(No Model.) 4 Sheets—Sheet 1.

# C. C. WORTHINGTON.

## DUPLEX PUMPING ENGINE.

No. 292,525. Patented Jan. 29, 1884.

Fig. 2.

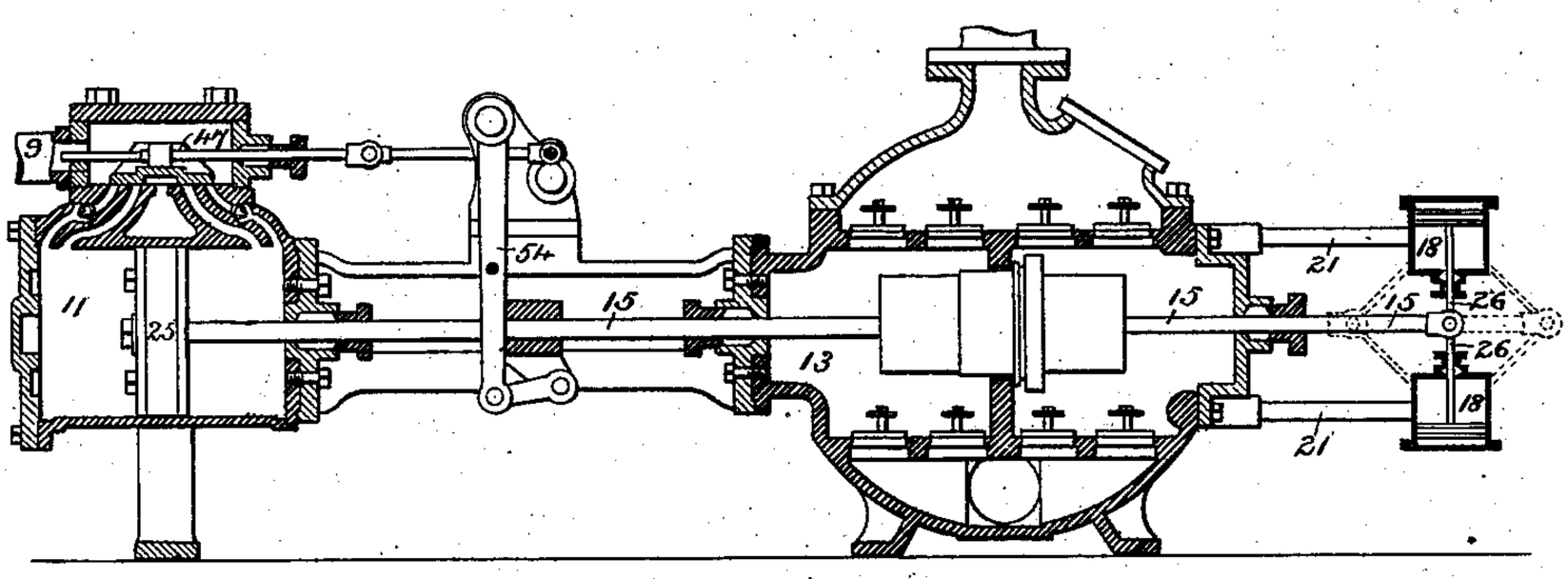



Fig. 1

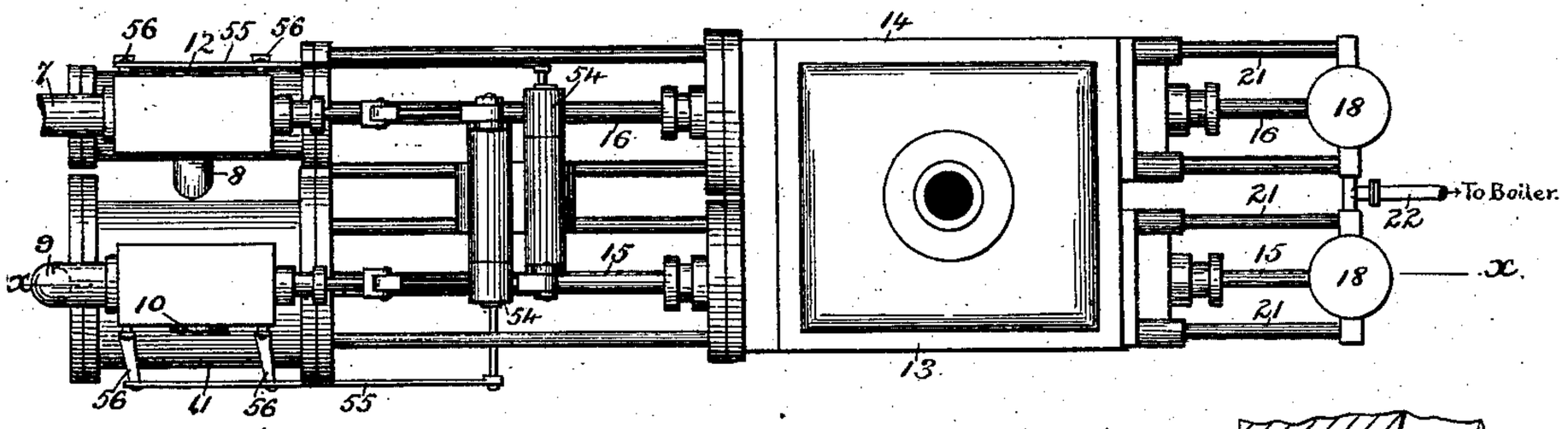



Fig. 17.

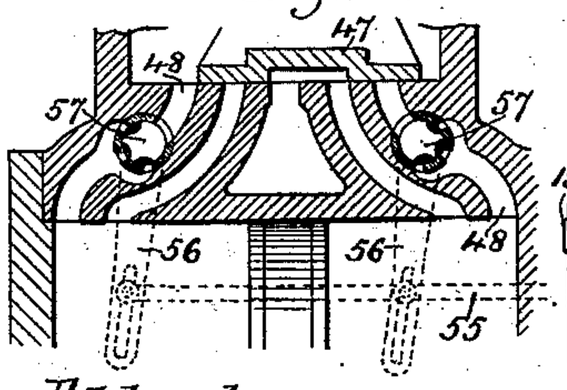



Fig. 3.

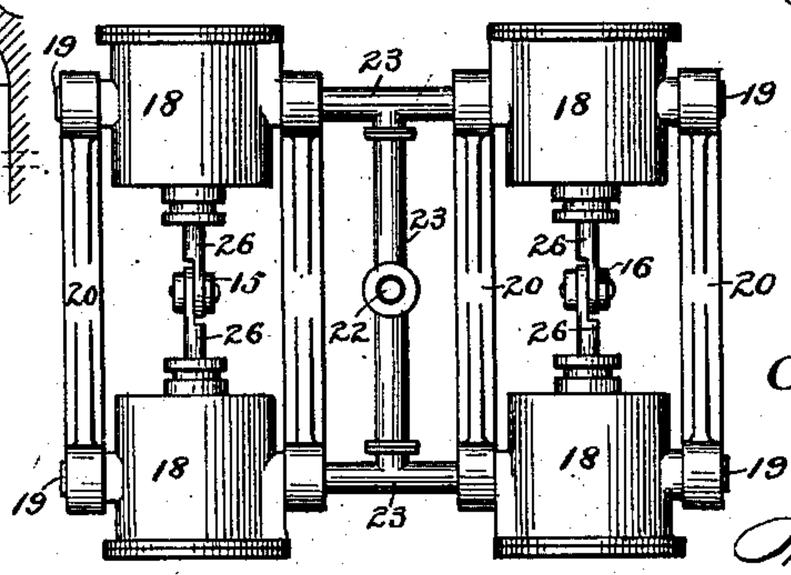
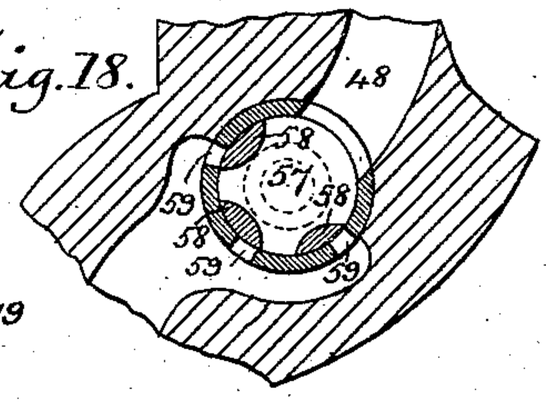



Fig. 18.

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C. C. Worthington,

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Munson & Philipp

Attys.

(No Model.) 4 Sheets—Sheet 2.

# C. C. WORTHINGTON.

## DUPLEX PUMPING ENGINE.

No. 292,525. Patented Jan. 29, 1884.

Fig. 5.

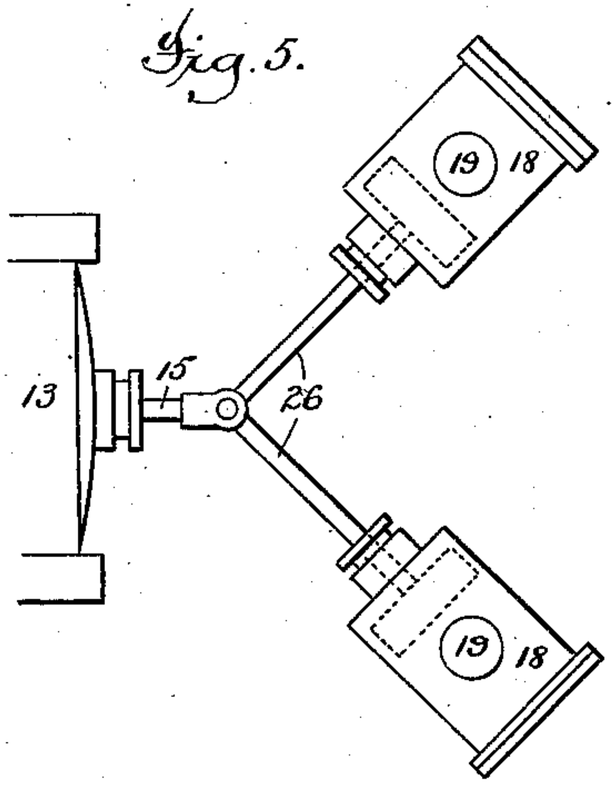



Fig. 4.

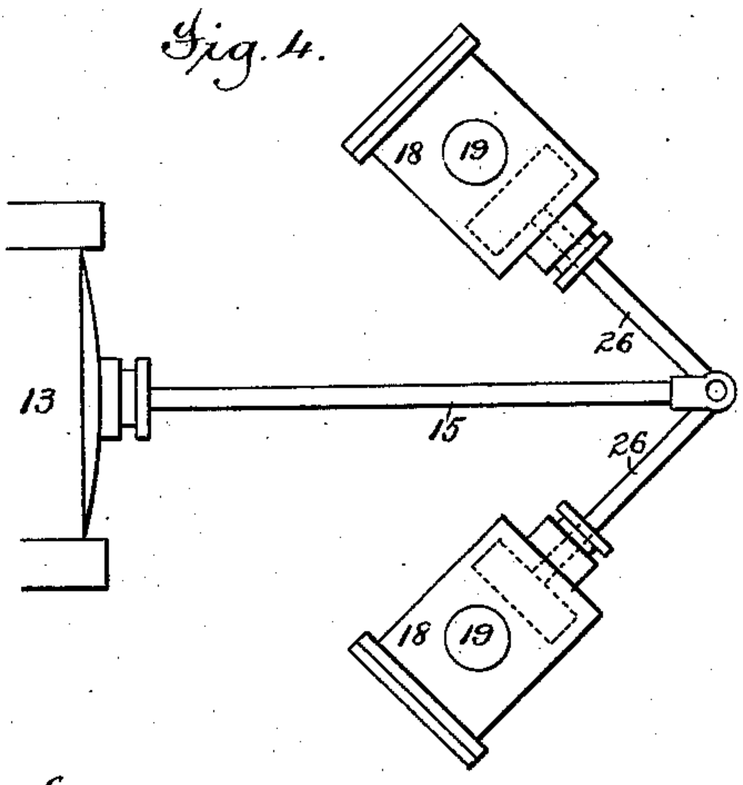



Fig. 15.

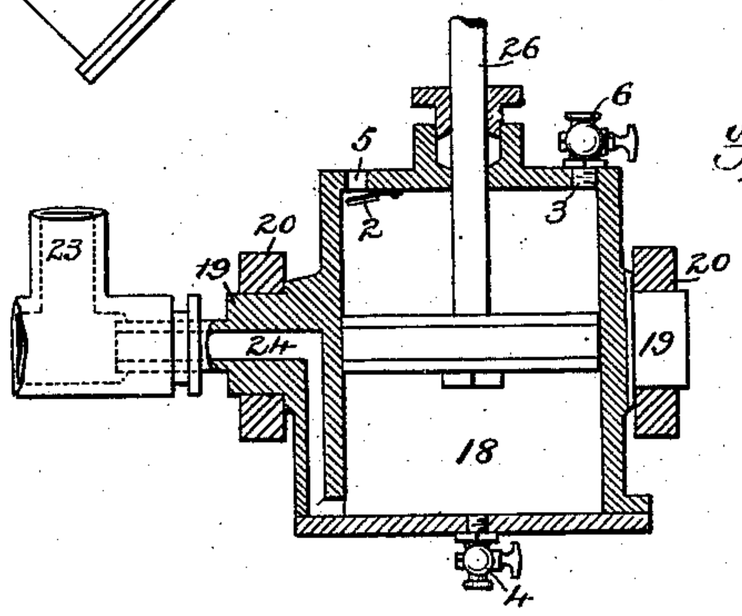



Fig. 10.

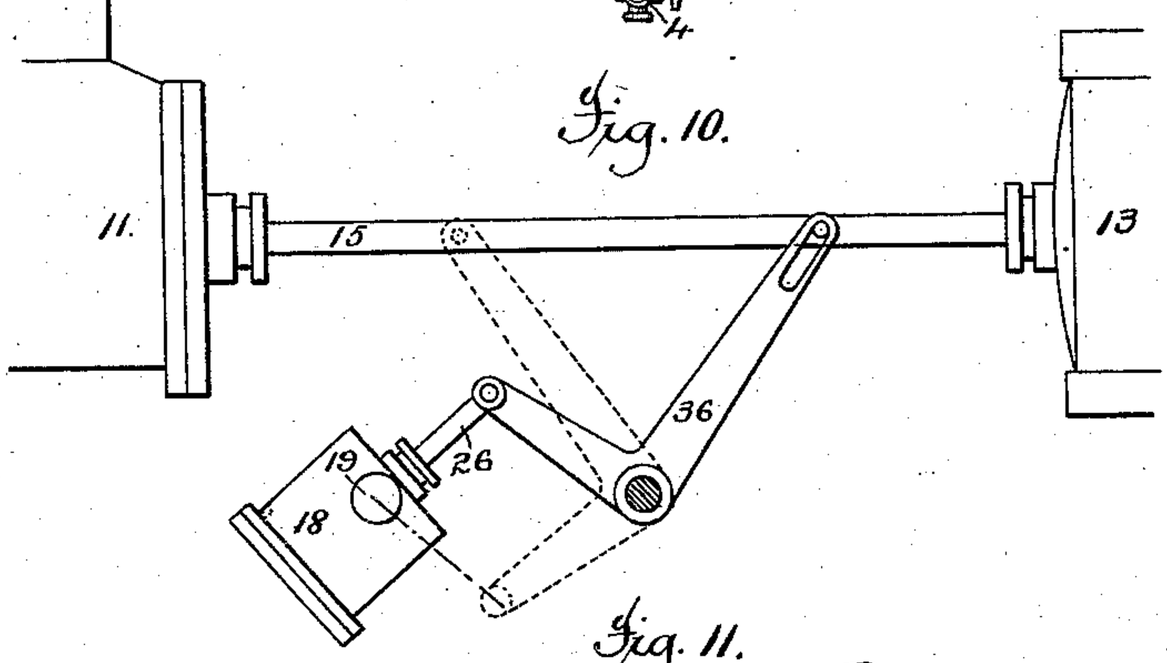
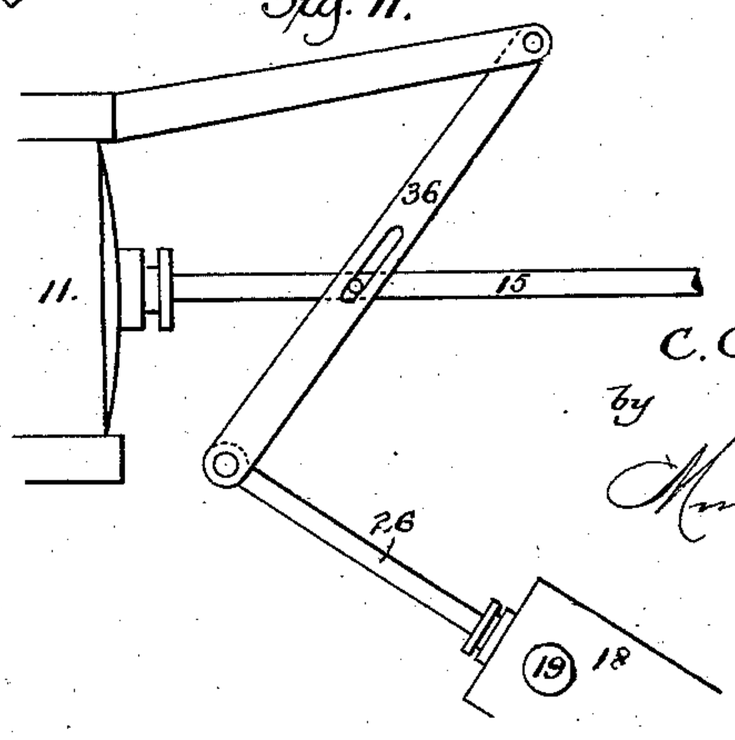



Fig. 11.

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## DUPLEX PUMPING ENGINE.

No. 292,525. Patented Jan. 29, 1884.

Fig. 13.

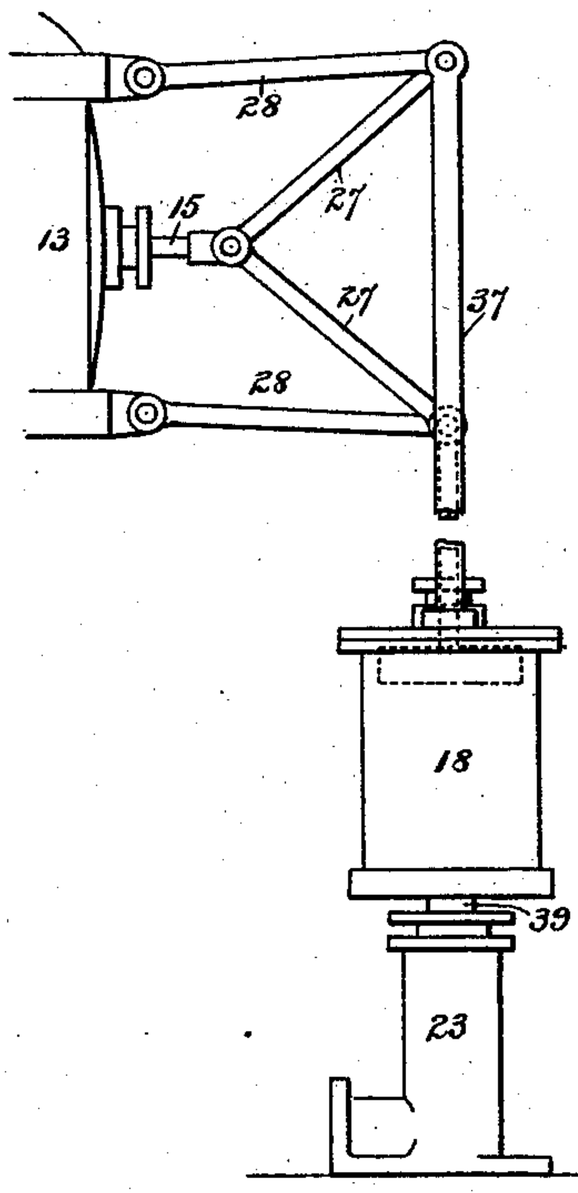



Fig. 6.

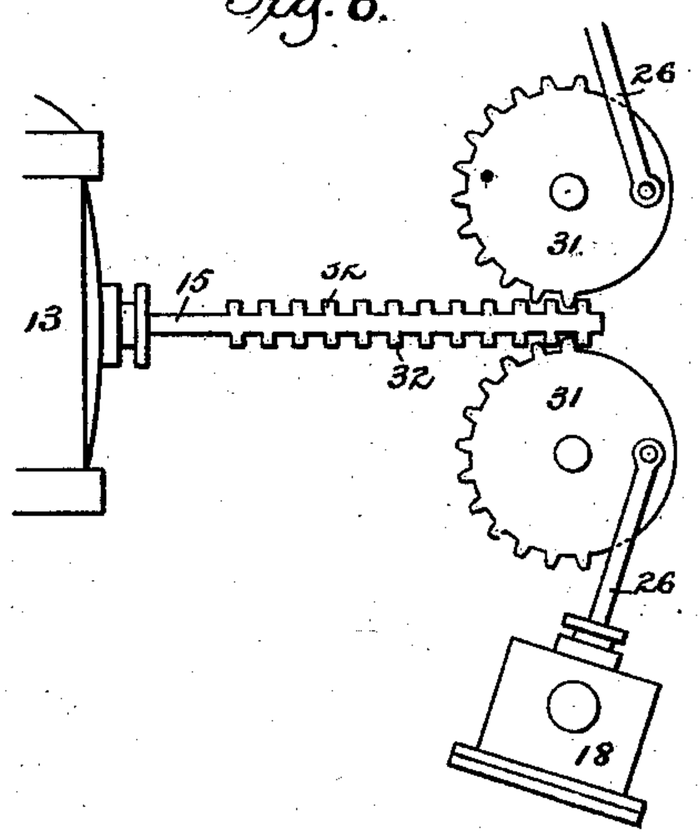



Fig. 16.

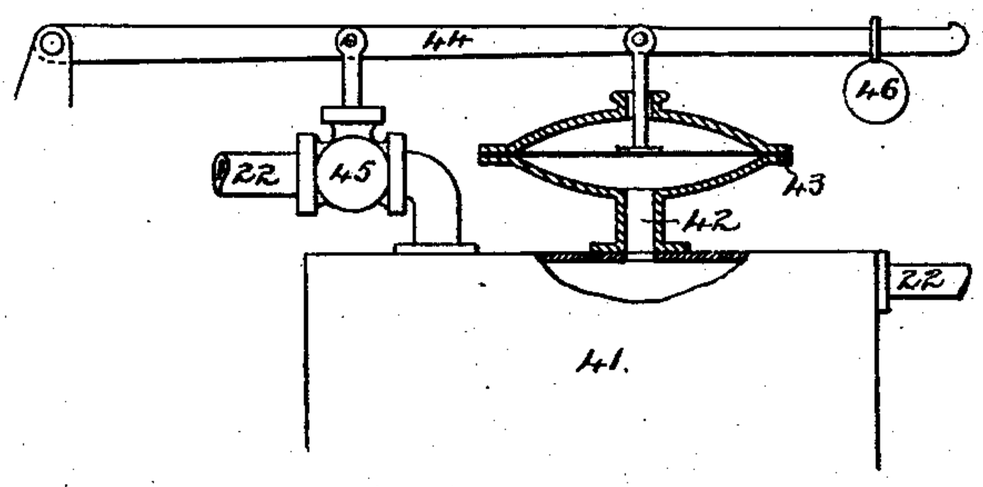
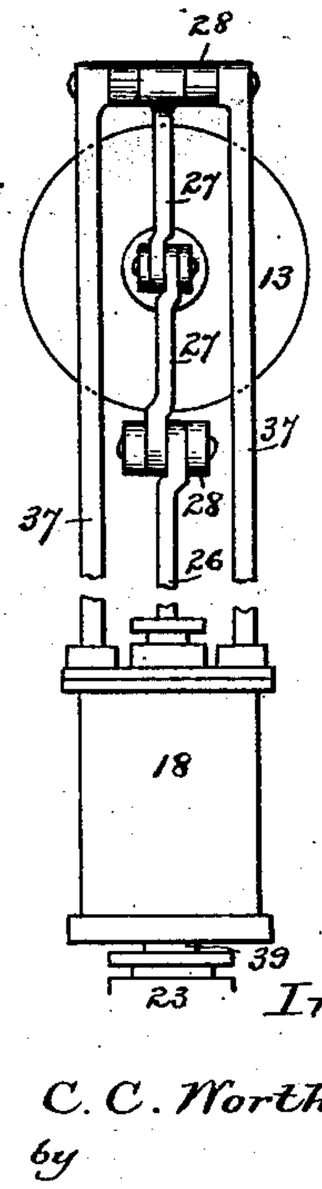



Fig. 14.

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(No Model.)

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# C. C. WORTHINGTON.

## DUPLEX PUMPING ENGINE.

No. 292,525. Patented Jan. 29, 1884.

Fig. 9.

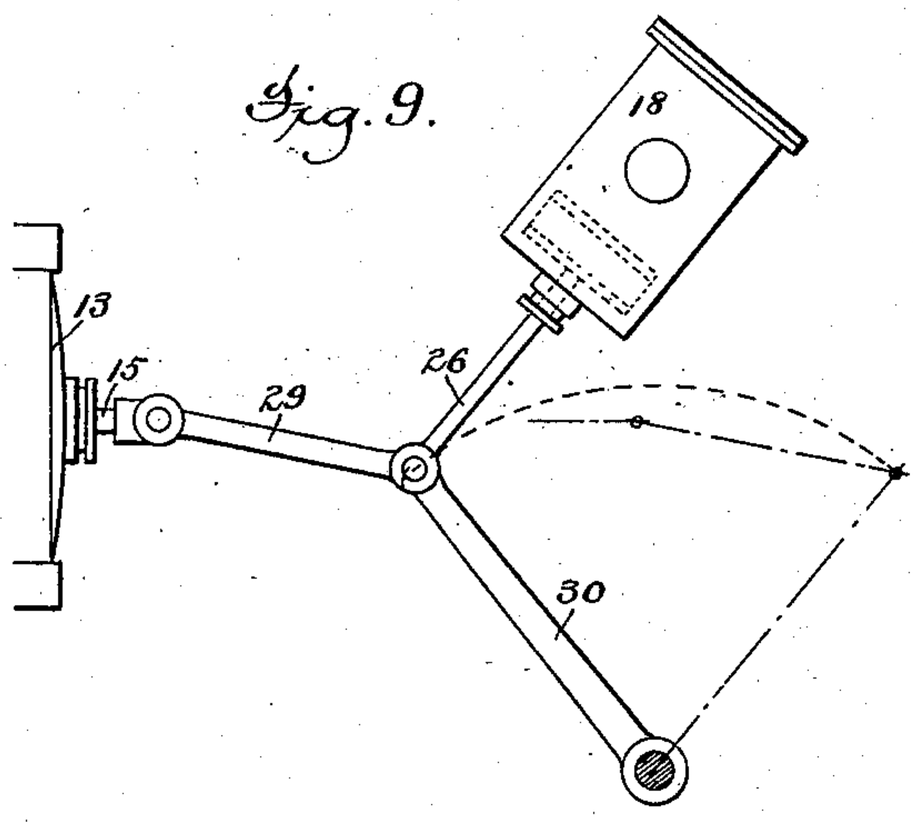



Fig. 7.

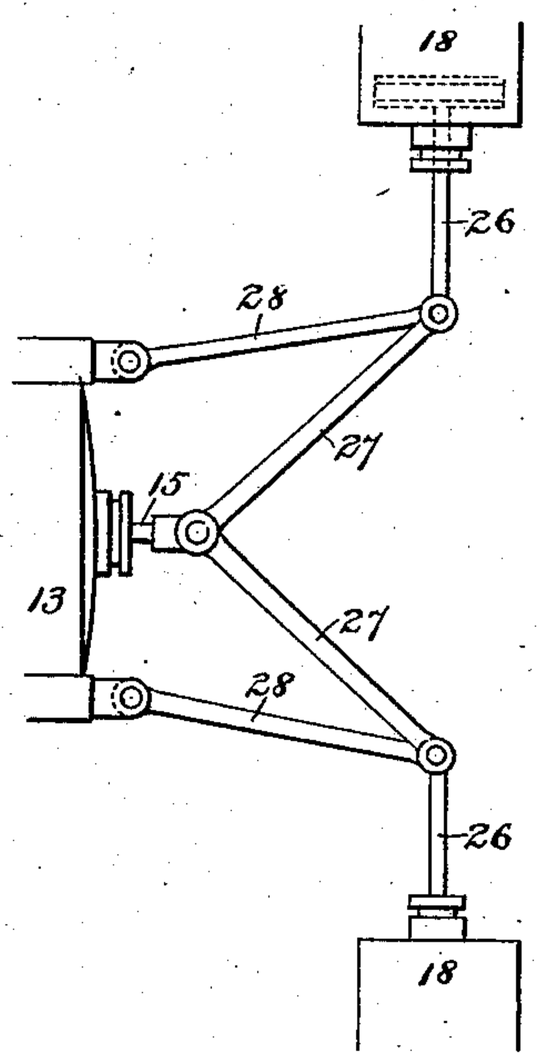



Fig. 8.

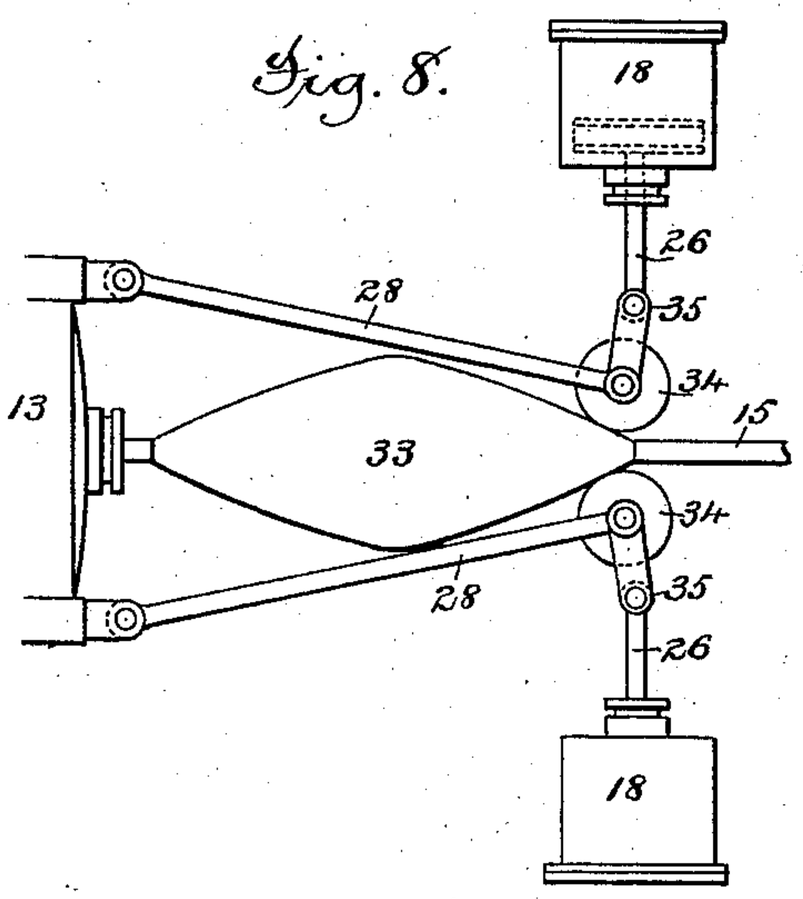
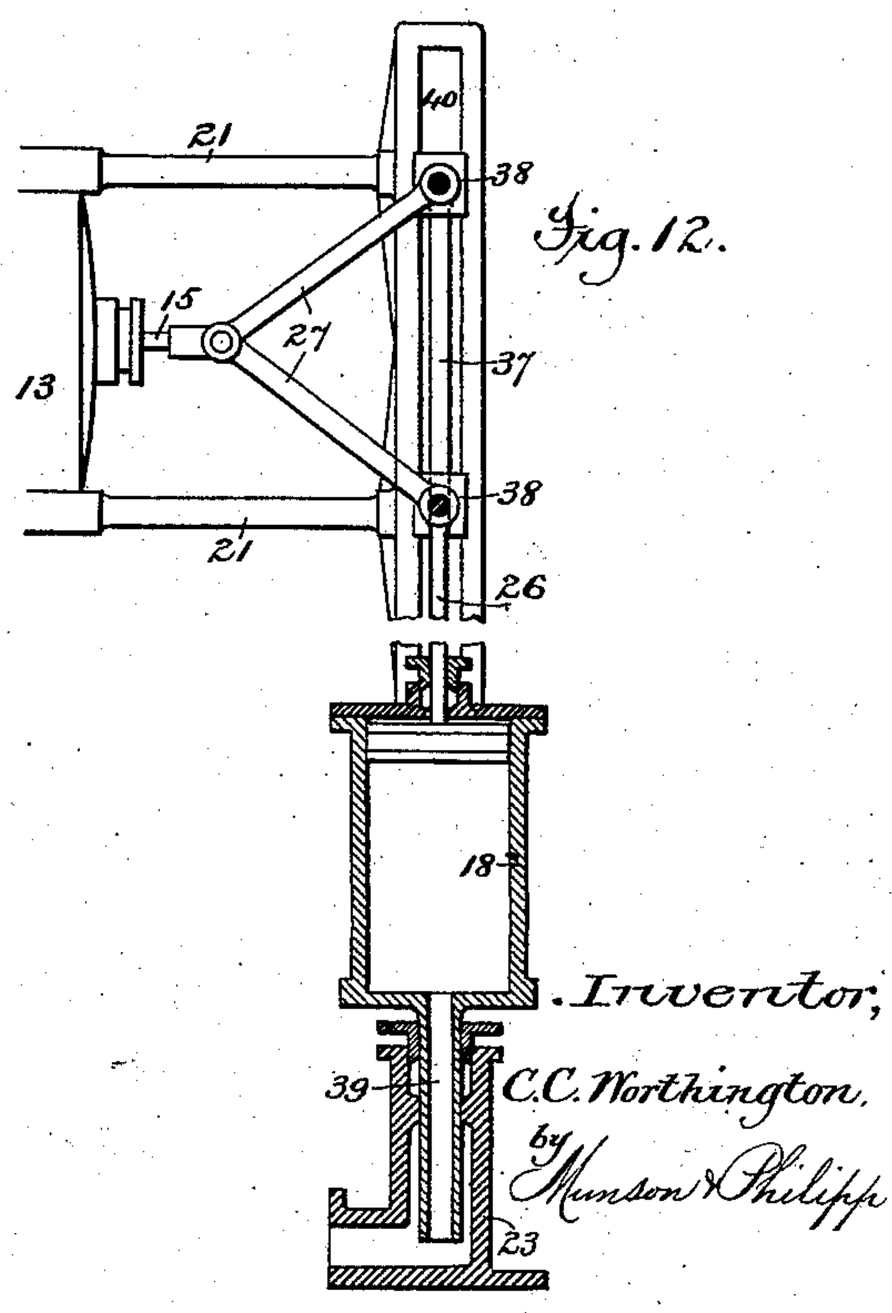



Fig. 12.

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# UNITED STATES PATENT OFFICE.

CHARLES C. WORTHINGTON, OF IRVINGTON, NEW YORK.

## DUPLEX PUMPING-ENGINE.

SPECIFICATION forming part of Letters Patent No. 292,525, dated January 29, 1884.

Application filed April 28, 1883. (No model.)

*To all whom it may concern:*

Be it known that I, CHARLES C. WORTHINGTON, a citizen of the United States, residing in the town of Irvington, county of Westchester, and State of New York, have invented certain new and useful Improvements in Duplex Pumping-Engines, fully described and represented in the following specification and the accompanying drawings, forming a part of the same.

It is well known to those familiar with the science of steam-engineering that to secure the greatest economy in the use of steam it is necessary to allow it to expand in the cylinder or cylinders of the engine. In using steam upon this principle, however, its propulsive force necessarily decreases toward the end of the stroke, and this decrease, unless compensated for, results in a spasmodic operation of the engine. In locomotives and marine-engines the momentum of the load is so great that no trouble is experienced from this source, while in stationary crank-engines this difficulty has usually been overcome by the use of a heavy fly-wheel. When a fly-wheel is employed, the parts are so proportioned that the power exerted by the steam at the beginning of the stroke is somewhat greater and at the end of the stroke somewhat less than is required to overcome the load upon the engine, the fly-wheel acting to distribute and equalize the power along the whole stroke by storing up the excess at the beginning and giving it off at the end. In the class of duplex pumping-engines, however, to which the present invention relates no fly-wheel is used, and the moving parts are, of necessity, so light as to acquire but little momentum during the stroke. It is therefore necessary, in order to overcome the constant or nearly constant load upon the engine, to maintain a uniform or nearly uniform pressure of steam upon the piston or pistons throughout the entire stroke of the engine. This being the case, it has been found impracticable in such direct-acting engines as heretofore constructed to utilize the expansive energy of the steam to any considerable extent, except by the use of compound cylinders.

It is the object of the present invention to provide means by which the steam may be used expansively in the cylinders of a duplex pumping-engine with an even distribution of power throughout the entire stroke, and without necessarily using compound cylinders.

To that end the invention consists in the combination, with a duplex pumping-engine provided with means whereby the inlet and exhaust valve or valves of one side thereof is or are operated by the other side, of means whereby power is stored up at one and utilized at another period of the stroke of each side of said engine without preventing the variable pause at the end of each stroke peculiar to this engine, substantially as hereinafter described; also, in the combination, with the main cylinders and pistons forming the two sides of a duplex pumping-engine, provided with means by which each actuates the inlet and exhaust valve or valves of the other, of a compensating cylinder or cylinders at each side of said engine, each provided with a piston and rod and supplied with a suitable motor-fluid, and acting in opposition to the main cylinders and pistons to which they are connected during the first part of the stroke of said main pistons and in conjunction therewith during the last part of their stroke; also, in other combinations and arrangement of parts and details of construction, all of which will be hereinafter fully described and claimed.

In the accompanying drawings, Figure 1 is a plan view, Fig. 2 is a vertical longitudinal section, and Fig. 3 an end elevation, of a duplex pumping-engine embodying the invention. Figs. 17 and 18 are sectional details of the cut-off mechanism employed therewith. Figs. 4 and 5 are views showing the position of the compensating-cylinders at the beginning and the end of the stroke. Figs. 6 to 14, inclusive, are views illustrating different modifications of the compensating-cylinders and connections. Fig. 15 is a sectional view of one of the compensating-cylinders, showing also a cushioning apparatus. Fig. 16 is an elevation, partly in section, of an apparatus for regulating the pressure of the fluid in the compensating cylinder or cylinders.

Referring particularly to Figs. 1 and 2, it

is to be understood that the pumping-engine here shown has two steam-cylinders, 11 12, and two water-cylinders, 13 14, and is provided with means whereby the piston-rod of each side of the engine operates the inlet and exhaust valve or valves of the other in substantially the same manner as is set forth in United States Letters Patent granted to Henry R. Worthington, dated July 19, 1859, No. 24,838. As here shown, the cylinders 11 and 12 are arranged to operate in connection with a tank in substantially the same manner as described in the United States Letters Patent No. 116,131, the steam being received from the generator through the pipe 7, and, after acting in the cylinder 12, passing out through the pipe 8 to the tank, (not shown,) from which it enters the cylinder 11 through the pipe 9, where it acts at a reduced pressure, after which it is exhausted through the pipe 10 into the condenser or into the open air. Each of said cylinders 11 12 may, however, receive its steam directly from the boiler and exhaust it directly into the condenser or into the open air, said cylinders in such case being of substantially the same size.

As shown in Figs. 1 and 2 of the drawings, each of the piston-rods 15 16 is arranged in the usual manner, to connect the steam-piston with the piston or plunger of the pump, and they are provided with the usual connections for operating the inlet and outlet valves 47 of the steam-cylinders. Each of the piston-rods 15 16, instead of terminating inside the water-cylinder, passes through a suitable stuffing-box in the opposite end of said cylinder, and is connected to the piston-rods of a pair of oscillating cylinders, 18, which are arranged in any convenient position, and provided with connections for receiving a supply of steam from the generator. As herein shown, these cylinders are provided with trunnions 19, having bearings in a suitable frame-work, 20, which is connected to the ends of the water-cylinder by suitable tie-rods, 21, and are supplied with steam through pipes 22 23, communicating with ducts 24 in one of said trunnions, as shown in Fig. 15. They may, however, be supported and supplied in any other manner which may be found more convenient or desirable.

For clearness, the construction and operation of one side of the duplex pumping-engine will now be described.

Assuming the piston 25 of the cylinder 11 to be in position to commence its stroke, and the cylinders 18 in the position shown in Fig. 4, the operation will be as follows: The inlet-valve 47 of the cylinder 11 will be at this point in its opened position, and steam will be admitted to the cylinder under sufficient pressure to overcome not only the load upon the engine, but also the resistance offered by the pressure of the steam against the pistons of the cylinders 18, the rods 26 of which are at that time, as will be seen by reference to Fig. 4, in such position as to act against the rod 15. As the piston 25 advances, the resistance offered by the steam in the cylinders 18 will, owing to the constant change in the angle of the rods 26, gradually decrease until the parts arrive at the position shown in full lines in Fig. 2, at which time the rods 26 will act directly against each other and offer no resistance to the rod 15. During the remainder of the stroke the operation of the cylinders 18 is reversed. Instead of acting in opposition to, they act in conjunction with, the piston 25, and add a constantly-increasing power to the engine until the end of the stroke is reached, at which time they will be in the position shown in Fig. 5. At the end of the stroke the valve 47 will be reversed, so as to admit steam upon the opposite side of the piston 25 and start it upon its return-stroke. During the return-stroke the operation of the cylinders 18 will be reversed. Starting from the position shown in Fig. 5, the rods 26 will act in opposition to the rod 15 during the first half of the stroke, and then in conjunction with said rod until they arrive at their original position, as shown in Fig. 4.

From the foregoing it will be seen that during the first half of the stroke of each side of the engine only a part of its power is available for performing the work to be done, the remainder being stored up in the cylinders 18, but that during the last half of the stroke the whole power of the engine is available for work, and in addition thereto the power stored up in the cylinders 18 during the first half. This being the case, it is apparent that, if the steam in the cylinder 11 is maintained at its initial pressure during the entire stroke, the available power of the engine will be much greater at the end than at the beginning of the stroke, and this fact makes it possible to use the steam expansively in the cylinder 11, and yet obtain a practically uniform propulsive power throughout the entire stroke. The cylinder 11 is therefore provided with suitable cut-off mechanism, by which, after the piston of said cylinder has advanced a certain distance—say one-half or somewhat more or less than one-half the stroke—the further ingress of steam is arrested, the remainder of the stroke being accomplished by the expansive force of the steam already in the cylinder and the force exerted by the compensating-cylinders, the gradual decrease of power due to the expansion of the steam in the one being compensated for by the gradual increase of power in the other. As the piston 25 arrives at the end of its stroke its rod 15 will operate the induction-valve of the cylinder 12, so as to start the opposite side of the engine, which side will then make a stroke, its compensating-cylinders operating in the manner just described. This stroke will in turn reverse the valve of the cylinder 11, so as to admit steam upon the opposite side of the piston therein, and so the operation will continue to be repeated. The valves of one side of the engine being oper-

ated by the piston-rod of the other side, as is described in said Letters Patent No. 24,838, the same results due to the pausing of the pistons at the end of their strokes is attained as is described therein.

One form of valve and cut-off mechanism is shown in the drawings at Figs. 17 and 18, for the purpose of cutting off steam at the proper point in the main cylinders. In this form 48 are the steam-admission ducts, which are provided with bushings, the plugs 57 in which extend through the sides of the steam-chests, and are provided with arms 56, which are connected by rods 55 with the valve-operating levers 54. The parts are so adjusted that as each piston of the main cylinders arrives at the point where it is desired to cut off the further admission of steam the plug 57 will be turned so that the solid parts 58 will close the ports 59. The parts 58 are made of such width that, although the plug will continue to turn during the remainder of the stroke, the ports 59 will not be uncovered. As the piston commences its return-stroke the movement of the plug 57 will be reversed, so that at the end of the stroke the ports 59 will be uncovered. The relative position of the parts 58 of the plugs at the opposite sides of the cylinders will of course be such that when one set of ports 59 are open the other will be closed at the beginning of any stroke. The arms 56 are slotted, as shown in Fig. 17, so that the point of attachment of the rod 55 may be varied, thereby affording means for changing the point of cut-off when desired, the rods 55 being jointed to permit this. The point of attachment of the rod 55 to the lever 54 can also be adjusted, if desired.

The cut-off mechanism just described is shown merely as an example, as it is apparent that any known form of mechanism for this purpose may be employed, if preferred.

By the employment of compensating-cylinders, as just described, all the advantages due to the use of the steam expansively are attained, and without the employment of a fly-wheel or other heavy moving attachment, or the use of compound cylinders. In the present case the compensating-cylinders are located at the end of the water-cylinders simply for the sake of convenience in illustrating the application of the invention. It will readily be understood that these cylinders may be located at any other convenient point, to act either upon the piston-rods or other moving parts of the engine. If found more convenient, they may be located between the steam and water cylinders, or the piston-rods may extend through the opposite ends of the steam-cylinders and connect with the rods 26 at that point.

It is manifest that the means by which the rods 26 of the compensating-cylinders are connected or made to act upon the moving parts of the engine may be varied greatly from that already described without departing from the principle of the invention.

In Figs. 6 to 14, inclusive, several such modified forms of connecting devices and compensating-cylinders are illustrated.

In the construction shown in Fig. 6, the rods 26, instead of being connected directly to the piston-rods of the engine, are attached to crank-pins projecting from the faces of segmental gears 31, which gears engage with racks 32, formed upon the extending end of the piston-rods. It is apparent that the operation of the compensating-cylinders will be the same in this organization as in that already described.

Fig. 7 illustrates a form of connection by which the compensating-cylinders receive little or no oscillating movement. To effect this, the rods 26 are connected to the piston-rods by means of links 27, the point of juncture between said rods and links being connected to the water-cylinders or some other fixed part by pivoted tie-rods 28. It will readily be seen that the effect of this arrangement is the same as of that already described, except that the compensating-cylinders remain practically stationary.

Fig. 8 illustrates another form of connections effecting substantially the same result. In this case the links 27 are omitted, and the pivoted tie-rods 28 are provided with rollers 34, which ride upon the opposite-inclined sides of cams 33, secured to the piston-rods of the engine. The rods 26 are also provided with joints 35, by which the compensating-cylinders are permitted to remain perfectly stationary. The operation of this construction is substantially the same as already set forth. During the first half of the stroke of each side of the engine the rods 26 act against the diverging edges of the cam 33 and resist the advancement of each piston-rod of the engine, while during the last half of the stroke they act against the converging edges of said cam and assist the advancement of each rod.

In the organizations shown in both Figs. 7 and 8 the rods 28 may, if preferred, be omitted and the ends of the rods 26 made to slide in a bearing similar to that shown in Fig. 12. It is also apparent that, instead of two, three or more of the compensating-cylinders may be employed on each side of the engine, or, if preferred, the number may be reduced to one. In Fig. 9 one form of connections for the latter purpose is shown. In this case the rod 26 is connected to the piston-rod of the engine by a link, 29, the joint between said link and the rod 26 being supported by an oscillating arm, 30. The link 29 and arm 30 may be dispensed with, the rod 26 being connected directly to the piston-rod and a stationary bearing provided, upon which the joint can slide back and forth. The arrangement shown is, however, preferable, in that it produces less friction.

In Figs. 10 and 11 organizations are shown in which the rod 26, instead of acting directly upon the piston-rod for each side of the en-

gine, acts upon a lever, 36, attached to said rod. In these figures, also, the compensating-cylinder is shown as located between the steam and water cylinders. In Fig. 10 the lever 36 is of the first order and of bell-crank form, while in Fig. 11 it is of the second order. It is apparent, however, that the form of the lever and its mode of attachment may be greatly varied, and also that more than one compensating-cylinder may be connected to each piston-rod in this manner, if desired.

In Figs. 12, 13, and 14 organizations are shown in which both the compensating-cylinder and its piston have a reciprocating motion. To effect this each piston-rod of the engine is provided with links 27, one of which is attached to the piston-rod 26, while the other is attached to the ends of a pair of rods, 37, secured to the end of the compensating-cylinder in substantially the manner shown in Fig. 14, the opposite end of said cylinder being provided with a tubular projection, 39, which extends through a stuffing-box and reciprocates in the end of the supply-pipe 23. The rods 26 and 37 may be provided with sliding bearings 38, which move in suitable guideways, 40, as shown in Fig. 12; or they may be connected to the end of the water-cylinder or other stationary part by pivoted tie-rods 28, as shown in Fig. 13. In these organizations, during the first half of the stroke the compensating-cylinder will be raised, while its piston will be lowered, thereby doubling the resistance of said cylinder, and during the last half of the stroke the piston will be raised, while the cylinder is lowered, thus permitting the pressure of the steam in both directions to be exerted upon the piston-rod of the engine.

Many other forms of connecting apparatus can readily be suggested by any person familiar with the art, but those shown and described are deemed sufficient to carry out the invention.

It will be observed that the steam is admitted upon only one side of the pistons of the compensating-cylinders, and that this admission is uninterrupted, it being allowed to flow freely in and out of said cylinders as the pistons move back and forth. It is found desirable, however, to provide means by which the pressure in the compensating-cylinders can be controlled, and also by which it can be maintained in a uniform condition, no matter what may be the pressure in the boiler or other source from which it is obtained. To effect this the pipe 22 is provided at some convenient point with a tank, 41, (see Fig. 16,) of such size that the withdrawal of sufficient steam to fill the compensating-cylinders will not materially reduce the pressure of the steam therein. This tank is provided with a small opening, 42, communicating with an ordinary diaphragm-regulator, 43, the lever 44 of which controls an ordinary throttle-valve, 45, located in the pipe 22 between the tank and the source of supply. The weight 46 being adjusted to the proper position, the steam will flow into the tank until the desired pressure is reached, when the diaphragm will rise and cause the lever to close the throttle and stop the admission. When, by reason of condensation and waste, the pressure in the tank falls below the desired point, the diaphragm will fall, thereby opening the throttle and admitting steam until the proper pressure is restored.

The regulating devices used in connection with the tank may be varied widely from those shown and described without departing from this part of my invention. Among other devices that may be employed is a piston in place of the diaphragm, or any of the well-known pressure-regulating valves in place of the diaphragm and throttle-valve.

Although it will usually be found most desirable to employ steam as the resisting medium in the compensating-cylinders, and to supply this from the main generator through connections substantially as herein shown, yet this is not necessary. Compressed air or other gas may be employed in these cylinders, and it may be supplied in any convenient manner. Water or other liquid fluid may, if preferred, be employed, it being introduced into the cylinders under a sufficient head to supply the desired pressure. When a liquid fluid is employed, the pressure-regulating apparatus just described will of course be inapplicable; but any of the well-known forms of apparatus for regulating the pressure of a liquid may be employed.

The compensating-cylinders may be provided with drain-cocks, as 4, (see Fig. 15,) located at any convenient point upon the cylinders, by which any water resulting from condensation can be withdrawn. The ends of these cylinders through which the rods 26 pass may be provided with stuffing-boxes, as shown, or with elongated metal sleeves, to form a tight joint around the rods, and this end of the cylinder or cylinders may be utilized to form a cushioning and governing apparatus for the engine. To effect this the head of each cylinder will be provided with an orifice, as 5, (see Fig. 15,) of considerable size, controlled by an inwardly-opening valve, 2, and a second orifice, as 3, controlled by a cock, 6. As the piston passes to the opposite end of the cylinder, the atmospheric air will pass freely through the orifice 5 and fill the space behind the piston. As soon as the piston commences to recede, the valve 2 will close, and the air in the cylinder will be forced to pass out through the opening in the cock 6. By opening the cock to the proper extent the air may be permitted to escape sufficiently fast to not interfere with the piston when the engine is running at its normal speed. If, however, the speed of the engine is suddenly accelerated by reason of accident or any sudden change in the condition of running, the confined air in the cylinder will act as a cushion

and prevent damage. The cock for controlling the escape of the air may be controlled automatically by any convenient governing device. Instead of the devices shown and described for controlling the inlet and outlet of the air, any other convenient devices may be employed for this purpose. The cock 6 can also be adjusted so as to act as a partial governor to the engine by increasing the resistance as the speed increases, and vice versa. If found more desirable in any case to use some other resisting medium instead of air, it may be done without departing from the principle of or losing the advantages of the invention.

When it is desired to obtain a very high ratio of expansion, compound cylinders may be employed, and these cylinders may be arranged to operate in connection with a tank, as herein shown, or in any of the other well-known ways.

Although for convenience in describing and illustrating the invention it is herein shown as applied to duplex engines for pumping water, it is equally useful in duplex engines designed for pumping and compressing air.

In the case of an ordinary direct-acting engine a fly-wheel or any other contrivance for storing up and imparting energy through the momentum of moving masses would enable it to perform the same service and to obtain equally good results as it could accomplish by aid of the compensating-cylinders. The compensating-cylinders would, however, alter the character of its motion somewhat, in so far as the increased momentum of their added weight would embarrass and interrupt it. The tendency of this weight would be to oppose the sudden and harsh reciprocation of the stroke inherent in this type of engine, and this would be found straining to the machine and a serious difficulty, especially at high speeds. With such direct-acting engines an important desideratum is that the weight of the moving parts should be reduced to a minimum to enable this sudden stopping and starting of the strokes to be effected with the least possible wrenching and distortion of the engine.

In the case of the duplex pumping-engine described, its one peculiar feature is the variable and adjustable pause which its valve motion permits at the end of each stroke. The effect of this pause when dealing with the pumping of fluids is well known in the art to be of great practical value. The combining with such an engine of a fly-wheel or any other contrivance known before this invention in which the momentum of moving masses is employed for the purpose of enabling it to run under higher ratios of expansion, and consequent economy, would rob it entirely of this distinctive and valuable characteristic, because only a determinate and instantaneous pause at the end of the stroke would then be possible. This fact has hitherto prevented the highest rate of economy being attained by this type of engine. By combining with it the compensating-cylinders, as described, a result heretofore considered impossible with it is accomplished, viz: Not only does it realize as high ratios of expansion as are possible with any fly-wheel type, but the valuable and adjustable pause at the end of the stroke is retained. The duplex pumping-engine thus becomes capable of attaining the highest economic results without the quality of its motion being affected in the least or its well-known smooth and quiet action sacrificed.

I am aware of United States Letters Patent No. 225,351, dated May 9, 1880, and make no claim herein to what is therein set forth; but

What I claim as new, and desire to secure by Letters Patent, is—

1. The combination, with a duplex pumping-engine provided with means whereby the inlet and exhaust valve or valves of one side thereof is or are operated by the other side, of means, substantially as described, whereby power is stored up at one and utilized at another period of the stroke of each side of said engine without preventing the variable pause at the end of each stroke peculiar to this engine.

2. The combination, with the main cylinders and pistons forming the two sides of a duplex pumping-engine, provided with means whereby the inlet and exhaust valve or valves of one side thereof is or are operated by the other side, of a compensating cylinder or cylinders at each side of said engine, each provided with a piston and rod and supplied with a suitable motor-fluid, and acting in opposition to the main cylinder and pistons to which they are connected during the first part of the stroke of said main pistons and in conjunction therewith during the last part of their stroke, substantially as described.

3. The combination, with the main cylinders and pistons forming the two sides of a duplex pumping-engine, provided with means whereby the inlet and exhaust valve or valves of one side thereof is or are operated by the other side, of a compensating cylinder or cylinders at each side of said engine, each provided with a piston and rod and supplied with a suitable motor-fluid, and acting in opposition to the main cylinders and pistons to which they are connected during the first part of the stroke of said main pistons and in conjunction therewith during the last part of their stroke, and a cut-off mechanism, substantially as described.

4. The combination, with a main cylinder and piston, of one or more compensating-cylinders and pistons and means for regulating the pressure of the fluid admitted to said compensating cylinder or cylinders, substantially as described.

5. The combination, with a main cylinder and piston, of one or more compensating cylinders and pistons, a tank, as 4, means for

regulating the pressure of the fluid in said tank, and connections, substantially as described.

6. The combination, with a cylinder, as 18, provided with a piston, and means for maintaining a constant pressure upon one side of said piston, of means for permitting the ingress and egress of a fluid from the opposite side of said piston in such manner as to cushion said piston when it exceeds its normal speed, substantially as described.

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

CHARLES C. WORTHINGTON.

Witnesses:

M. B. PHILIPP,

T. H. PALMER.