons moving in small motor-cylinders 11 12 13 14, mounted above the respective force-chambers. The suction-valves *o p q r* are similarly connected by the piston-rods 3 to pistons 4, moving in cylinders 15 16 17 18, mounted above the respective suction-chambers. These small cylinders are connected to the water-cylinders on the opposite side of the pump as follows: The cylinders 11 12, controlling the force-valves *k l* on the leading side of the pump, are connected by means of the pipes 19 20 to the water-cylinder D on the following side of the pump, these pipes communicating with the water-cylinders on the same end of the plunger as their respective valves *k l*, controlled thereby. The cylinders 15 16, controlling the suction-valves *o p* on the leading side of the pump, are connected by pipes 21 22 to the pipes 20 19 and are so arranged that the suction-valves are controlled from the diagonally opposite ends of the plunger on the opposite side of the pump. Thus the pressure on the following side of the pump controls both the force and suction valves on the leading side of the pump through the pipes 19 20, but the force-valves are controlled by the pressure at the ends of the plunger which correspond to those at which the said valves are located relatively to the plunger on their own side of the pump, while the suction-valves are controlled by the pressure at the diagonally opposite ends of the plunger.

The cylinders 13 14, controlling the force-valves *m n* on the following side of the pump, are connected by means of pipes 24 23 to the water-cylinder on the leading side of the pump, these pipes being reversed in crossing, so that the force-valve at one end of the plunger is operated by the pressure in the opposite water-cylinder at the diagonally opposite end of the plunger on that side. The cylinders 17 18, controlling the suction-valves *q r*, are connected by pipes 25 26 to the pipes 23 24, these pipes being so arranged that the suction-valves are operated by the pressure at the corresponding ends of the plunger in the opposite water-cylinder. Thus the pressure on the leading side of the pump controls both the force and suction valves on the following side of the pump through the pipes 23 24; but the force-valves are controlled by the pressure at the ends of the plunger diagonally opposite the ends at which the valves are located relatively to the plunger on their own side of the pump, while the suction-valves are controlled by the pressure at the corresponding ends of the plunger.

Each of the pipes transmitting the pressure from the water-cylinders to the small motor-cylinders is provided with a hand-valve 5, by which the passage of the water through the pipes and consequently the time or rapidity of movement of the force and suction valves can be accurately adjusted. Any other suitable means for adjusting the time or rapidity of movement of the valves may be used. For instance, the stroke of the pistons in the motor-cylinders may be varied, as shown in Fig. 17, the upward movement of the pistons 2 being limited by adjustable stop 54, so that the distance through which the valve moves in closing may be varied as desired.

The pipes transmitting the pressure from the water-cylinders enter the motor-cylinders above the pistons 2. Below the pistons the cylinders are preferably connected to the suction-main by means of pipes 6 for a purpose hereinafter stated.

The arrangement of pipes is fully shown in the drawings, especially in Figs. 2, 3, and 4, and will be readily understood from the above statement.

The operation of the mechanism which has been described is as follows: It is to be remarked that, as shown in the drawings, the pump is at rest and both sides of the pump are on center. This is not a position that the two sides of the pump will assume at the same time when in actual operation, but has been adopted for the purpose of illustration.

In describing the operation it will be assumed that the piston *a* of the leading side of the pump is started at the beginning of its stroke from left to right, the piston on the following side being then in the position of, say, five-sixths stroke from right to left. As the piston on the leading side moves to the right the water in front of the plunger *b* will be forced past the valve *l* of that end of the cylinder, raising the valve in the usual manner, and at the same time the water will be drawn in behind the plunger *b*, raising the

suction-valve at that end of the cylinder. As the piston *a* and plunger *b* approach the end of their stroke the cut-off valves S will operate to cut off the steam behind the piston, the piston will cover the exhaust-port *h* and cushion itself upon the steam confined in the end of the steam-cylinder beyond this port, and the piston *a* and plunger *b* will be arrested. When the piston *a* on the leading side of the pump is on the latter part of its stroke, the exact point varying in different pumps and being adjusted in the same pump in accordance with the duty to be performed, the piston *a* on the following side of the pump will have completed its stroke in the same manner as above described, paused, and will start in the same direction as that in which the piston on the leading side is moving—that is, from left to right—the two pistons moving in the same direction until the piston upon the leading side has completed its stroke, when the motion of the latter is reversed and it returns partially during the forward stroke on the following side. This is the usual operation in duplex pumps.

It will readily be seen that if no special means are provided for closing the valves, except the springs usually employed, the force-valves will be open at the time the plungers are stopped, so that the full pressure of the water in the force-main and force-chamber will be permitted to act for a short period of time upon the plunger. If the speed of the pump be such that the momentum of the moving parts compresses the steam between the piston and cylinder-head sufficiently, the back pressure of this steam-cushion, together with the pressure of the force-main upon the plunger, will cause a rebound or recoil of the piston and plunger, thus producing a rapid current from the force-main through the force-valves into the water-cylinder, which slams the force-valves violently to their seats, as above described. This recoil of the plunger slams also the suction-valves at the other end of the plunger which have not had time to close. It will be seen that besides the objectionable noise caused by this action it produces also a jar upon the pump which increases with the speed and practically prevents the attainment of high speeds. Apart from the necessity of overcoming this combined action of the cushion and pressure from the force-main, moreover, it is desirable that means should be provided for closing the valves positively as the plunger reaches the end of its stroke, so that certainty and promptness in the closing of the valves are secured. This closing is preferably gradual, so that an increasing cushioning pressure is applied to the plunger and the plunger is stopped slowly and without shock, the cushioning pressure required in the steam end being reduced thereby.

In the present organization as the plunger *b* on the leading side advances to the right, as before described, the pressure in the water-cylinder C in front of the plunger is transmitted through the pipe 24 to the cylinder 13 and operates the piston 2 to positively and gradually close the force-valve *m* on the following side of the pump in advance of the plunger *b*, which is then just completing its stroke from right to left. This pressure is transmitted also through pipes 24 and 26 to cylinder 18 and operates the piston 4 to positively close the suction-valve *r* on the following side behind the plunger. The plunger *b* on the following side having completed its stroke from right to left returns from left to right, and as the plunger *b* on the leading side completes its stroke from left to right the pressure in the water-cylinder D in front of the plunger is transmitted through pipes 20 and 21 to the cylinders 12 15 and operates the pistons 2 4 to close the force-valve *l* and suction-valve *o* respectively in front of and behind the plunger *b* on the leading side. As the plunger on the leading side is reversed and moves from right to left the pressure in advance of the plunger is transmitted through the pipes 23 and 25 to the cylinders 14 17 and closes the force-valve *n* and suction-valve *q* as the plunger *b* on the following side completes its stroke from left to right, and as the plunger *b* on the following side reverses it closes through pipes 19 22 and cylinders 11 16 the force-valve *k* and suction-valve *p* as the plunger on the leading side completes its stroke from right to left. This operation is constantly repeated during the operation of the pump.

It will be seen that as the movement of one of the plungers is reversed the pressure upon one set of force and suction valves upon the opposite side of the pump is released and the pressure transmitted to the other set of valves. As the pressure is released upon the force and suction valves they are operated by the pressure of the water acting under them, as usual in pumps.

If the small motor-cylinders were closed at their lower ends the air contained therein would produce an upward pressure upon the pistons which must be overcome by the pressure from the water-cylinder, it being impracticable to maintain a vacuum in the cylinders. Moreover, a certain amount of water must in time pass the pistons 2 4 and collect in the lower ends of the cylinders. The lower ends of the cylinders, therefore, are preferably entered by the pipes 6, previously referred to, which form drip-tubes. The drip from the cylinders will be relieved by these pipes if they open to the air, but as the pressure of the air is generally in excess of the low pressure on the suction side of the plunger the pipes 6 are preferably connected to the suction-main, as shown in Fig. 2, thus producing an equilibrium of pressure upon the opposite sides of the pistons 2 4 when the pressure from in front of the plungers is removed therefrom.

As the pump is generally constructed and

adjusted so that the plunger on one side commences its stroke somewhat prior to the completion of the stroke then being made on the other side of the pump, and as the pressure in advance of the plunger is at once transmitted to the pipes connected with the opposite side, it may in some cases be necessary to provide some means whereby the transmission of the pressure through the pipes shall be retarded or the operation of the pistons and valves otherwise controlled, so that the valves shall not be fully closed until the plunger reaches the end of its stroke. This adjustment may be made permanently in the construction of the pump by proportioning the sizes of the pipes and cylinders, but means, such as the hand-valves 5 or stops 54, will preferably be provided by which the operation may readily be adjusted, as described above.

In the organization thus far described the force and suction valves are operated directly by the pressure from the water-cylinder on the opposite side of the pump. The connections through which these valves are operated may be varied widely as to form without departing from my invention, and the valves operated may be the main force and suction valves, as ordinarily applied and as above described, or auxiliary valves located anywhere in the force and suction chambers of the water-cylinders, either between the main valves and force and suction mains or between the plunger and main valves.

In Figs. 6 to 8 is shown an organization similar to that previously described, except that the pistons 2 are connected not to the force-valves but to auxiliary valves 7, located between the force-valves and the force-main and operating to close communication between the water-cylinder and force-main and cut off the pressure in front of the plunger as the latter reaches the end of its stroke. This construction involves a slight modification in the form of the force-chamber, but the relations of the parts remain substantially unchanged. In this organization no connections to the suction-valves are shown, although such may be used if desired, the latter being similar to those shown in the construction previously described, or auxiliary valves similar to those shown in connection with the force-valves and placed either inside or outside of the suction-valves. The arrangement of pipes and connections between the water-cylinders and the auxiliary valves on opposite sides of the pump are identical with those used in the construction in which the pistons are connected to the force-valves, and no further description is necessary, the same references being applied to corresponding parts in the two constructions. It is evident that in this construction the closing of the auxiliary valve exerts a gradual stopping pressure upon the plunger in addition to cutting off the pressure of the force-main, so that substantially all the advantages of the construction previously described are obtained by the auxiliary valve.

In Figs. 9, 10, and 11 is shown an organization in which auxiliary valves are used on the force side, as in Figs. 6, 7, and 8, but the construction and arrangement of the parts are varied. The force-chamber on each side of the pump is divided into two compartments, one for each end of the plunger, and these compartments communicate by ports 27 with the force-main. These ports are controlled by means of disk valves 28, which are carried by a single valve-rod 29 on each side of the pump, passing through the wall of the force-chamber, these rods being provided at their outer ends with pistons 7, which pistons move in cylinders 30 31 on respectively the leading and following sides of the pump. The pressure from the water-cylinders is transmitted to the cylinders 30 31 on the opposite sides of the pump to actuate the pistons 7 and control the valves 28 by the following means: The water-cylinder C on the leading side of the pump is connected to the motor-cylinder 31 on the following side by the pipes 32 33, these pipes entering the cylinder 31 on opposite sides of the piston 7 and connecting opposite ends of the water-cylinder C with the corresponding ends of the motor-cylinder, so that the pressure transmitted through pipes 32 33, respectively, operates the piston in a direction to close the port 27 in advance of the plunger *b* on the following side and to open the port behind the same at the moment when that plunger completes its stroke in either direction. The water-cylinder D on the following side of the pump is connected to the cylinder 30 on the leading side by means of pipes 34 35, these pipes, however, being so arranged as to connect the ends of the water-cylinder on the following side to the opposite ends of the motor-cylinder on the leading side, so that one set of connections are reversed, as in the constructions previously described. While the pipes reversed in this construction are those connecting the water-cylinder on the following side to the motor-cylinder on the opposite side instead of those from the water-cylinder on the leading side to the motor-cylinder on the following side, as in the constructions previously described, it is evident that the result is the same in both cases, as an excess of pressure at one end of the motor-cylinder closes the valve at the opposite end of the water-cylinder, so that the pressure in front of the plunger on the leading side still is transmitted to the valves at the diagonally opposite ends of the water-cylinder on the following side and that on the following side to the valves at the corresponding ends of the cylinder on the leading side. It is evident that the operation of this construction is substantially the same as that previously described, the reversal of the plunger on either side relieving the pressure on one side of the motor-piston 7 on the opposite side of the pump and transmitting

pressure to the opposite side of the piston, the suction and force pressure on one side of the pump being thus alternately transmitted to opposite sides of the pistons 7 on the opposite side of the pump. In this case the pressure behind the plunger on one side of the pump is transmitted directly to one side of the motor-piston on the opposite side of the pump and the pressure in front of the plunger is similarly and simultaneously transmitted to the other side of the same piston. It is apparent, therefore, that the piston is actuated in one direction or the other by the difference between the pressures in front of and behind the plunger on the opposite side of the pump. This, however, although less evident, is substantially the action in the constructions previously described employing the pipe 6 connecting the lower ends of the motor-cylinders to the suction, as the pressure behind the plunger is the same as that of the suction, and therefore the pistons are operated by the difference between the pressures at opposite ends of the plunger. The only substantial difference between the constructions is that in this modification but a single cylinder and piston is used for controlling all the valves on one side of the pump, the pressure in front of the plunger being transmitted alternately to opposite sides of the same piston instead of to different motor-cylinders and pistons, as in the constructions previously described. If, however, the pipes 6 are omitted or open to the air, the pressure in front of the plungers is opposed, not by the suction-pressure, as in the modification, but by the constant pressure of a single atmosphere.

While it is more desirable for simplicity of construction to place the auxiliary valves shutting off the reaction of the water column upon the plunger beyond the force-valves—that is, between the force-valves and force-main, as shown in Figs. 5 to 11—they may be located between the plunger and the force-valves and operate as already described. Such an arrangement applied to the pump last described is shown in Fig. 12, in which the construction is the same as that shown in Figs. 9 to 11, except that the auxiliary valves are placed inside of the force-valves, ports 36 opening from the water-cylinders into the force-chamber at opposite ends of the plunger and being controlled by slide-valves 37, carried by valve-rod 29, while the usual force-valves *k l* open from the force-chamber outside the auxiliary valves to the force-main. A similar arrangement may be used on the suction side.

In the construction shown in Figs. 9 to 12 it is obvious that if the voluntary valves be omitted the positively-operated valves will be closed, so as to cut off the pressure of the force-main from in front of the plunger and open the opposite end of the cylinder to the force-main as the plunger reaches the end of its stroke, so that these constructions may be used without the voluntary valves, provided that the valve be operated just at the end of the stroke. It is preferable, however, to use the voluntary valve, so that the pump-cylinder may be opened to the force-main behind the plunger before the plunger reaches the end of its stroke, except as it is closed by the voluntary valves, so that the valves may be closed in front of the plunger gradually.

While I have shown constructions in which either auxiliary or the main valves are actuated by the pressure in the pump-cylinders on the opposite side of the pump, and I prefer this method of operation, it is evident that a construction may readily be devised and substituted therefor in which the valves are controlled by the pressure in the pump-cylinders, but not closed thereby, but by pressure from some other source. Thus the pistons may be subjected to a constant pressure, as from the force-main, air-chamber, or an outside source of pressure tending to close the valve, and the pipes transmitting the pressure from the pump-cylinders may be arranged to connect with the motor-cylinders on the opposite side of the pistons from the constant pressure, so that as the plunger on one side is reversed and the pressure in the motor-cylinder on the opposite side of the pump reduced to that behind the plunger the constant pressure will close the valve at the proper moment. Upon the reversal of the plunger the higher pressure in front of the same will be transmitted to the cylinder and will counterbalance the constant pressure and permit the opening of the valve, as usual. Such an organization is shown in Figs. 13 and 14 applied to the pump of Figs. 6, 7, and 8, the constant pressure being transmitted from the force-main M to the upper sides of the pistons 2 through pipes 39 and the pipes 19 20 and 23 24 from the respective pump-cylinders entering the motor-cylinders below the pistons 2. It is apparent that this construction necessitates a complete reversal of the arrangement of the pipes forming the connections between the pump-cylinders and motor-cylinders in the construction of Figs. 6 to 8, as the controlling pressure is transmitted from behind the plungers when the valves are to be closed instead of from in front of the plunger, as before. Thus, as shown, the pipes 23 24 from the leading side of the pump pass directly to the opposite side and the pressure in the ends of the pump-cylinder on the leading side controls the closing of the valves at the corresponding ends of the plunger on the following side, while the pipes 19 20 from the following side are reversed in crossing and the pressure in the ends of the pump-cylinder on the following side controls the valves at the diagonally opposite ends of the plunger on the leading side.

In Fig. 15 is shown an organization in which constant pressure is applied to close the valves as just described, but is controlled by the varying pressure operating a valve which admits the constant pressure to one side or

the other of the piston actuating the valves. This modification is shown as applied to the pumps shown in Figs. 9 to 11 and previously described, but may be applied readily to other constructions.

Referring to Fig. 15, the parts embodying the modification will be briefly described. The construction on opposite sides of the pump being the same and the general arrangement of the pipes transmitting the varying pressure being unchanged, only the leading side is shown and a description of this will suffice. The auxiliary-valve rod 29, carrying the auxiliary valves 28, as in Fig. 9, is provided at the end with a piston 40, moving in a cylinder 41, located on the side of the force-chamber in a position similar to that of cylinder 30, the piston being actuated in either direction by a constant pressure transmitted from the force-main or other suitable source through pipe 42, valve-chamber 43, and the usual ports opening to the opposite sides of the piston 40. These ports are controlled by a slide-valve 44, the valve-rod of which is connected to a piston 45, working in a cylinder 46, entered on opposite sides of the piston by pipes 34 35 of Figs. 9 to 11, by which the pressure is transmitted from the water-cylinder on the opposite side of the engine. The operation of this construction is exactly the same as that of the construction shown in Figs. 9 to 11, except that the movement of the piston acted upon by the varying pressure does not control the valve directly, but through the slide-valve 44 controls the constant pressure and piston 40, so as to secure the closing of the auxiliary valves 28 in the same manner as when they are directly operated by the varying pressure. This construction affords also a convenient arrangement in employing auxiliary suction-valves. As shown in Fig. 15, the construction on the suction side is exactly the same as that upon the force side, ports 47 connecting the suction-main and suction-valves and being controlled by auxiliary disk valves 48, carried by a valve-rod 49, which is connected to the piston 50, operating in a cylinder 51 similar to cylinder 41 on the force side. The constant pressure may be transmitted to the cylinder 51 on the suction side in any suitable manner, but the construction shown will be found simple and efficient, in which pipes 52 connect the cylinders 41 and 51, so that the single valve 44 controls the admission of the constant pressure to both cylinders on one side of the pump. As the force and suction valves closed simultaneously are at opposite ends of the plunger, the valve-rods 49 and 29 must move in opposite directions, which result may readily be attained by crossing pipes 52 53 between the cylinders 41 51, as shown, or in any other suitable manner.

While I have shown the pipes as connected directly to the body of the pump-cylinders, it is evident that they may connect anywhere between the plunger and the inside valves on the force or suction side of the pump, as the pulsations of the fluid are the same at any point inside of these valves. By the term "pump-cylinder," therefore, I intend to cover the entire space between the inner valves on the suction and force sides of the plunger. It will be understood also that the term "plunger" covers a piston.

In the constructions thus far described the pressure within the pump-cylinders has in all cases been used as the varying pressure controlling the valves. It is apparent, however, that the pressure behind the steam-pistons varies in the same manner as the pressure in front of the corresponding plungers. The pressure within the steam-cylinders, therefore, may be used in place of that within the water-cylinders with substantially the same results, as described. Such a modification is shown in Fig. 16, in which the construction is identical with that shown in Figs. 6 to 8, except that the pipes transmitting the varying pressure connect not to the water-cylinders at opposite ends of the plungers, but to the steam-cylinders at opposite ends of the steam-pistons. As the pressure behind the piston corresponds to that in front of the plunger, and vice versa, it is evident that, as in the construction shown in Figs. 13 and 14, a complete reversal of the pipes forming the connections between the opposite sides of the pump is necessary. The pipes 23 24, therefore, from the opposite ends of the steam-cylinders on the leading side pass to the valves at the corresponding ends of the plunger on the following side, while the pipes 19 20 from the following side are crossed and pass to the valves at the opposite ends of the plunger on the leading side. The pressure by which the valves are operated, however, corresponds in the two constructions, the reversal of the arrangement of the pipes only offsetting the reversal in the ends of the cylinders at which the operating pressure is found and the pressure behind the piston being only substituted for its equivalent, the pressure in front of the plunger.

It is evident that the pressure from the steam-cylinders may be substituted also for the pressure from the water-cylinders in the other constructions shown, whether the valves be operated by the varying pressure or by an outside pressure controlled by the varying pressure. Such constructions involve only corresponding modifications in the arrangements of the pipes transmitting the pressure and require no special description or illustration.

By the use of an auxiliary valve placed between the cylinder and the main, either between the plunger and the valves or between the valves and main, I do not in any respect alter the function of the valves. In case the auxiliary valve on the force side becomes obstructed at any time or held from its seat by any foreign matter passing through the pump the force-valves are still free to

act and prevent the pressure of the main from entering the water-cylinder during the suction-stroke, which would place both sides of the plunger in equilibrium to the great danger and probable damage of the pump. Arranged as shown and described the only result would be a noisy action of the pump until the auxiliary valve has been relieved and the regular action of the pump resumed. Further, in case of any accident or breakage, either to the auxiliary force-valve or the controlling connections, the valve may be removed for repair, during which interval the pump may be operated as in the common construction at a somewhat slower piston speed than is customary with the auxiliary valve in commission.

It is apparent that many other changes might be made in the organization shown without departing from my invention, and I do not intend to limit myself to any of the special constructions shown and described, as the invention has been shown embodied in these pumps only for the purpose of illustration and as well adapted to exhibit my invention in those forms which I consider preferable. The broad invention, however, is of general application to pumps independently of the special type of pump to which it is applied.

By the term "duplex pump," used in some of the claims, I mean and intend to cover a pump having a plurality of plungers acting with each other, but with their strokes timed differently—as, for instance, in the Worthington duplex pumping-engine, shown herein, and other well-known pumping-engines—and I do not mean to include therein an engine having only a single plunger or a plurality of plungers connected so as to move in unison, as in the case of a single double-acting pump.

I do not claim herein, broadly, a valve located between the plunger and main and positively closed against the pumping pressure, nor, broadly, an auxiliary valve thus located and closed, as these subject-matters are claimed in Patent No. 526,429, granted to me September 25, 1894. The method and construction in which the valve is closed by a constant pressure controlled by a varying fluid-pressure forms the subject-matter of another application, Serial No. 447,189, filed September 28, 1892.

What I claim is—

1. The method of closing a pump-valve against the pumping pressure, which consists in applying to the valve against the pumping pressure a fluid-pressure in excess of the pumping pressure, substantially as described.

2. The method of controlling a pump-valve, which consists in applying a fluid-pressure to the valve against the pumping pressure and varying said pressure during the stroke of the pump-plunger from a pressure below to a pressure in excess of the pumping pressure, substantially as described.

3. The combination with a pump-valve, of a column of fluid having a pressure in excess of the pumping pressure applied to close said valve against the pumping pressure, substantially as described.

4. The combination with a pump-valve, of a column of fluid having a pressure varying during the stroke of the pump-plunger applied to close said valve against the pumping pressure, substantially as described.

5. The combination with a pump-valve, of a column of fluid having a pressure in excess of the pumping pressure applied to said valve against the pumping pressure, and means for controlling said pressure in accordance with the action of the plunger, whereby the valve is closed against the pumping pressure as the plunger reaches the end of its stroke, substantially as described.

6. In a pump, the combination with a valve between the plunger and force-main, of a column of fluid having a pressure in excess of the pumping pressure applied to close said valve against the pumping pressure, substantially as described.

7. In a pump, the combination with a valve between the plunger and force-main, of a column of fluid having a pressure varying during the stroke of the pump-plunger applied to close said valve against the pumping pressure, substantially as described.

8. In a pump, the combination with a valve between the plunger and force-main, of a column of fluid having a pressure in excess of the pumping pressure applied to said valve against the pumping pressure, and means for controlling said pressure in accordance with the action of the plunger, whereby the valve is closed against the pumping pressure as the plunger reaches the end of its stroke, substantially as described.

9. In a duplex pump, the combination with a pump-valve, of a column of fluid applied to said valve against the pumping pressure, and means for controlling said pressure from the opposite side of the pump, substantially as described.

10. In a duplex pump, the combination with a pump-valve, of a column of fluid from the opposite side of the pump having a pressure varying during the stroke of the pump-plunger on the valve side of the pump applied to said valve, substantially as described.

11. In a duplex pump, the combination with a valve between the plunger and force-main, of a column of fluid applied to said valve against the pumping pressure, and means for controlling said pressure from the opposite side of the pump, whereby the valve is closed in front of the plunger as the latter reaches the end of its stroke, substantially as described.

12. In a duplex pump, the combination with a valve between the plunger and force-main, of a column of fluid from the opposite side of the pump having a pressure in excess of the pumping pressure applied to said valve against the pumping pressure as the plunger

reaches the end of its stroke, substantially as described.

13. In a duplex pump, the combination with the pump-valves, of columns of fluid from each side of the pump having a pressure varying during the stroke of the pump-plunger on the opposite side applied to the valves on the opposite side of the pump, substantially as described.

14. In a duplex pump, the combination with the pump-valves, of motor-cylinders controlling said valves, and connections between said motor-cylinders and a source of fluid-pressure on the opposite side of the pump varying during the stroke of the pump-plunger, whereby a varying fluid-pressure on one side of the pump is transmitted to the motor-cylinders and controls the valves on the opposite side of the pump, substantially as described.

15. In a duplex pump, the combination with the pump-valves, of motor-cylinders controlling said valves, and connections between said motor-cylinders and a source of fluid-pressure on the opposite side of the pump in excess of the pumping pressure, whereby a fluid-pressure on one side of the pump is transmitted to the motor-cylinders and closes the valves on the opposite side of the pump as the plunger reaches the end of the stroke, substantially as described.

16. In a duplex pump, the combination with the pump-valves, of motor-cylinders controlling said valves, connections between said motor-cylinders and a source of varying fluid-pressure on the opposite side of the pump whereby a varying fluid-pressure on each side of the pump is transmitted to the motor-cylinders and controls the valves on the opposite side of the pump, and means for adjusting the time of action of said pressure on said valves, substantially as described.

17. In a duplex pump, the combination with valves located between the plungers and force-main, of motor-cylinders controlling said valves, and connections between said motor-cylinders and a source of varying fluid-pressure on the opposite side of the pump, whereby a varying fluid-pressure on each side of the pump is transmitted to the motor-cylinders and controls the closing of the valves in front of the plunger on the opposite side of the pump as the plunger reaches the end of its stroke, substantially as described.

18. The combination with the pump-cylinders, plungers and pump-valves of a duplex pump, of motor-cylinders controlling said valves, and connections between said motor-cylinders and the pump-cylinder on the opposite side of the pump, whereby the pressure in the pump-cylinder on each side of the pump is transmitted to the motor-cylinders and controls the valves on the opposite sides of the pump, substantially as described.

19. The combination with the pump-cylinders and plungers of a duplex pump, of valves located between the plungers and force-main, motor-cylinders controlling said valves, and connections between said motor-cylinders and the pump-cylinder on the opposite side of the pump, whereby the pressure in the pump-cylinder on each side of the pump is transmitted to the motor-cylinders and controls the valves in front of the plunger on the opposite side of the pump, substantially as described.

20. The combination with the pump-cylinders, plungers, and suction-valves of a duplex pump, of motor-cylinders controlling said suction-valves, and connections between said motor-cylinders and the pump-cylinder on the opposite side of the pump whereby the pressure in the pump-cylinder on each side of the pump is transmitted to the motor-cylinders and controls the suction-valves on the opposite side of the pump, substantially as described.

21. The combination with the pump-cylinders, plungers, and force and suction valves of a duplex pump, of motor-cylinders controlling said force and suction valves, and connections between said motor-cylinders and the pump-cylinder on the opposite side of the pump whereby the pressure in front of the plunger on each side of the pump is transmitted to the motor-cylinders and closes the force and suction valves respectively in front of and behind the plunger on the opposite side of the pump as the plunger reaches the end of its stroke, substantially as described.

22. In a duplex pump, the combination of valves controlling communication between each end of the plungers and the force and suction mains, a motor-cylinder on each side of the pump controlling said valves, and connections between said motor-cylinders and a source of varying fluid-pressure on the opposite side of the pump, whereby a varying pressure on each side of the pump is transmitted to a motor-cylinder and controls the valves at both ends of the plunger at the opposite side of the pump, substantially as described.

23. In a direct-acting pump, the combination with a motor-piston and its plunger, of a valve between the plunger and force-main, and a column of fluid having a pressure in excess of the pumping pressure applied to close said valve against the pumping pressure as the plunger reaches the end of its stroke, substantially as described.

24. The combination with the motor-pistons and the plungers of a direct-acting duplex pump, of valves between the plungers and force-main, columns of fluid having a pressure in excess of the pumping pressure applied to close said valves against the pumping pressure, and means for controlling said fluid-pressure from the opposite side of the pump, substantially as described.

25. The combination with the motor-pistons, and the pump-cylinders and plungers of a direct-acting duplex pump, of valves between the plungers and force-main, and connections between said valves and the pump-cylinders on the opposite sides of the pump, whereby the pressure in the pump-cylinder

on each side of the pump is transmitted to and controls the valves on the opposite side of the pump, substantially as described.

26. The combination with the motor-pistons, and the pump-cylinders and plungers of a direct-acting duplex pump, of valves between the plungers and force-main, and connections between said valves and the pump-cylinder on the opposite sides of the pump constructed to apply pressure to the valve against the pumping pressure, whereby the pressure in front of the plunger on each side of the pump is transmitted to the valve on the opposite side of the pump against the pumping pressure and is applied to close the valve against the pumping pressure, as the plunger reaches the end of its stroke, substantially as described.

27. In a direct-acting pump, the combination with a motor-cylinder, its main and cut-off valves and the piston and plunger, of a valve between the plunger and force-main, and a column of fluid having a pressure in excess of the pumping pressure applied to close said valve against the pumping pressure as the plunger reaches the end of its stroke, substantially as described.

28. The combination with the motor-cylinders, their main and cut-off valves, and the pistons and plungers of a direct-acting duplex pump, of valves between the plungers and force-main, columns of fluid having a pressure in excess of the pumping pressure applied to close said valves against the pumping pressure, and means for controlling said pressure from the opposite side of the pump, substantially as described.

29. The combination with the motor-cylinders, their main and cut-off valves, and the pistons and plungers of a direct-acting duplex pump, of valves between the plungers and force-main, and connections between said valves and the pump-cylinder on the opposite side of the pump, whereby the pressure in the pump-cylinder on each side of the pump is transmitted to the valves on the opposite side of the pump and applied to close said valves against the pumping pressure as the plunger reaches the end of its stroke, substantially as described.

30. The combination with a pump-valve, of a piston controlling said valve, and a column of fluid having a pressure in excess of the pumping pressure applied to said piston to close the valve against the pumping pressure, substantially as described.

31. The combination with a pump-valve, of a piston controlling said valve, and a column of fluid varying in pressure during the stroke of the pump-plunger applied to said piston to secure the closing of the valve against the pumping pressure as the plunger reaches the end of its stroke, substantially as described.

32. The combination with a pump-valve opened by the pumping current of a piston controlling said valve, a column of fluid having a pressure in excess of the pumping pressure applied to said piston to close the valve against the pumping pressure, and means for releasing said pressure, substantially as described.

33. In a duplex pump, the combination with a pump-valve, of a piston controlling said valve, and connections between said piston and a source of fluid-pressure on the opposite side of the pump having a pressure varying during the stroke of the pump-plunger on the valve side, substantially as described.

34. The combination with a pump-valve, of a piston controlling said valve, a source of fluid-pressure in the pump varying during the stroke of the pump-plunger, and connections between said piston and source of pressure for applying said pressure to said piston to secure the closing of the pump-valve against the pumping pressure as the plunger reaches the end of its stroke, substantially as described.

35. The combination with a pump-valve, of a piston controlling said valve, a source of varying fluid-pressure, connections between said piston and source of pressure, and adjusting devices between the source of pressure and the valve for varying the time of action of the valve relatively to the variations in the pressure-supply, to secure the closing of the pump-valve against the pumping pressure, as the plunger reaches the end of its stroke, substantially as described.

36. In a duplex pump, the combination with a pump-valve, of a piston controlling said valve, connections between said piston and a source of varying fluid-pressure on the opposite side of the pump, and adjusting devices between the source of pressure and the valve for varying the time of action of the valve relatively to the variations in the pressure-supply, substantially as described.

In testimony whereof I have hereunto set my hand in the presence of two subscribing witnesses.

CHARLES C. WORTHINGTON.

Witnesses:
LOUIS R. ALBERGER,
H. W. TILLINGHAST.