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C. C. WORTHINGTON.

VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,534. Patented June 15, 1897.

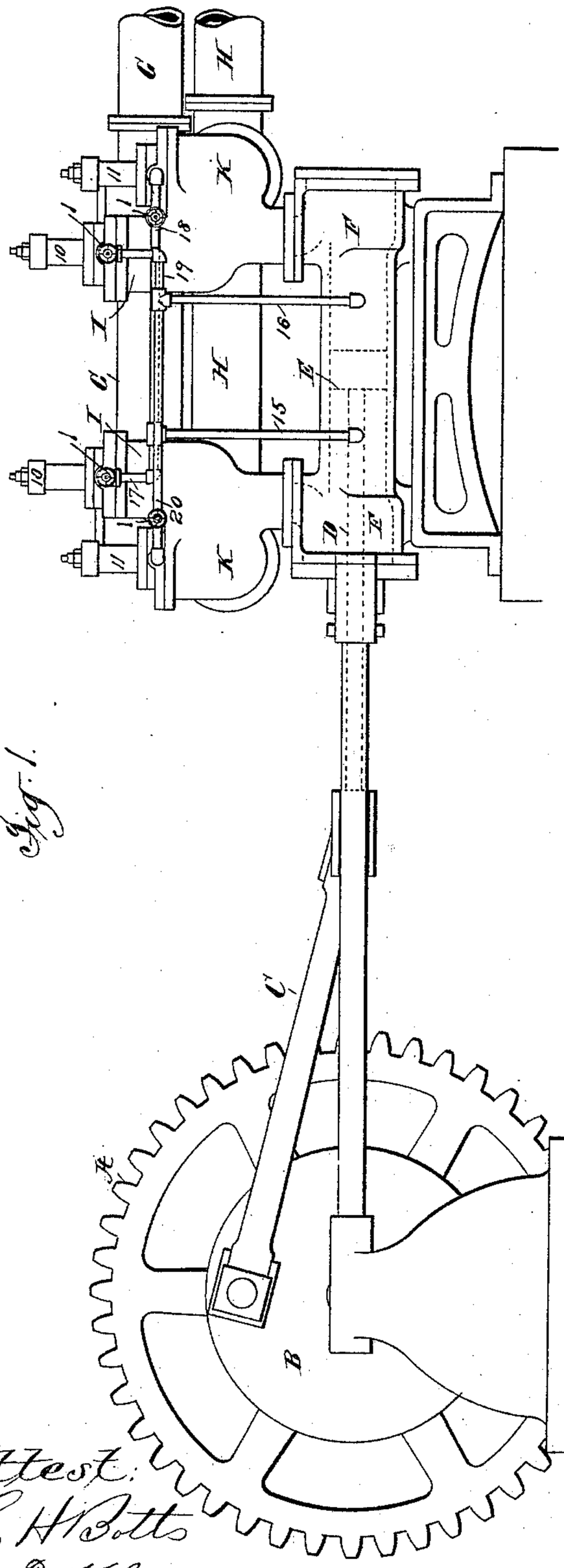

Fig. 1.

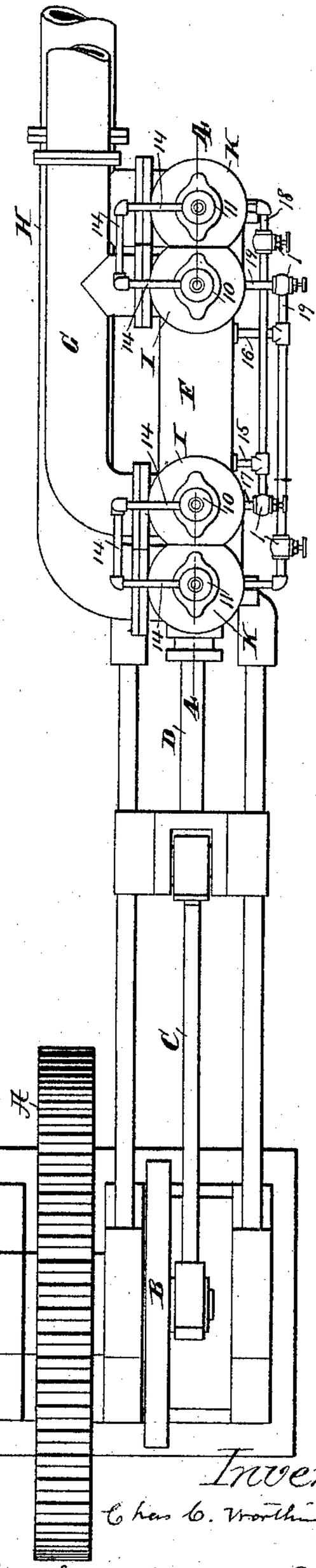

Fig. 2.

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VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,534. Patented June 15, 1897.

Fig. 3.

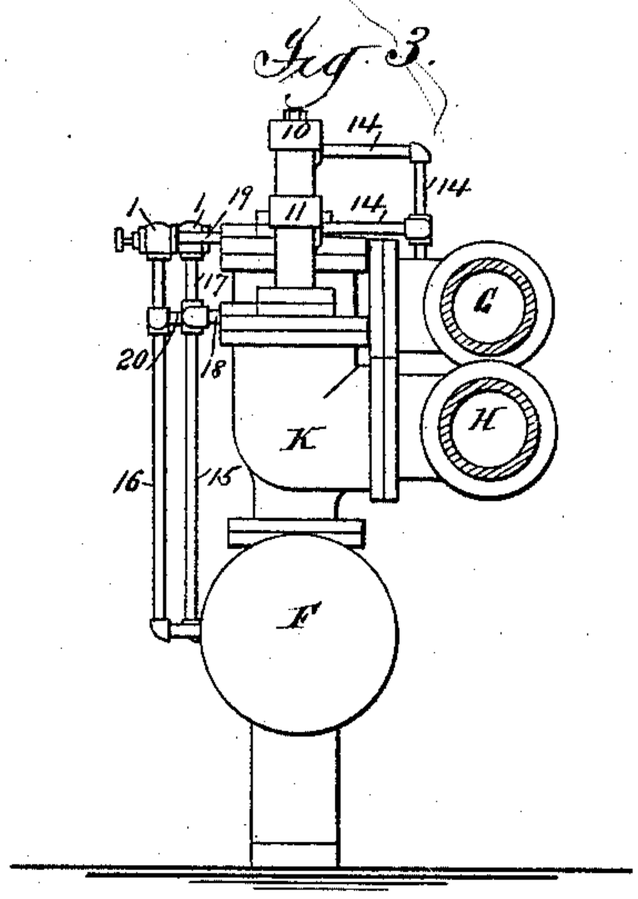
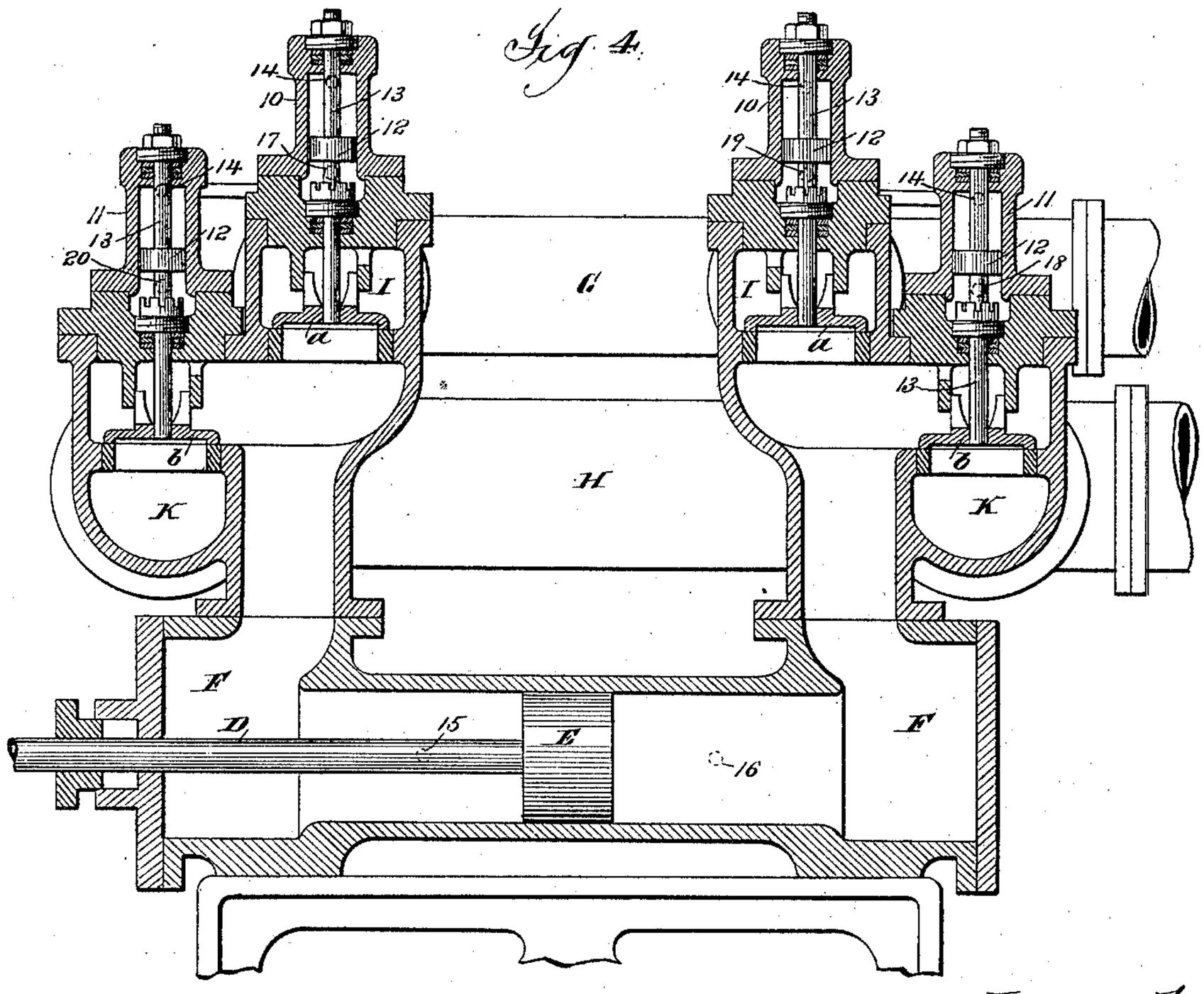


Fig. 4.



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VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,534. Patented June 15, 1897.

Fig. 5.

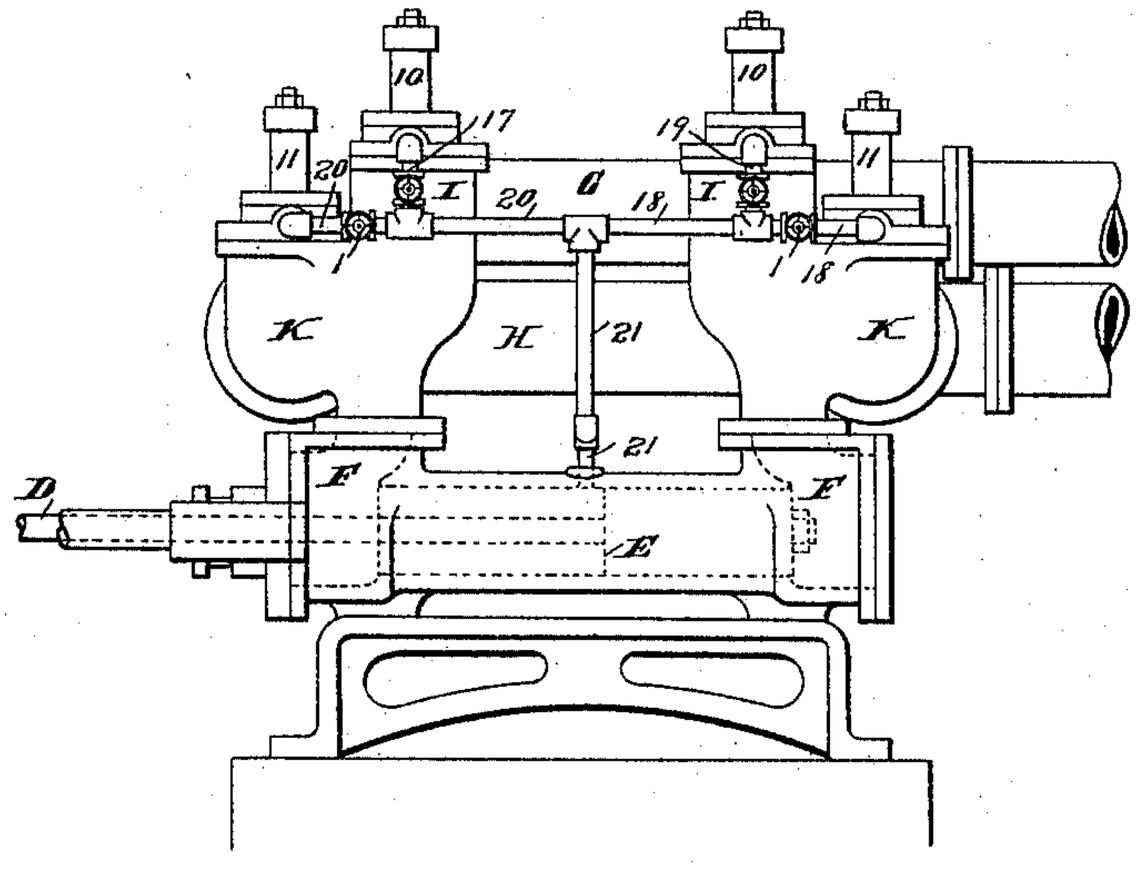
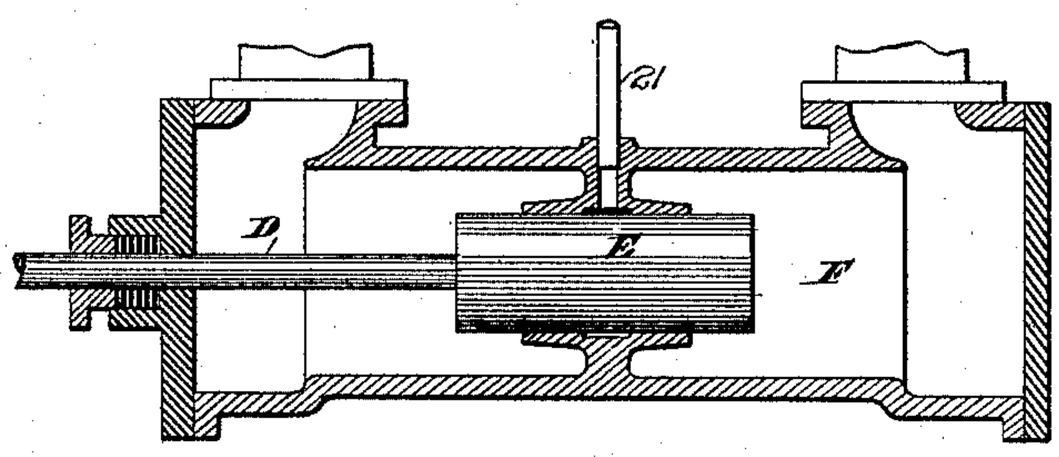


Fig. 6.



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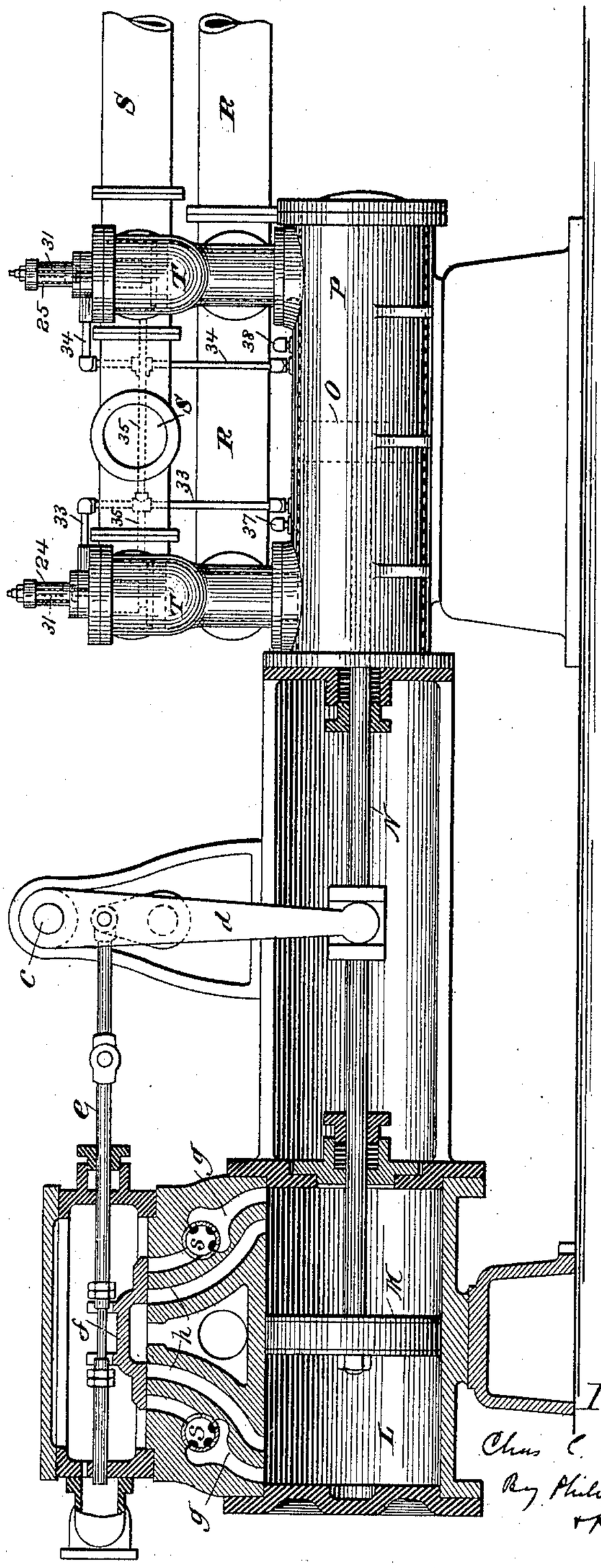
VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,534. Patented June 15, 1897.

Fig. 7.



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VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,534. Patented June 15, 1897.

Fig 8.

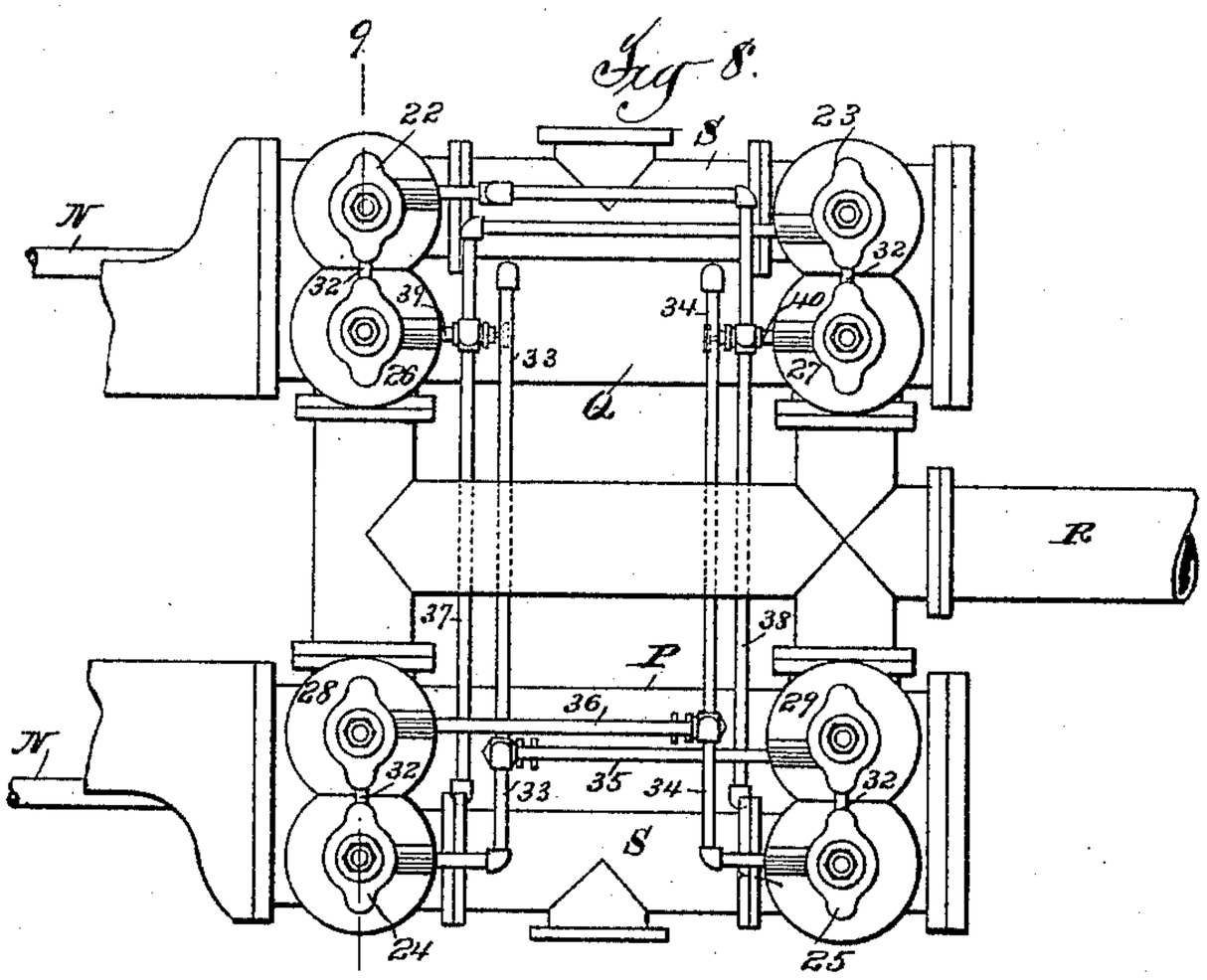
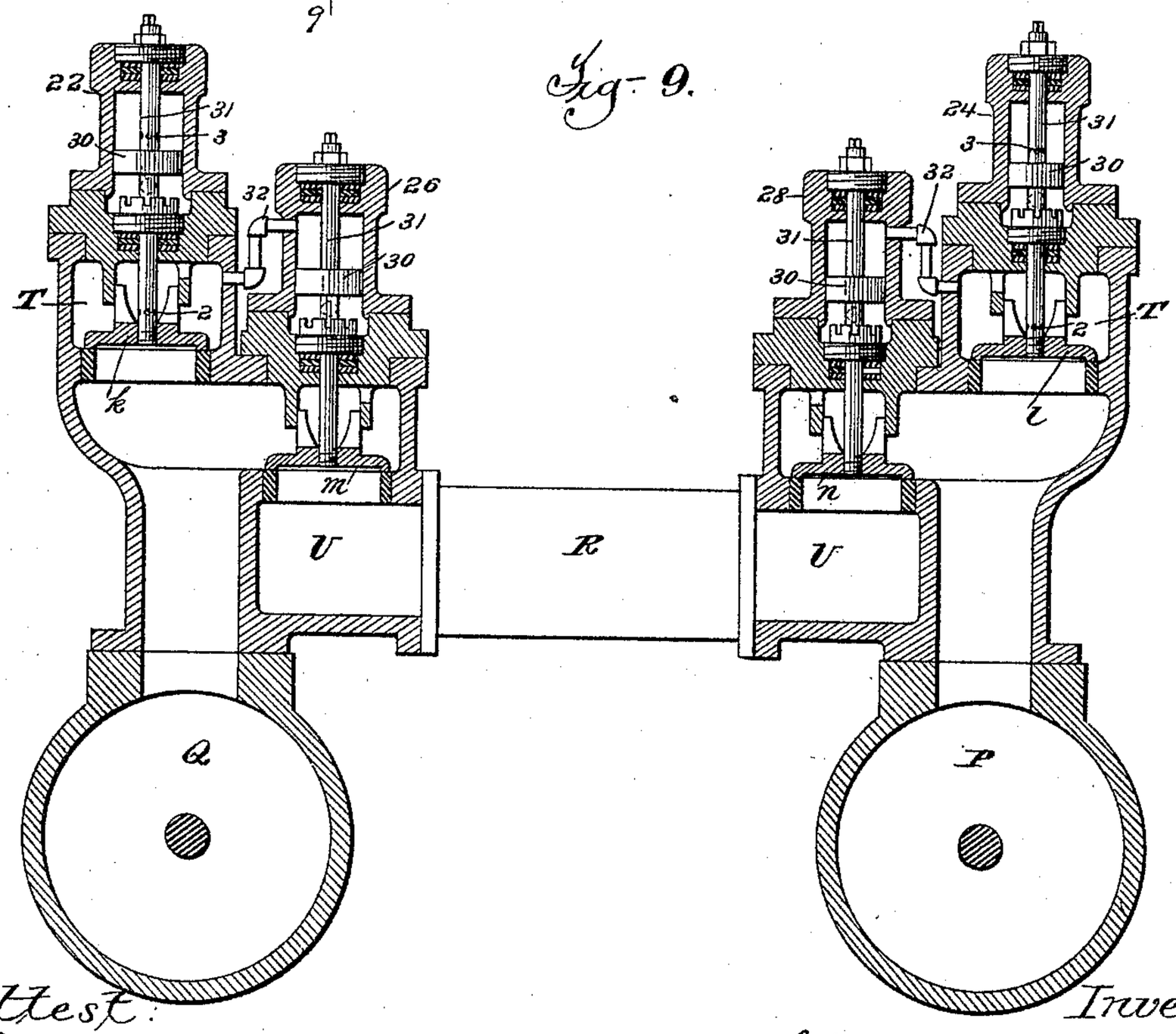


Fig- 9.



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VALVE MOVEMENT FOR PUMPS AND METHOD OF CLOSING PUMP VALVES.

No. 584,534. Patented June 15, 1897.

Fig. 11.

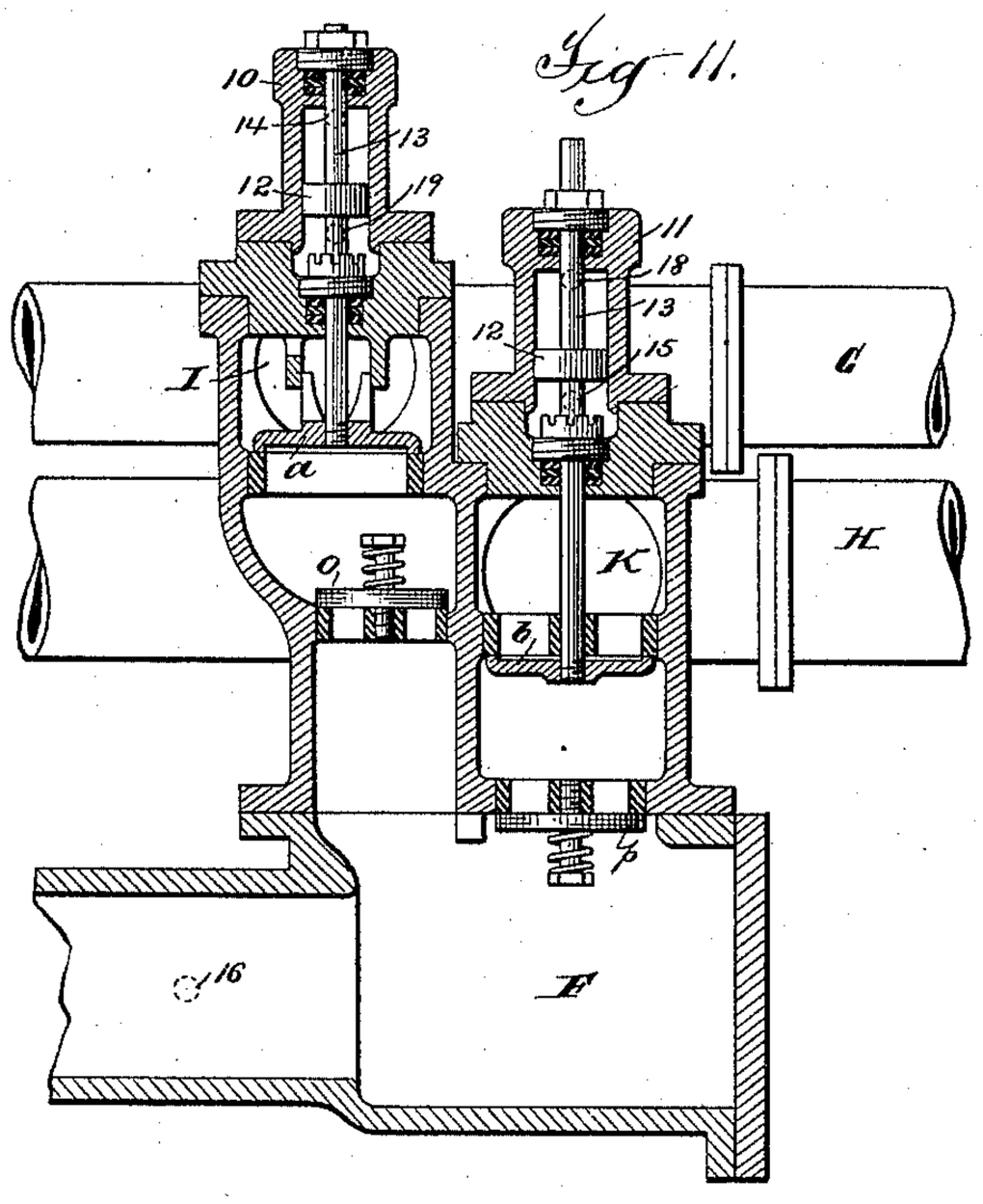
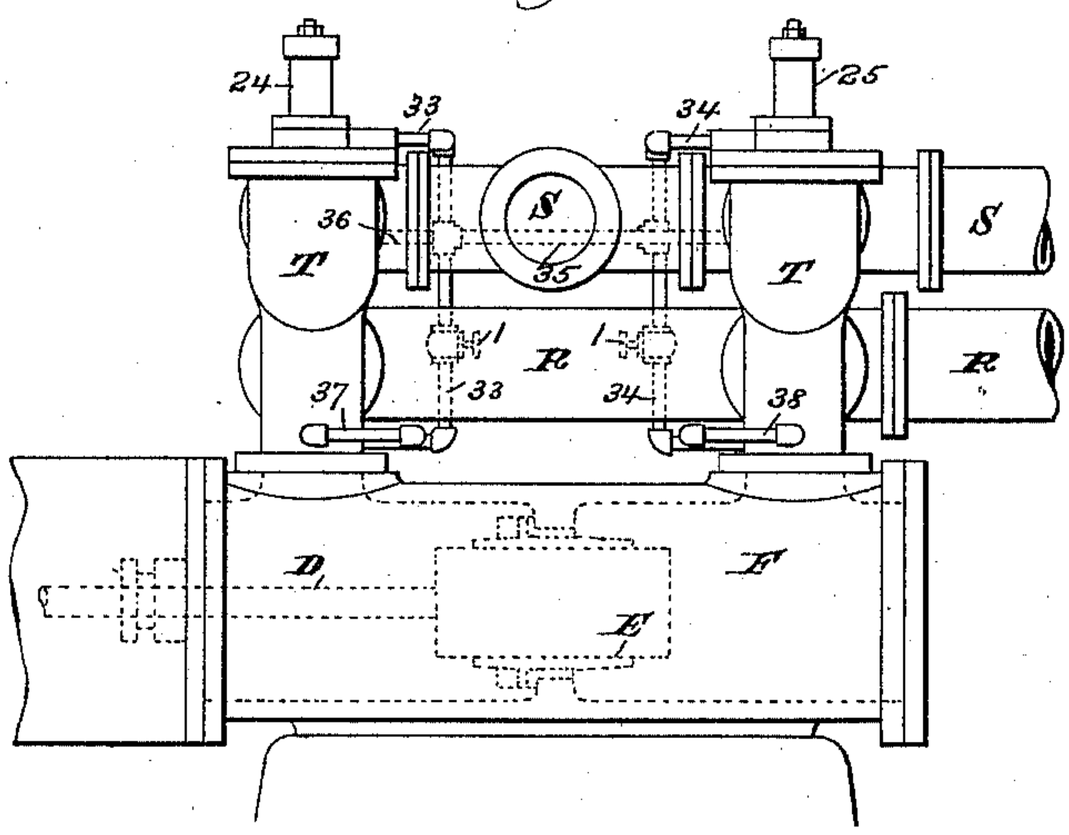


Fig. 10.



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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. 584,534, dated June 15, 1897.

Application filed September 28, 1892. Serial No. 447,189. (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 method of closing pump-valves, and especially to secure a more uniform action of steam and power pumps and to increase the speed at which they can be operated successfully.

One of the specific objects of my invention is to provide a method of and means for positively controlling the pump-valves, and especially to provide a method and means by which the force-valves or auxiliary valves between the plunger and force-main 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 plunger. I attain this object in accordance with the present invention by applying to the valves against the pumping pressure a constant pressure in excess of the pumping pressure and transmitting to the valves, so as to oppose the constant pressure, a fluid-pressure varying during the stroke of the pump-plunger, so that the valve or valves are closed by the constant pressure when the varying pressure is relieved or reduced to the required point, the pressure in the force-main being thereby cut off from the plunger of the pump at the end of the stroke and the plunger stopped wholly or partially by the pressure of the water in 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. I prefer to apply this closing pressure directly to the force-valves, so as to insure their gradual and positive closing in front of the plunger as the latter reaches the end of its stroke, and I prefer to apply it also to the suction-valves to insure their closing behind the plunger at or about the same time; but the pressure may be applied only to the force-valves or to an auxiliary valve or valves controlling communication between the water-cylinder and the force-main, so as to secure the results desired, and similar auxiliary valves may be used also with the suction-valves.

The constant pressure may be fluid-pressure from any suitable source, or the pressure of a spring or weight, and the varying pressure may be supplied from any suitable source in single or duplex pumps, but I preferably use the force-main pressure as the constant pressure and use as the varying pressure the pressure in the pump-cylinder, this varying pressure being applied alternately from in front of and behind the plunger and in duplex pumps from the pump-cylinders on the opposite side of the engine.

My improved valve-movement is applicable to all forms of pumps, whether operated by steam or power, but it is of special application to direct-acting steam-pumps or pumping-engines in which the improved valve-movement coöperates with other features of the construction to secure certain special results not obtained in other pumps.

In this class of pumps, as is well known, the motor-pistons are connected to the rods which carry the pump-plungers in such a 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, and it is necessary that some means should be provided by which the piston and plunger are gradually arrested at the end of the stroke in either direction. For this purpose double steam-ports have generally been provided, so that the piston is cushioned upon a small portion of the exhaust-steam remaining in the cylinder. While this method is satisfactory at the speeds at which pumps of this class are usually run, it is found that at higher speeds the momentum of the moving parts is sufficient to compress the steam-cushion to such a pressure that by this pressure, together with the pressure in the force-main acting upon the plunger at the end of the stroke, a rebound or recoil of the moving parts of the pump is caused. Coincident with this recoil the wa-

ter in the force-chamber flows rapidly through the force-valves into the pump-chamber, producing a current which tends to slam the force-valves. The suction-valves at the opposite end of the plunger also are slammed by the pressure produced by the recoil movement of the plunger.

It has been customary with steam-cushions to provide some means by which the amount of exhaust-steam retained in the cylinder is varied in accordance with the speed of the pump, so that the piston is properly cushioned at different speeds without the employment of a permanently large cushion.

With my improved valve-movement, in which the valves are positively closed so as to cut off the pressure of the force-main in front of the plunger as the piston approaches the end of its stroke, the piston and plunger are cushioned by the water retained within the pump-cylinder and may be stopped thereby wholly or partially, thus doing away with the steam-cushion, or, if it be retained, avoiding the necessity of adjusting the cushion in accordance with the speed of the pump and rendering it possible to employ only a moderate steam-cushion at all speeds. While the piston and plunger may be stopped entirely by applying this increased pressure upon the plunger at the end of the stroke, 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.

In attaining the highest speeds with steam-pumps provided with positive water-valves acting as described it may be found in some cases that the available constant pressure is not sufficient to close the valves, because as they begin to close the speed of the plunger is lessened, and there immediately follows a packing of the steam behind the steam-piston, causing an increase of the steam-pressure. When a very high speed is desired, therefore, it is desirable to provide the steam cylinder or cylinders with cut-off valves which shall operate to cut off the admission of steam to the cylinder at the latter end of the stroke, so that the water-valves are positively closed and the plunger and piston stopped without the packing of the steam in the steam-cylinder.

With my improved valve-movement and the high speed rendered possible thereby it will be found that the steam may be cut off earlier in the stroke than in the ordinary direct-acting pumps now in use and a higher economy of steam obtained thereby, as the momentum acquired by the piston and plunger at the high piston speed 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.

For a full understanding of my invention a detailed description of single and duplex pumps embodying my improvements in their preferred form will now be given, reference being had to the accompanying drawings, forming a part of this specification, and the method and features of construction forming the invention specifically pointed out in the claims.

In the drawings, Figure 1 is a side elevation of a simple crank-power pump provided with my improved valve-movement. Fig. 2 is a plan view of the same. Fig. 3 is a rear elevation. Fig. 4 is a section on the line 4 4 of Fig. 2 on an enlarged scale. Fig. 5 is a side elevation of water end similar to Fig. 1, showing a single pipe for transmitting the varying pressure. Fig. 6 shows a modification of the same. Fig. 7 is a sectional side elevation of a duplex direct-acting steam-pump, the section being taken through the steam-cylinder on the leading side. Fig. 8 is a plan view of the water end of the same. Fig. 9 is a section on the line 9 9 of Fig. 8 on an enlarged scale. Fig. 10 shows a modification in the connections with the pump-cylinders. Fig. 11 shows a modification employing auxiliary force and suction valves.

Referring now particularly to Figs. 1 to 4, the engine shown is as to its general construction a common form of crank-engine, A being the gear; B, the crank-disk; C, the connecting-rod; D, the plunger-rod; E, the plunger; F, the water-cylinder; G H, the force and suction mains, and I K the force and suction chambers, communication between the pump-cylinder and these chambers being controlled by force-valves *a* and suction-valves *b* at the opposite ends of the cylinder. These parts form an ordinary double-acting crank-pump.

Referring now to the parts embodying my invention, a small motor-cylinder 10 11 is mounted above each of the force and suction valves, respectively, the valves being actuated by motor-pistons 12, moving in said cylinders and carried by the valve-stems 13. The motor-cylinders 10 11 are entered above the pistons 12 by pipes 14, through which a constant pressure is transmitted to the motor-pistons, tending to close the valves. These pipes 14 are shown as connected with the force-main G, but may be connected to any other suitable source of pressure either within or without the pump.

On the opposite side of the pistons 12 from the pipes 14, transmitting the constant pressure, the motor-cylinders 10 11 are connected with the water-cylinder in the following manner: The pipes 15 16 communicate with the water-cylinder at opposite ends and have branches 17, 18, 19, and 20 entering the motor-cylinders 10 11, these pipes connecting each end of the water-cylinder with the motor-cylinder controlling the force-valve at the same end of the pump and with the motor-cylinder controlling the suction-valve at the opposite end. The pipes 16 15 enter the pump-cylinder at points within the path of the pump-plunger, and the pump-plunger as it approaches the end of its stroke in either

direction will pass the port of one of the pipes and leave it uncovered behind it, so that the suction-pressure in the cylinder is transmitted through the same to the motor-cylinders above the force and suction valves controlled thereby.

For the purpose of adjusting the time at which the pressure from the pump-cylinder acts upon the piston in the motor-cylinder, each of the pipes through which the pressure is transmitted is provided with a throttle-valve 1. In the construction shown this enables the times at which the pressure acts on the force and suction valves to be adjusted relatively to each other, which is especially desirable when a single connection is made with the pump-cylinder for a force and suction valve, as in the construction shown. It will be understood, however, that there may be two openings into the pump-cylinder for each motor-cylinder, so that the connections for the force and suction valves are independent of each other. The throttle-valves or other suitable adjusting means will still be used, however, to secure the proper timing of the action of the motor-cylinders upon the valves.

The operation of this construction is as follows: As the plunger E moves to the right from the position shown in Figs. 1 to 4 the pressure in front of the plunger is transmitted through pipes 16 and branches 19 20 to the motor-cylinders 10 11 above the force and suction valves, respectively in front of and behind the plunger. This pressure counterbalances the constant pressure admitted to the other side of the pistons 12 through pipes 14, and these valves are opened by the water-current. This continues until the plunger E has passed the pipe 16 and opened the latter behind it, when the pressure in the pipe 16 and below the pistons 12 in cylinders 10 11 is reduced to that of the suction and the valves are closed by the excess of the constant pressure above the pistons, it being understood that the pressure upon the opposite sides of the valves *a b*, independently of the pistons, is the same, so that a slight excess of pressure suffices to close them. As the plunger is reversed and moves from right to left the pressure in front of the plunger is again transmitted through pipe 16 and branches 19 20, equalizing the pressure in the motor-cylinders above the pistons, but the force-valve is closed behind the plunger by the force-pressure and the suction-valve in front of the plunger by the pressure in the pump-cylinder produced by the plunger. As the plunger is reversed, however, the pressure in front of the plunger is transmitted also through the pipe 15 and branches 17 18 to the motor-cylinders 10 11 above the force and suction valves, respectively in front of and behind the plunger, and, the pressure on the opposite sides of the motor-pistons 12 being equal, the valves are opened by the water-current. This operation is repeated at each stroke of the plunger.

The time of closing of the valves may be adjusted as desired by varying the position of the pipes 15 16 relatively to the plunger E, so that any desired operation of the valves may be secured. The time and rapidity of closing of the valves may also be adjusted conveniently by means of the throttle-valves 1, the passage of the water through the pipes being controlled thereby as desired.

While the pipes have been shown transmitting the constant pressure from the force-main, and I prefer that constant pressure should be applied thus or from an outside source of pressure, it will be understood that the pistons may be open above to the air and air-pressure be employed as the constant pressure, if desired, this necessitating only an increase in the size of the motor-pistons depending upon the work to be performed. It will be understood also that it is not necessary that the constant pressure should be that of a fluid, but that a spring or weight may be substituted therefor, if desired.

Although the construction shown will probably be found preferable, as it reduces the size of the plunger, it is not necessary to employ two pipes communicating with the water-cylinder.

In Fig. 5 I have shown a construction in which a single pipe 21 communicates with the water-cylinder midway of its length, the branches 17 18 and 19 20 all communicating with this pipe. In this construction the length of the plunger E is nearly the length of the stroke, as shown in Fig. 5.

The operation of this construction is as follows: As the piston E reaches the end of its stroke the port of pipe 21 is uncovered behind it, and the pressure below all the motor-pistons 12 is the suction-pressure, and the valves are all closed by the constant pressure. As the plunger commences its return stroke the pressure in front of the plunger is transmitted through the pipe 21 and its branches to all the cylinders 10 11 and the constant pressure is counterbalanced therein. The force and suction valves, respectively in front of and behind the plunger, are then opened by the water-current, while the force and suction valves, respectively behind and in front of the plunger, are closed by the pressure of the force-main and in the pump-cylinder The result, therefore, is substantially the same as with the construction previously described.

With this construction of a single pipe communicating with the water-cylinder my improvements may be applied to the common plunger and diaphragm or ring construction of pumps, the pipe 21 being placed within the ring or diaphragm, as shown in Fig. 6, and communicating with the pump-cylinder through a circular port or series of ports, as preferred.

Referring now to Figs. 7, 8, and 9, the duplex direct-acting steam-pump shown therein

as embodying my improvements will be described. The pump is, as to its general construction, of a common form, consisting of two steam-cylinders L, provided with pistons M, connected by piston-rods N to the plungers O, moving in the water-cylinders P Q on respectively the leading and following sides of the pump.

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" refer, respectively, to the sides of the pump, the pistons of which lead or follow when both are moving in the same direction.

The steam-cylinders are provided with the usual valve-gear, consisting of rock-shafts *c*, levers *d*, and valve-rods *e*, by which the main valves *f* on each side of the pump are operated from the piston-rods on 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 M near the end of their strokes in either direction they cover the exhaust-port *h* and confine a small amount of exhaust-steam in front of them in the cylinder, by which the pistons are cushioned and arrested. This is a common method of cushioning, but it will be understood that any other form of apparatus may be used for this purpose, and, 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. The construction of rotary cut-off valves is that shown in my prior patent, No. 292,525, and the operating connections are the same and need not be described herein. It will be understood, however, that any other form of cut-off valves and operating connections may be substituted, if desired.

The water end of the pump consists of the water-cylinders P Q on the leading and following sides, respectively, the force and suction mains R S and their chambers T U, communication between the pump-cylinders and these chambers being controlled by force-valves *k l* and suction-valves *m n* on respectively the leading and following sides of the pump.

Referring now to the parts in which my invention is embodied, above each of the force and suction valves is mounted a motor-cylinder, the motor-cylinders above the force-valves on the leading side of the pump being numbered 22 23 and on the following side of the engine 24 25, and the motor-cylinders above the suction-valves on the leading side being numbered 26 27 and those on the following side 28 29, at the opposite ends of the water-cylinders, respectively. Each of the valves is controlled by a piston 30, moving in the corresponding motor-cylinder, these pistons being carried by the valve-stems 31.

The constant pressure is transmitted from the force-main to the motor-cylinders in the following manner: The valve-stem 31 of each of the force-valves is hollow and, as shown in Fig. 9, is provided at its lower end with a series of perforations 2, opening into the force-chamber T, and at its upper end above the piston 30 with a series of perforations 3, opening into the motor-cylinder. The constant pressure is transmitted from the force-chamber T to the cylinders above the suction-valves by pipes 32, as shown in the same figure.

The motor-cylinders below the pistons 30 are connected with the water-cylinders, so that the varying pressure therein is communicated to the motor-cylinders in the following manner: Pipes 33 34 extend from the opposite ends of the water-cylinder on the leading side of the pump to the opposite side and communicate, respectively, with the motor-cylinders 24 25 above the force-valves on the following side, and by branches 35 36 also communicate, respectively, with the motor-cylinders 29 28 upon the following side, so that the pressure in the water-cylinder upon the leading side of the pump is transmitted to the force and suction valves upon the following side of the pump, but the connections to the suction-valves are reversed, so that the pipes 33 34 control the force-valves at the corresponding ends of the water-cylinder on the following side, but the suction-valves at the diagonally opposite ends of the cylinder. Pipes 37 38 connect the opposite ends of the water-cylinder on the following side of the pump with the motor-cylinders 23 22 above the force-valves at the diagonally opposite ends of the water-cylinder on the leading side of the pump, and by branches 39 40 also communicate, respectively, with the motor-cylinders 26 27 above the suction-valves at corresponding ends of the water-cylinder on the leading side, so that pipes 37 38 from the following side of the pump control the force-valves at the diagonally opposite ends of the water-cylinder on the leading side and the suction-valves at the same end of the water-cylinder.

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

In describing the operation it will be assumed that the piston M of the leading side of the pump is started from left to right, the piston on the following side being 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

O on that side will be forced past the valve *k* in front of the plunger, raising the valve in the usual manner, and at the same time the water will be drawn in, raising the suction-valve *m* behind the plunger. As the piston and plunger approach the end of their stroke the cut-off valve *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 and plunger will be arrested. When the piston 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 on the following side of the pump will have completed its stroke in the opposite direction and will start in the same direction as that in which the piston on the leading side is then 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 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 the pressure from the force-main is transmitted through the hollow valve-stems 31 to the motor-cylinders above the pistons 30, controlling the force-valves, so that the pistons are constantly subjected to the pressure of the force-main, tending to move them in a direction to close the force-valves. The force-pressure is transmitted also through the pipes 32 from the force-chambers T to the motor-cylinders mounted above the suction-valves, so as to tend to close the suction-valves in the same manner as the force-valves.

As already explained, the pipes transmitting the varying pressure from the pump-cylinder on one side of the engine to the motor-cylinders upon the opposite side enter the motor-cylinders below the pistons, so that their pressure is opposed to the pressure from the force-main above the pistons, this varying pressure being equal to the pressure from the force-main when transmitted from in front of the plunger, but reduced to the suction-pressure when the plunger has passed the ports by which the pipes transmitting the varying pressure communicate with the pump-cylinders.

As the plunger on the leading side commences its stroke from left to right, as before described, the pressure in the water-cylinder P in front of the plunger is transmitted for a short time through the pipe 33 and branch 35 to the motor-cylinders 24 29 below the pistons controlling the force-valve *l* and suction-valve *n*, respectively in front of and behind the plunger on the following side of the pump, counterbalancing the force-pressure above the pistons in those cylinders, and these valves are opened by the water-current as the plunger O on the following side continues its stroke from right to left for the one-sixth stroke still remaining.

As the plunger on the leading side continues its stroke, however, it soon passes and uncovers behind it the port of pipe 33, so that the pressure in pipe 33 and branch 35, and consequently that below the pistons in the motor-cylinders 24 29, is reduced to the suction-pressure and the force-valve *l* and suction-valve *n*, respectively in front of and behind the plunger on the following side of the pump, which are controlled by these pistons, are gradually and positively closed just as the plunger on this side reaches the end of its stroke from right to left. The pressure in front of the plunger upon the leading side is still transmitted through the pipe 34 and branch 36 to the motor-cylinders 25 28 below the pistons, so that the constant pressure in these cylinders is counterbalanced, and as the plunger on the following side is reversed and moves from left to right the force and suction valves, respectively in front of and behind the plunger, which are controlled by the pistons in these cylinders, are opened by the water-current. On this reversal of the plunger on the following side the pressure in front of the plunger is transmitted for a short time through the

pipe 37 and branch 39 to the motor-cylinders 23 26, controlling the force and suction valves respectively in front of and behind the plunger on the leading side, and counterbalances the constant pressure therein, so that these valves remain open as the plunger on the leading side continues its stroke from left to right. The plunger on the following side, however, soon passes and uncovers behind it the port of pipe 37 and the movement of the water and consequent transmission of the pressure through pipe 37 and branch 39 to the motor-cylinders 23 26 is so adjusted that the pressure below the pistons in the motor-cylinders 23 26 is reduced to that of the suction at the proper time, so that the force and suction valves respectively in front of and behind the plunger on the leading side, which are controlled by the pistons in these motor-cylinders, are gradually and positively closed by the constant pressure as the plunger on the leading side reaches the end of its stroke.

As the plunger on the leading side is reversed and moves from right to left, it operates by proper adjustment of the passage of the water and consequent transmission of the pressure to secure the gradual and positive closing of the force and suction valves respectively in front of and behind the plunger on the following side as this plunger reaches the end of its stroke.

The operation described is constantly repeated during the action of the pumps.

The time of closing of the valves may be adjusted in the construction of the pump by proper determination of the points at which the pipes transmitting the varying pressure enter the pump-cylinders or by proportioning the sizes of the pipes and motor-cylinders. It will, however, be found convenient and may in some cases be necessary to provide means whereby the passage of the water 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 may conveniently be done by means of the throttle-valves upon the pipes, by which the varying pressure is transmitted, the passage of the water and consequently the variations of the pressure below the motor-pistons being thus adjusted as desired.

In the constructions thus far described the varying pressure below the pistons is controlled by the passage of the plungers in the pump-cylinders over the ports by which the pipes transmitting the varying pressure communicate therewith, but this is not necessary.

I may employ an organization for duplex engines similar to that previously described except that the pipes transmitting the varying pressure are not opened and closed by the plunger, so that the change from force to suction pressure is made during the stroke of the plunger, but the pipes are in constant free communication with the pump-cylinders and the change from force to suction pressure is made on the reversal of the plungers at the ends of their strokes in either direction.

In Fig. 10 I have shown such a construction applied to a pump of the common diaphragm ring and plunger construction. The arrangement of pipes is identical with that shown in Figs. 7 to 9 and previously described, except that the pipes transmitting the varying pressure communicate freely at all times with the pump-cylinder, they being shown as communicating above the pump-cylinders with the passages leading to the force and suction chambers, although it will be understood that they may open into the pump-cylinders at any points upon the opposite sides of the central diaphragm.

The operation of this construction is substantially the same as that of the duplex engine previously described, except that the pressure below the pistons 30 in the motor-cylinders above the force and suction valves is changed from force to suction, and vice versa, only as the plungers are reversed on completing their strokes in either direction.

As previously described, the variations of the pressure below the motor-pistons are controlled by the throttles, so as to secure the proper closing of the valves by the force-pressure above the pistons when the pressure below the pistons is reduced by the reversal of the controlling-plunger; but any other suitable means may be used for this purpose.

In the organizations thus far described the motor-pistons control the force and suction valves directly; but, as stated above, auxiliary valves may be provided between the pump-cylinder and the force and suction mains, either between the force and suction valves and the mains or between the pump-cylinders and the force and suction valves.

In Fig. 11 I have shown such an organization in which the construction is similar to that shown in Fig. 4, except that the force and suction chambers communicate with the pump-cylinder by separate passages, and these passages are controlled by force and suction valves *o p* of the usual construction, the valves *a b* of the construction in Fig. 2, which are controlled by the pistons 12, being auxiliary valves.

By the use of an auxiliary valve placed between the cylinder and the main on either side of the main valves *l* do not in any respect alter the function of the main valves. In case the auxiliary valves on the force side become obstructed at any time or held from their seats 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, the only result in the arrangement described being a noisy action of the pump until the auxiliary valve has been relieved. In case of any accident or breakage to the auxiliary force-valve it

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 evident that with the auxiliary valve as shown in Fig. 11 substantially all the advantages of the positive action of the force and suction valves are obtained, the gradual closing of the auxiliary valve closing the force-main and exerting a gradual stopping pressure upon the plunger.

It is apparent that many other changes may be made in the organizations 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 as 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 "constant pressure" I do not mean that the pressure tending to close the valve is unvarying, as it is evident that this pressure will vary in the construction shown with the changes in the pressure per square inch in the force-main, and variations in the constant pressure are immaterial so long as it is in excess of the pumping pressure when the opposing varying pressure is reduced to secure the closing of the valve against the pumping pressure. Under the term "constant pressure in excess of the pumping pressure," therefore, I mean to include any total pressure or force of sufficient amount to close the valve against the pumping pressure and so far independent of the pump movement as to require to be controlled by an opposing varying pressure to secure the proper valve movement.

It is evident that the total pressure or force required to close the valve 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 that 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 constant 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 do not claim herein, broadly, a valve located between the plunger and main of a direct-acting pumping-engine and positively closed against the pumping pressure, nor, broadly, an auxiliary valve thus located and closed, as these subjects-matter are claimed in Patent No. 526,429, granted to me September 25, 1894.

I also do not claim herein, broadly, the method of or construction for closing a pump-valve by applying to the valve against the pumping pressure a fluid-pressure in excess of the pumping pressure; nor broadly a construction for applying pressure or a varying pressure to the pump-valves on one side of a duplex pump from the opposite side of the pump; nor the method of or construction for controlling a pump-valve by applying a fluid-pressure to the valve against the pumping pressure and varying said pressure during the stroke of the pump-plunger; nor a construction of duplex pump in which said pressure is taken from the opposite side of the pump; nor any of such constructions employing motor cylinders or pistons for applying the pressure to the valves or adjusting devices between the source of pressure and valve; nor a piston controlling a pump-valve and connected with a source of varying fluid-pressure in the pump, as these subjects-matter are claimed in another application, Serial No. 383,088, filed February 27, 1891.

What I claim is—

1. The method of closing a pump-valve against the pumping pressure, which consists in applying to said valve against the pumping pressure, a constant pressure in excess of the pumping pressure and controlling said constant pressure by an opposing fluid-pressure varying during the stroke of the pump-plunger and reducing said opposing fluid-pressure to secure the closing of the valve against the pumping pressure by the constant pressure as the plunger reaches the end of its stroke, substantially as described.

2. The method of closing a pump-valve against the pumping pressure, which consists in applying to said valve against the pumping pressure a constant pressure in excess of the pumping pressure, and applying alternately against said constant pressure the suction and force pressures of the pump, the suction-pressure being applied to secure the closing of the valve against the pumping pressure by the constant pressure as the plunger reaches the end of its stroke, substantially as described.

3. The combination with a pump-valve subjected to a constant pressure against and in excess of the pumping pressure, of a column of fluid having a pressure varying during the stroke of the pump-plunger applied against said constant pressure, substantially as described.

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

5. The combination with a pump-valve subjected to a constant pressure against and in excess of the pumping pressure, of connections between said valve and a source of fluid-pressure in the pump varying during the

stroke of the pump-plunger whereby a varying pressure is applied against the constant pressure, substantially as described.

6. The combination with a pump-valve subjected to a constant pressure against and in excess of the pumping pressure, of connections between said valve and a source of fluid-pressure in the pump varying during the stroke of the pump-plunger whereby a varying pressure is applied against the constant pressure, and adjusting devices between the source of varying pressure and the valve for varying the action of the valve relatively to the variations in the pressure-supply, substantially as described.

7. The combination with a pump-valve opened by the pumping-current, of a motor-piston controlling said valve and subjected to a constant pressure against and in excess of the pumping pressure, and a column of fluid having a pressure varying during the stroke of the pump-plunger applied to said piston against said constant pressure, substantially as described.

8. The combination with a pump-valve, of a motor-piston controlling said valve and subjected to a constant pressure against and in excess of the pumping pressure, and a column of fluid having a pressure varying during the stroke of the pump-plunger applied to said piston against the constant pressure, substantially as described.

9. The combination with a pump-valve, of a motor-piston controlling said valve and subjected to a constant pressure against and in excess of the pumping pressure, and connections between said piston and the pump-cylinder whereby the suction and force-pump pressures are applied alternately to said piston against the constant pressure during the stroke of the pump-plunger, substantially as described.

10. The combination with a pump-cylinder and its plunger, of a pump-valve, a motor-piston controlling said valve and subjected to a constant pressure against and in excess of the pumping pressure, and connections between said piston and the pump-cylinder whereby the suction and force-pump pressures are applied alternately to said piston against the constant pressure during the stroke of the pump-plunger, substantially as described.

11. The combination with a pump-cylinder and its plunger, of a valve, a motor-piston controlling said valve, connections between said piston and the force-main whereby the force pressure is applied to said piston against the pumping pressure, and connections between the opposite side of said piston and the pump-cylinder whereby the suction and force-pump pressures are applied alternately to said piston during the stroke of the pump-plunger, substantially as described.

12. The combination with a pump-cylinder and its plunger, of a pump-valve, a motor-piston controlling said valve and subjected to a constant pressure against and in excess of the pumping pressure, and connections between the opposite side of said piston and the pump-cylinder, the connection-port in the pump-cylinder being so located as to be opened behind the plunger before the latter reaches the end of its stroke, substantially as described.

13. The combination with a pump-cylinder and its plunger, of a pump-valve, a motor-piston controlling said valve and subjected to a constant pressure against and in excess of the pumping pressure, and connections between the opposite side of said piston and the pump-cylinder, the connection-port in the pump-cylinder being so located in the pump-cylinder as to be opened behind the plunger before the latter reaches the end of its stroke, and adjusting devices between the pump cylinder and valve for varying the action of the valve relatively to the pressure variations in the pump-cylinder, substantially as described.

14. The combination with a pump-cylinder and its plunger, of a pump-valve, a motor-piston controlling said valve, connections between said piston and the force-main whereby the force pressure is applied to said valve against the pumping pressure, and connections between the opposite side of said piston and the pump-cylinder, the connection-port being so located in the pump-cylinder as to be opened behind the plunger before the latter reaches the end of its stroke, substantially as described.

15. The combination with a pump-cylinder and its plunger, of a valve between the plunger and force-main, a motor-piston controlling said valve and subjected to a constant pressure against and in excess of the pumping pressure, and connections between said piston and the pump-cylinder whereby the suction and force-pump pressures are applied alternately to said piston against the constant pressure during the stroke of the pump-plunger, substantially as described.

16. The combination with a pump-cylinder and its plunger, of valves between the plunger and force and suction mains, motor-pistons controlling said valves and subjected to a constant pressure against and in excess of the pumping pressure, and connections between said pistons and the pump-cylinder whereby the suction and force-pump pressures are applied alternately to said pistons against the constant pressure during the stroke of the pump-plunger, substantially as described.

17. In a duplex pump, the combination with a pump-valve subjected to a constant pressure against and in excess of the pumping pressure, of a column of fluid from the opposite side of the pump having a pressure varying during the stroke of the pump-plunger applied against the constant pressure, substantially as described.

18. In a duplex pump, the combination with a valve between the plunger and force-main subjected to a constant pressure against and in excess of the pumping pressure, of a col-

umn of fluid from the opposite side of the pump having a pressure varying during the stroke of the pump-plunger applied against said constant pressure, substantially as described.

19. In a duplex pump, the combination with a pump-valve, of a piston controlling said valve and subjected to a constant pressure against and in excess of the pumping pressure, and connections between said piston and a source of fluid-pressure on the opposite side of the pump varying during the stroke of the pump-plunger whereby a pressure varying during the stroke of the pump-plunger is applied to said piston against the constant pressure, substantially as described.

20. In a duplex pump, the combination with a pump-valve, of a piston controlling said valve and subjected to a constant pressure against and in excess of the pumping pressure, connections between said piston and a source of fluid-pressure on the opposite side of the pump varying during the stroke of the pump-plunger whereby a pressure varying during the stroke of the pump-plunger is applied to said piston against the constant pressure, and adjusting devices between the source of varying pressure and the valve for varying the action of the valve relatively to the variations in the pressure-supply, substantially as described.

21. In a duplex pump, the combination of valves located between the plungers and force-main, motor-pistons controlling said valves and subjected to a constant pressure against and in excess of the pumping pressure, and connections between said pistons and a source of fluid-pressure on the opposite side of the pump, varying during the stroke of the pump-plunger whereby pressure varying during the stroke of the pump-plunger is applied to said pistons against the constant pressure, substantially as described.

22. In a duplex pump, the combination of valves located between the plungers and force-main, motor-pistons controlling said valves and subjected to a constant pressure against and in excess of the pumping pressure, connections between said pistons and a source of fluid-pressure on the opposite side of the pump varying during the stroke of the pump-plunger whereby a fluid-pressure varying during the strokes of the pump-plungers is applied to said pistons against the constant pressure, and means for adjusting the time of action of said valves, substantially as described.

23. The combination with the pump cylinders and plungers of a duplex pump, of pump-valves, motor-pistons controlling said valves and subjected to a constant pressure against and in excess of the pumping pressure and connections between said pistons and the pump-cylinder on the opposite side of the pump whereby the suction and force pressure in the cylinder on each side of the pump is applied alternately against the constant pressure on the opposite side of the pump and during the stroke of the pump-plunger on the opposite side of the pump, substantially as described.

24. The combination with the pump cylinders and plungers of a duplex pump, of valves located between the plungers and force-main, motor-pistons controlling said valves and subjected to a constant pressure against and in excess of the pumping pressure, and connections between said pistons and the pump-cylinder on the opposite side of the pump whereby the suction and force pressures in the pump-cylinder on each side of the pump are alternately applied against the constant pressure on the opposite side of the pump and during the stroke of the pump-plunger on the opposite side of the pump, substantially as described.

25. In a direct-acting pump, the combination with a motor-piston and its plunger, of a valve or valves between the plunger and force-main subjected to a constant pressure against and in excess of the pumping pressure, and a column of fluid having a pressure varying during the stroke of the pump-plunger applied against said constant pressure, substantially as described.

26. The combination with the motor-pistons and the plungers of a direct-acting duplex pump, of valves between the plungers and force-main subjected to a constant pressure against and in excess of the pumping pressure, and connections between said valves and a source of varying fluid-pressure on the opposite side of the pump whereby the varying pressure is applied against said constant pressure, 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 subjected to a constant pressure against and in excess of the pumping pressure, and a column of fluid having a varying pressure applied against the constant pressure, 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 subjected to a constant pressure against and in excess of the pumping pressure, and connections between said valves and a source of varying fluid-pressure on the opposite side of the pump whereby the varying pressure is applied against said constant pressure, substantially as described.

29. The combination with a pump-valve, of a motor cylinder and piston controlling said valve, and a hollow valve-stem opening into the valve-chamber and the motor-cylinder, substantially as described.

30. The combination with a pump-valve, of a motor cylinder and piston controlling said valve, a hollow valve-stem opening into the valve-chamber and the motor-cylinder,

and connections between the valve-chamber on the opposite side of the piston and a source of varying fluid-pressure in the pump, substantially as described.

31. The combination with a pump-valve, of a motor cylinder and piston controlling said valve, a hollow valve-stem opening into the valve-chamber and the motor-cylinder above the piston, and connections between the valve-chamber on the opposite side of the piston and the pump-cylinder, the connection-port in the pump-cylinder being opened behind the plunger during the stroke of the latter, substantially as described.

32. The combination with a pump-valve having a hollow valve-stem, of a motor-cylinder communicating with the valve-chamber through the hollow valve-stem, and a motor-piston carried by said valve-stem, 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,
E. S. CRONISE.