(No Model.)

6 Sheets—Sheet 1.

C. C. WORTHINGTON.

DIRECT ACTING ENGINE.

No. 332,857. Patented Dec. 22, 1885.

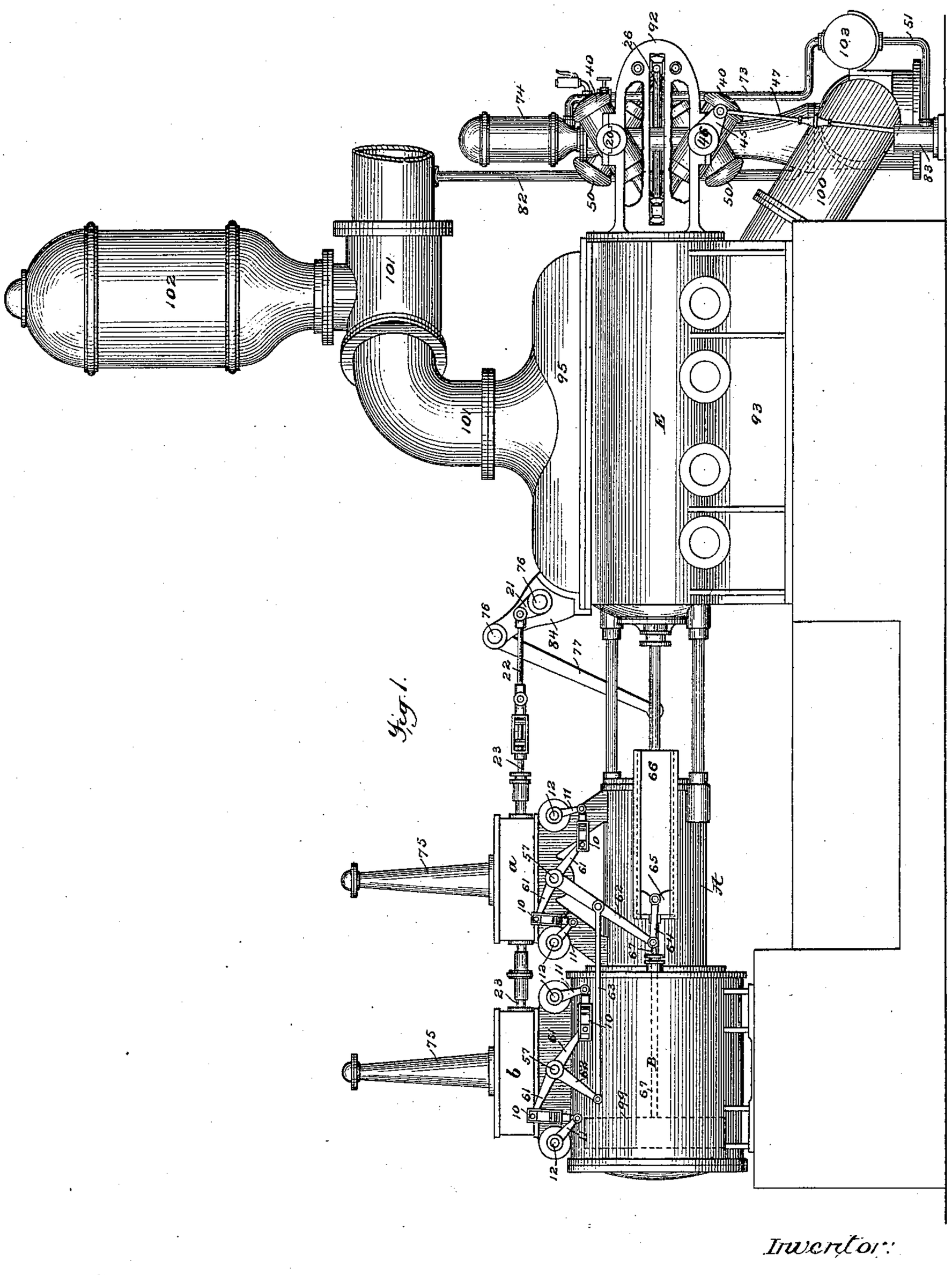

Fig. 1.

Attest:

Geo. H. Botts.

J. A. Harvey

Inventor:

Chester C. Worthington

by Munson & Philipp

Attys

(No Model.) 6 Sheets—Sheet 2.

C. C. WORTHINGTON.

DIRECT ACTING ENGINE.

No. 332,857. Patented Dec. 22, 1885.

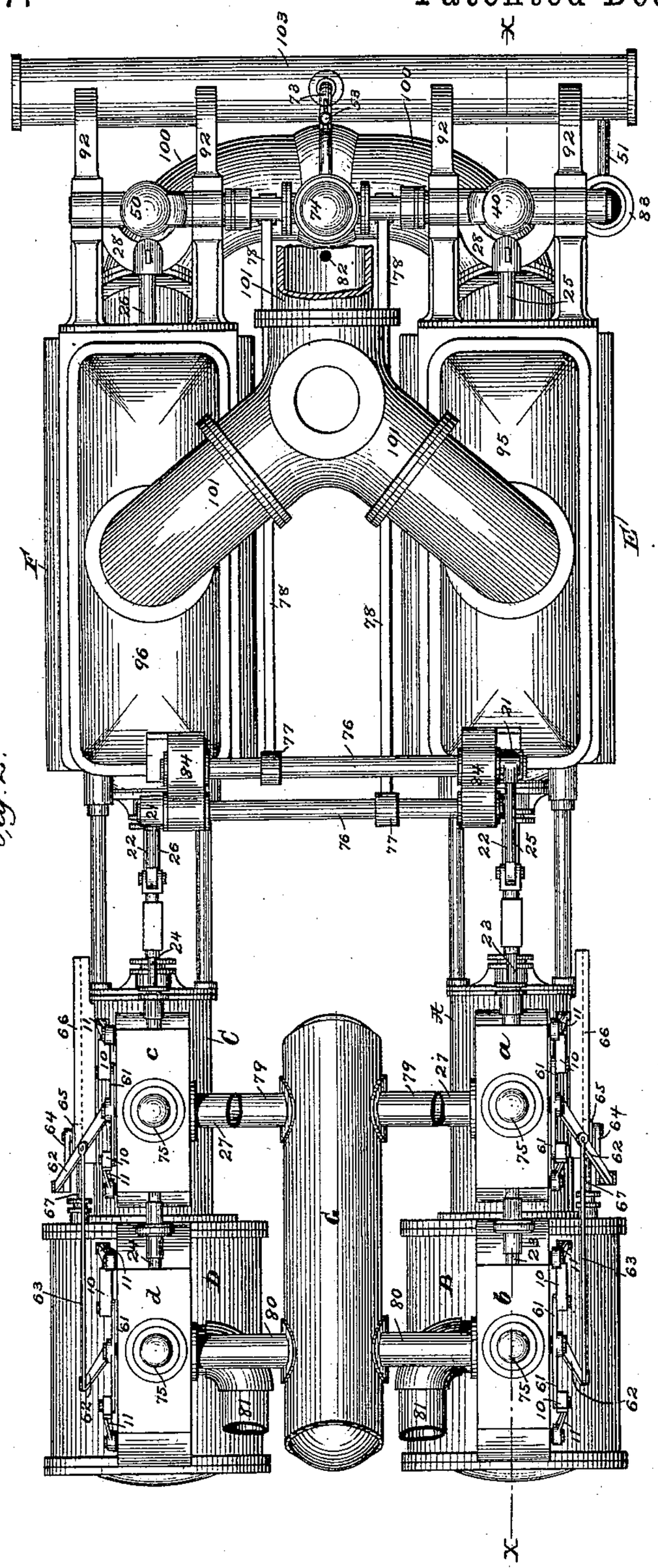

Fig. 2.

Witnesses:

Geo. H. Botts.

Jos. A. Keevey

Inventor:

Charles C. Worthington

by Munson & Philipp

Attys.

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C. C. WORTHINGTON.

DIRECT ACTING ENGINE.

No. 332,857. Patented Dec. 22, 1885.

Fig. 6.

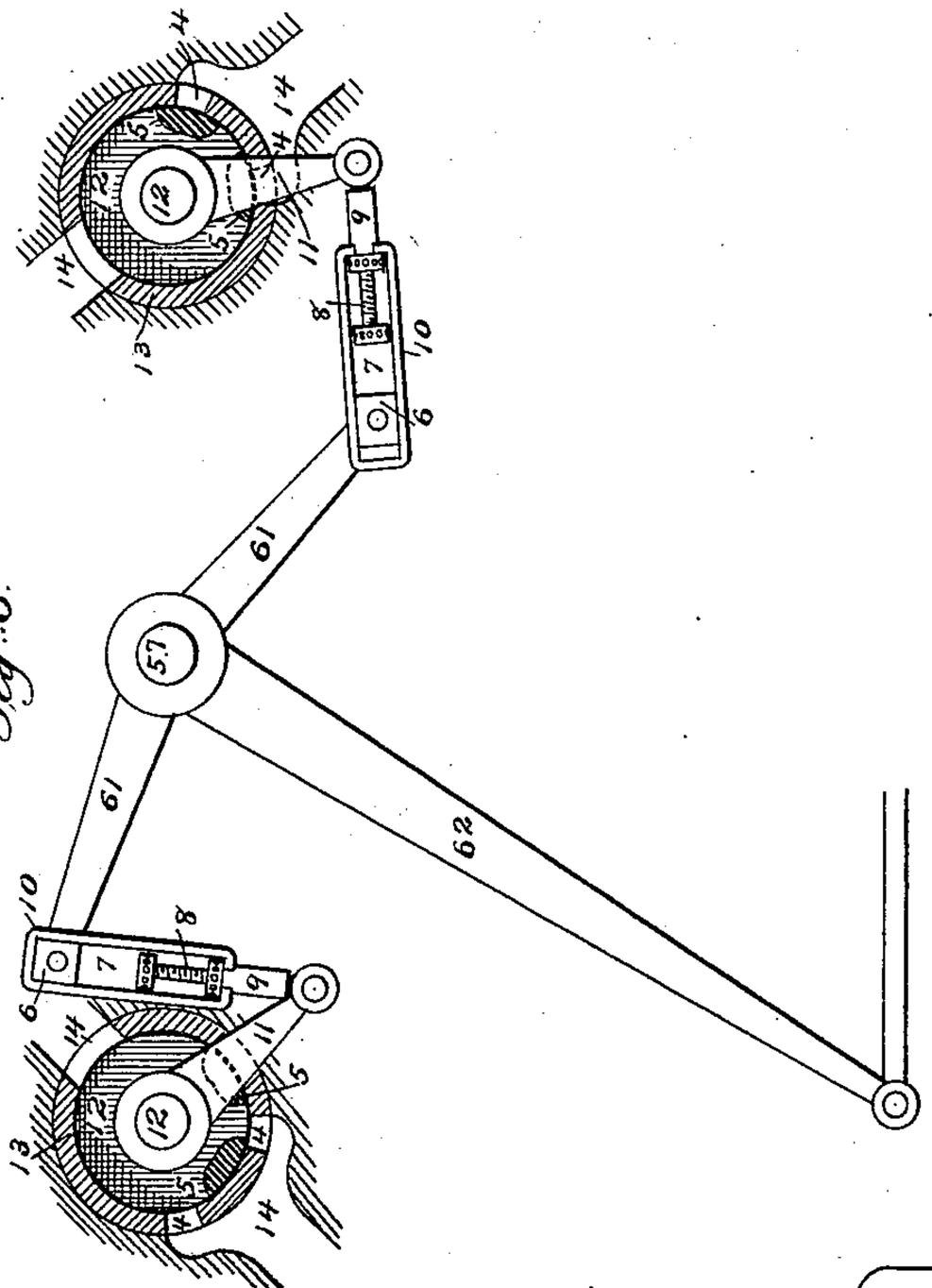
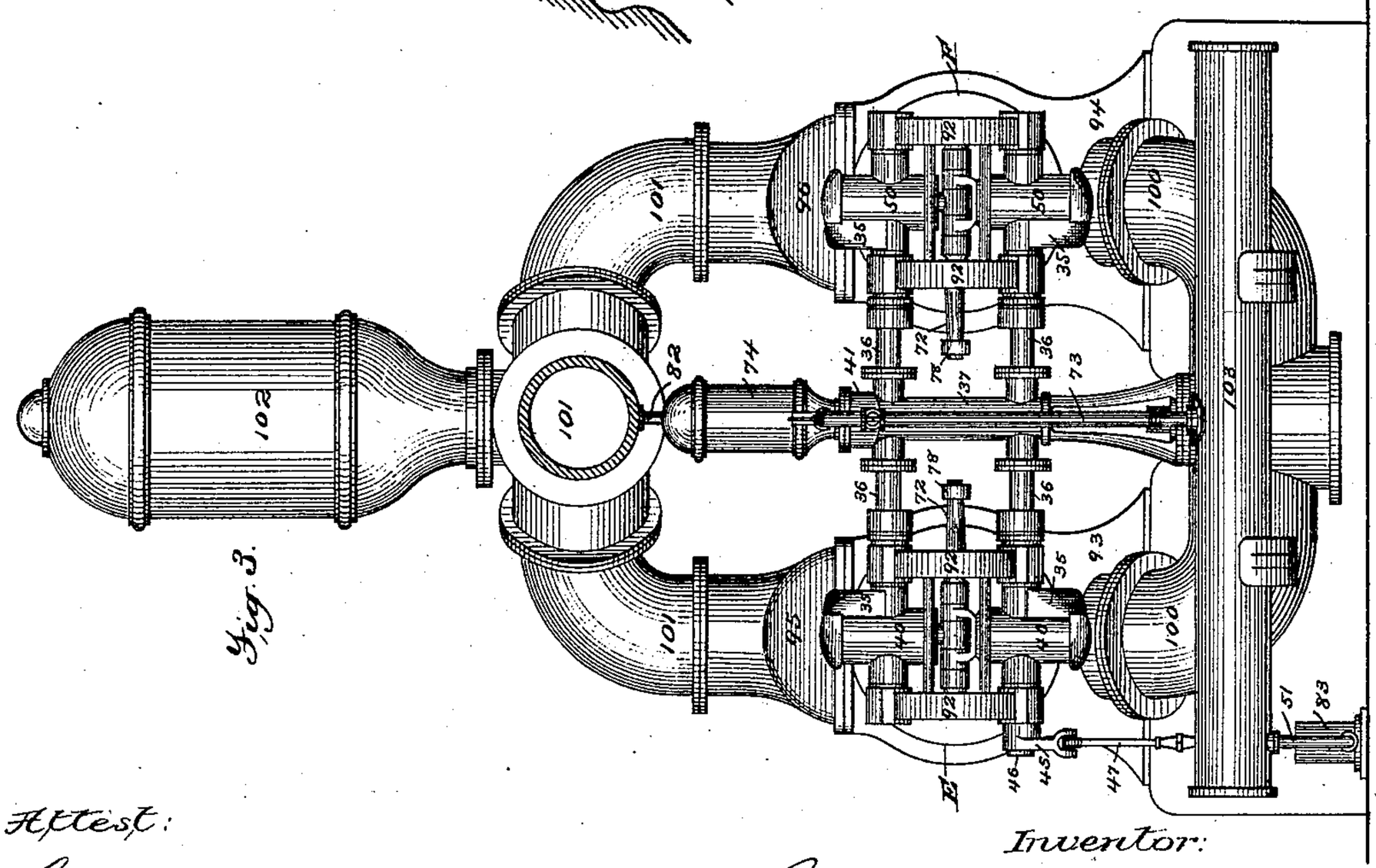


Fig. 3.



Attest:

Geo. H. Botts.

J. A. Hervey

Inventor:

Charles C. Worthington

by Munn & Co

Attys:

(No Model.) 6 Sheets—Sheet 4.

C. C. WORTHINGTON.

DIRECT ACTING ENGINE.

No. 332,857. Patented Dec. 22, 1885.

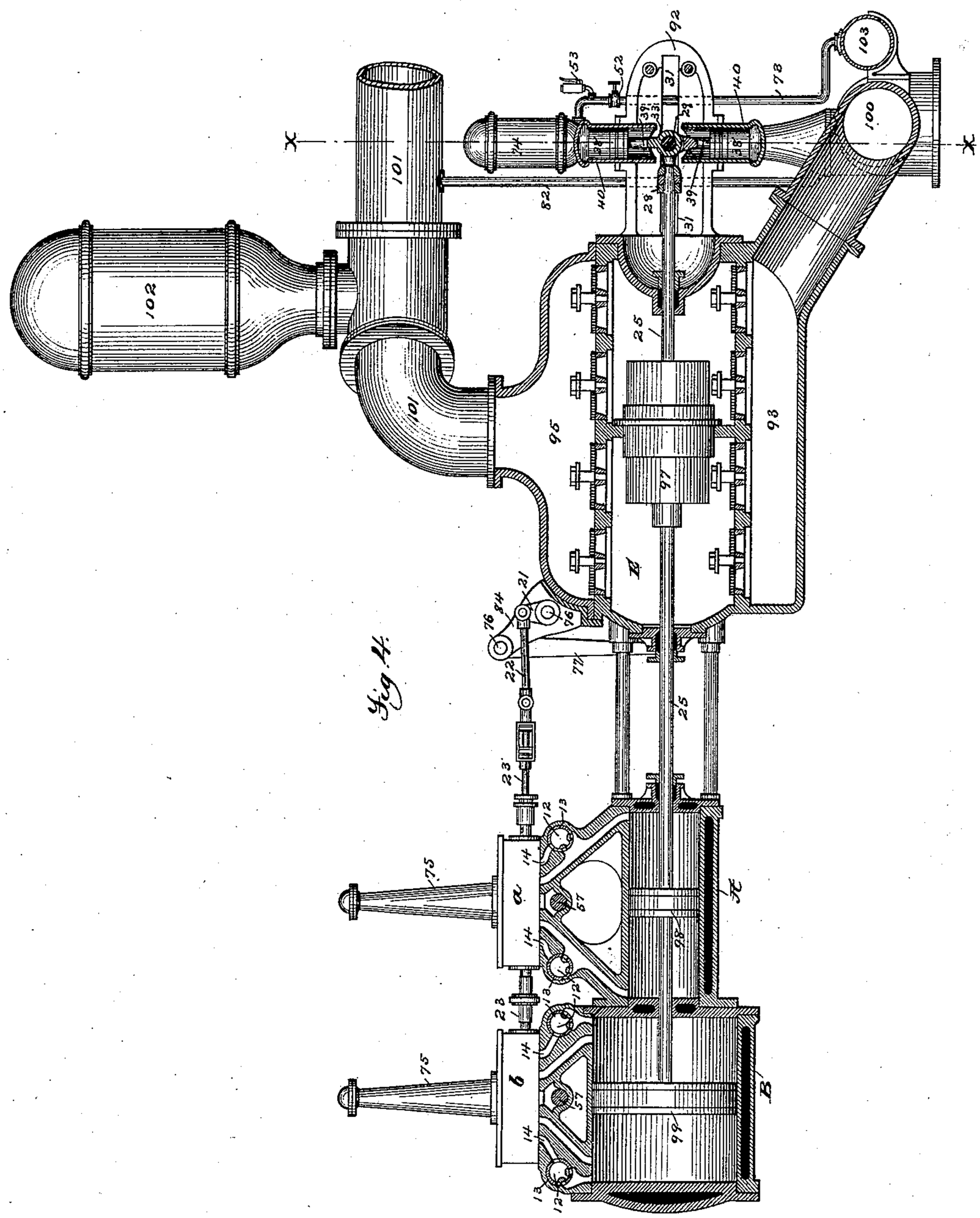


Fig. 4.

Witnesses:
Geo. H. Botts.
J. A. Hervey

Inventor:
Charles C. Worthington.
by Munson & Philipp
Attys.

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C. C. WORTHINGTON.

DIRECT ACTING ENGINE.

No. 332,857. Patented Dec. 22, 1885.

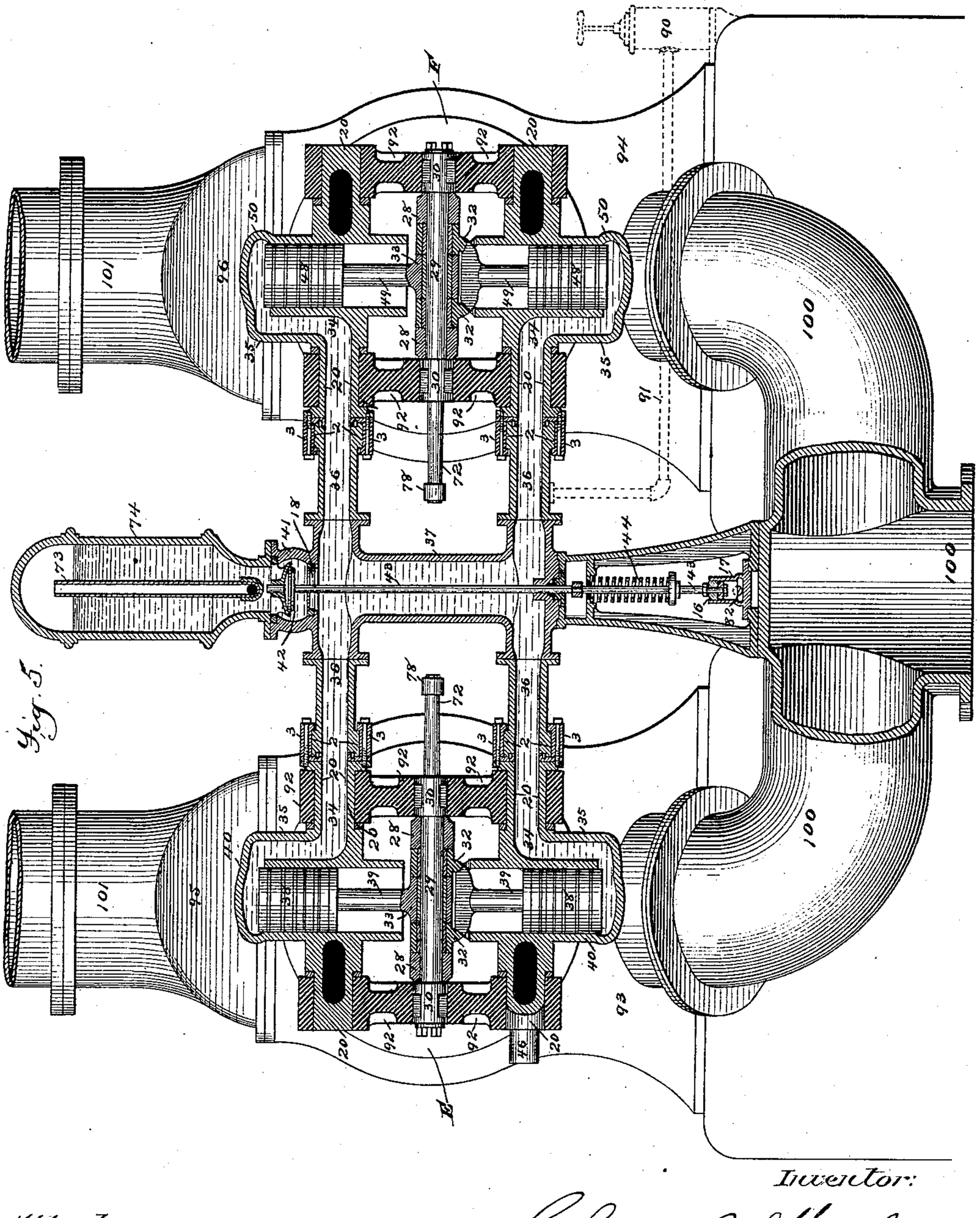


Fig. 5.

Attest:
Geo. H. Botts.
J. A. Covey

Inventor:
Charles C. Worthington
by
J. Munson & Philipp
Attys.

(No Model.) 6 Sheets—Sheet 6.

C. C. WORTHINGTON.

DIRECT ACTING ENGINE.

No. 332,857. Patented Dec. 22, 1885.

Fig. 9.

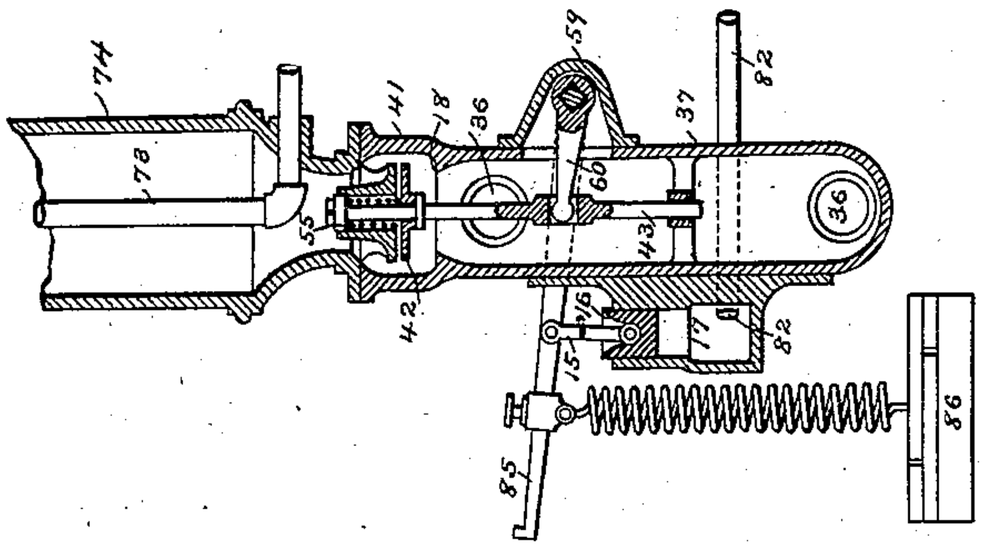


Fig. 10.

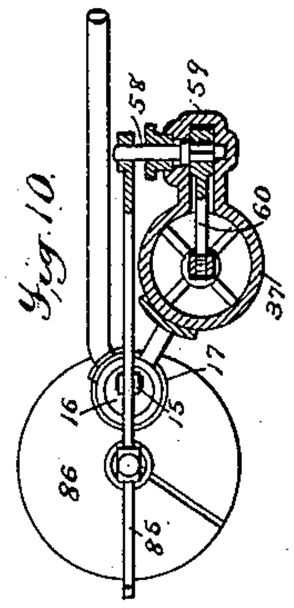


Fig. 11

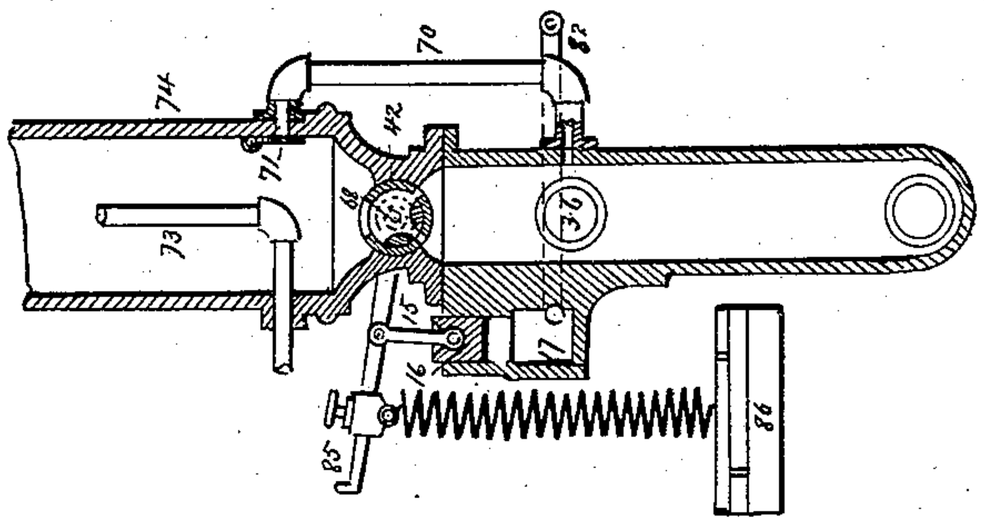


Fig. 8.

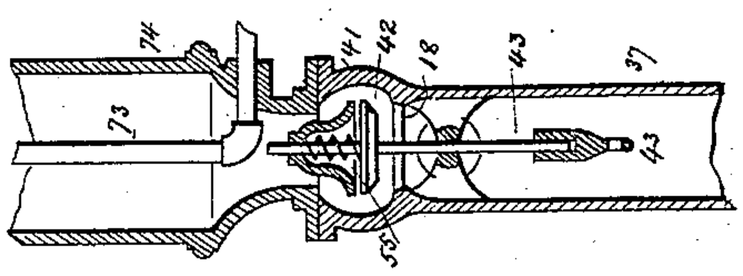
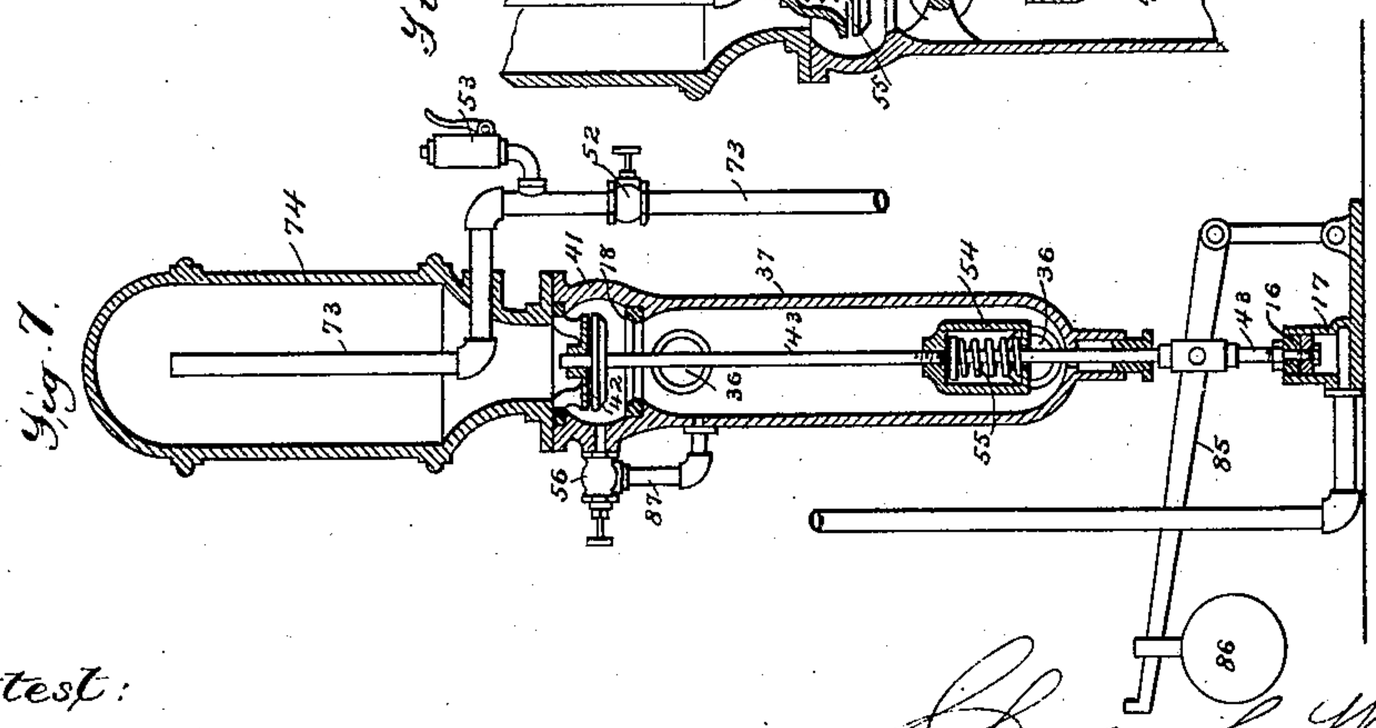


Fig. 7.



Attest:
George H. Botts.
J. A. Hovey

Inventor:
Charles C. Worthington
by Munn & Philipp

Attys.

UNITED STATES PATENT OFFICE.

CHARLES C. WORTHINGTON, OF IRVINGTON, NEW YORK.

DIRECT-ACTING ENGINE.

SPECIFICATION forming part of Letters Patent No. 332,857, dated December 22, 1885.

Application filed September 26, 1885. Serial No. 178,248. (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 Direct-Acting Engines, fully described and represented in the following specification and the accompanying drawings, forming a part of the same.

The present invention relates, generally, to that class of engines which are known as "direct-acting," and particularly to those engines which are provided with one or more compensating or auxiliary cylinders and pistons which are supplied with a suitable motor-fluid, and are arranged to act in opposition to the main piston or pistons during the first part of the stroke of the latter, and in conjunction therewith during the latter part of the stroke, enabling the admission of steam to the main cylinder or cylinders to be cut off before the stroke is completed without reducing the power of the engine at the end of the stroke. One form of such an engine is shown and described in United States Letters Patent No. 292,525, heretofore granted to me.

The present invention consists in various improvements upon the construction and organization therein shown, whereby the engine as a whole is rendered more effective and desirable.

These improvements, briefly stated, consist, first, in a governor valve or cock and connections, which are so arranged that when the engine is running without its load or with less than its full load, or when it is suddenly relieved of its load, the valve or cock will operate to shut off the admission of the motor-fluid to the compensating cylinder or cylinders, and thus prevent the engine from acting violently and causing damage; second, in the interposition of a volume of liquid between the motor-fluid and the piston or pistons of the compensating cylinder or cylinders, which liquid fills the cylinder or cylinders and connections and transmits the pressure of the elastic motor-fluid to the piston or pistons; and, third, in connections by which the valve or valves of the main steam-cylinders are operated in such manner that the breaking of a piston or plunger rod operates to stop the engine.

As a full understanding of these various improvements can only be imparted by a detailed description of the whole organization in which they are embodied, all further preliminary description will be omitted and a detailed description given, reference being had to the accompanying drawings, in which—

Figure 1 is a side elevation of a duplex compound pumping-engine embodying the present invention, the parts being shown in the positions they will occupy when the pistons of the two sides of the engine are at the ends of their strokes in opposite directions. Fig. 2 is a plan view of the engine, showing the parts in the positions they will occupy when the pistons of both sides of the engine are at the middle of their strokes. It is to be understood, however, that when in operation the two sides of the engine are never in these relative positions, they being shown in these positions simply for the purpose of more readily explaining the invention. Fig. 3 is an elevation of the water end of the engine, showing particularly the compensating-cylinders, the parts being in the same position as in Fig. 2. Fig. 4 is a sectional elevation taken upon the line *x x* of Fig. 2. Fig. 5 is an enlarged sectional elevation taken upon the line *x x* of Fig. 4. Fig. 6 is a diagrammatic view illustrating the operation of the cut-off mechanism; and Figs. 7, 8, 9, 10, and 11 are views illustrating modifications in certain details, which will be hereinafter referred to.

Referring to said drawings, it is to be understood that as there illustrated the steam end of the engine, or what may be termed the "engine proper," consists of four steam-cylinders, A B and C D, which are arranged in pairs and to operate upon the compound principle, the pair A B forming one side and the pair C D the other side of the duplex engine. The pistons 98 99 of the cylinders A B are connected to the single piston-rod 25, and the pistons of the cylinders C D are connected to the single piston-rod 26 in the same manner. The cylinders A B and C D are provided with the usual steam-chests, *a b* and *c d*, having ordinary slide-valves, (not shown,) which are provided with balancing-pistons suspended from swinging rods, which are hung in the trunks 75 in the well-known manner. The two valves for each side of the engine are operated by

the same valve-rod, and these rods 23 24 are provided with the usual connections, consisting of links 22, rock-shafts 76, having arms 21 77, and links 78, by which the valves of each side of the engine are operated by the movement of the other. The particular arrangement of these connections constitutes one feature of the present invention, and will be hereinafter fully described. The steam-chests *a c* are provided with induction-pipes 27, through which the steam is supplied to the cylinders A C direct from the boiler. After acting in the cylinders A C the steam is exhausted through the pipes 79 and enters the tank G at a reduced pressure, which pressure is determined by the amount of expansion permitted in the cylinders A C. From the tank G the steam passes through the pipes 80 to the steam-chests *b d*, and thence to the larger cylinders B D, in which it acts, and is allowed to expand down to any desired point, after which it is exhausted through the pipes 81 to a condenser or to the open air.

The organization and operation thus briefly described is common, and will be readily understood by those familiar with this class of engines.

The water end of the engine consists of two water-cylinders, E F, the plungers 97 of which (only one of said plungers being shown) are connected directly to the piston-rods 25 26 in the usual manner. The water-cylinders E F are provided with the usual suction and force chambers, 93 94 and 95 96, the former communicating with the suction-main 100 and the latter with the force-main 101 in the usual manner. The force-main is also provided with the usual air-compression chamber, 102, to equalize the flow of the water discharged from the pump.

The piston-rods 25 26, instead of terminating at the plungers of the water-cylinders, are extended and pass through stuffing-boxes in the ends of said cylinders, and are connected to the piston-rods 39 49 of two pairs of oscillating cylinders, 40 50, which are arranged at the ends of the water-cylinders, substantially as shown in my former Letters Patent before referred to, and are mounted upon trunnions 20, which are supported in a suitable frame-work, 92, extending from the ends of the water-cylinders.

The piston-rods 25 26 are connected to the piston-rods 39 49 of the oscillating cylinders as follows: Each of the rods 25 26 is provided at its end with a yoke, 28, (see Fig. 2,) the arms of which are provided with openings through which passes a rod, 29, the ends of which are provided with suitable heads, 30, which slide in bearings 31 formed in the frames 92. The rods 39 49 of one cylinder (the lower one, as shown) of each of the pairs 40 50 are provided with yokes 32, the arms of which lie just inside the arms of the yokes 28, and are pivoted to the rods 29. The rods 39 49 of the other cylinder of each of the pairs 40 50 are provided with heads 33, which just fit between the arms of the yokes 32, and are also pivoted to the rods 29. The rods 29, where they pass through the heads 33 and the arms of the yokes 32, are provided with suitable bushings, as shown, to reduce the wear upon the bearings.

The motor-fluid is supplied to the oscillating cylinders 40 50 as follows: The inside trunnions, 20, of the cylinders are provided with ducts 34, which, extending through enlargements 35 formed on the sides of the cylinders, open into the outer ends of the cylinders behind their pistons 38 48, as shown in Fig. 5. The ducts 34 communicate with four horizontal branch pipes, 36, which abut against the ends of the trunnions 20, and lead to a main vertical pipe, 37, which opens at its upper end into a closed chamber, 74, which has a capacity at least equal to the combined displacement of the four pistons 38 48. The ends of the pipes 36 which abut against the trunnions 20 are provided with flanges or enlargements 2, over which fit flanged couplings 3, which are bolted to the ends of the trunnions. By this means and by the use of a suitable packing between the ends of the trunnions and the pipes 36 a tight joint is formed between the oscillating trunnions and the stationary pipes 36. The upper end of the pipe 37 is slightly enlarged, so as to form a chamber, 41, for a valve, 42, the rod 43 of which extends downward through the pipe 37 and passes out through a suitable stuffing-box located in the lower end of the pipe. The bottom of the chamber 41 is so formed that when the valve 42 is permitted to fall to its seat 18 it will shut off all communication between the chamber 74 and the pipe 37. The purpose of this arrangement will be made clear when the operation of the apparatus is explained. The lower end of the rod 43 is provided with a small piston, 16, which works in a cylinder, 17, the bottom of which communicates by a pipe, 82, with the force-main 101. By means of this arrangement the pressure of the water in the force-main is always exerted upon the bottom of the piston 16, and this pressure, under ordinary working conditions, is sufficient to raise the piston in its cylinder and hold the valve 42 in its raised position. The rod 43 is provided with a spring, 44, which is arranged between a collar on the rod and a stationary part of the fame-work, and the tendency of which is to force the rod 43 and valve 42 downward, so as to close the valve and shut off communication from the chamber 74 to the pipe 37. The purpose of this arrangement will also be made clear when the operation of the apparatus is described.

As explained in my former Letters Patent, No. 292,525, the motor-fluid which is used in the compensating-cylinders 40 50 may be steam, which can be supplied from the boiler of the engine and admitted to the cylinders either directly or through a tank, in which it is maintained at a suitable pressure; or it may

be a liquid which is maintained at a suitable pressure by any means; or it may be compressed air or other gas, which is maintained at the proper pressure in any suitable manner, as by a compressing-pump operated either by the engine, as shown and described in my Letters Patent No. 309,676, or in any other convenient manner. There are, however, many cases in which it is not desirable to use steam in the compensating-cylinders, and it has also been found in practice that there are certain disadvantages incurred in the use of compressed air or other gas in these cylinders which it is desirable to avoid.

Among other things, it has been found particularly difficult to prevent the air or other gas from leaking past the pistons of the compensating-cylinders without packing these pistons so tightly as to cause a considerable loss of power by reason of the friction.

I have found that the most satisfactory results can be attained by using a compressed gas, preferably air, as the motor-fluid and transmitting the pressure of the gas to the pistons of the compensating-cylinders through the medium of a body of a water, oil, or other non-compressible fluid which fills the cylinders and connections and acts directly upon the pistons. By this means a liquid packing is interposed between the compressed gas, which, for convenience, will be called "air," and the pistons of the compensating-cylinders, which fills the cylinders and connections, and thus acts to prevent the escape of the air by leakage, and also to keep the pistons well lubricated.

The compressed air which acts upon the pistons 38 48 through the body of liquid, which, for convenience, will be called "water," contained in the chamber 74 and the cylinders 40 50 and connections, is supplied and maintained at the proper pressure by any suitable form of air-compressing apparatus. The apparatus for this purpose will preferably, however, consist of an air-compressing pump, 83, of the construction shown in my former Letters Patent, No. 309,676, and this pump will preferably be operated from a crank-arm, 45, which is fixed on an extension, 46, of one of the trunnions 20 of the oscillating cylinders. By operating the pump 83 in this manner it is caused to make two strokes to each stroke of the engine, the advantages of which operation are fully set forth in my said former Letters Patent. The rod 47 of the pump 83 may, however, be connected to and operated from any other moving part of the engine. The discharge-pipe 51 of the pump 83 communicates with a closed tank, 103, the same as described in my said former Letters Patent, and this tank is provided with a conduit-pipe, 73, which enters the bottom of the chamber 74 and extends upward in the chamber, terminating at a point above the surface of the water therein. The pipe 73 is provided with a cock or valve, 52, by which it can be closed when it is desired to prevent the passage of the air from the tank 103 to the chamber 74. The pipe 73 or the chamber 74 is also provided with a relief-valve, 53, by which the air is allowed to escape if its pressure becomes too great, or by which it can be drawn out if it is desired to remove all pressure from the chamber 74, or the chamber and the tank 103.

The rock-shafts 76, through which the valve-rods 23 24 are operated from the links 78, instead of being mounted in bearings supported upon the tie-rods which connect the steam and water cylinders, as has been heretofore common, are mounted in bearings 84, secured to the ends of the water-cylinders or their force-chambers, and the links 78, instead of being connected to and receiving motion from cross-heads secured to the piston-rods 25 26, between the steam and water cylinders, as has heretofore been customary, are arranged to pass between the water-cylinders, and are connected to extensions 72 of the rods 29. By reason of this arrangement not only can the distance between the steam and water cylinders be reduced so as to make the engine much more compact, but the valves of the steam-cylinders are also so operated that they will be arrested upon the breaking of either of the main piston-rods 25 26, thereby stopping the engine. This latter is a feature of great importance, as when the valves were operated from cross-heads upon the piston-rods the breaking of a rod at any point between the cross-head and the pump-plunger did not arrest the valves, and consequently the engine would continue to operate; but being relieved of the load the pistons would move with great violence and endanger the engine.

The operation of the engine thus organized will now be described. For the purpose of this description it will be assumed that the chamber 74 and the connections leading to the cylinders 40 50 are filled with water, which rises in the chamber to a point somewhat below the top of the pipe 73, as indicated in Fig. 5, and also that the compressor 83 has been operated, by hand or otherwise, so that the proper pressure exists in the tank 103 and on the surface of the water on chamber 74. For the purpose of filling the chamber 74 and the connections leading to the cylinders 40 50 with water, there may be provided a small hand-pump, as 90, (shown by dotted lines in Fig. 5,) which is connected by a pipe, 91, with one of the pipes 36, or with the pipe 37 or the chamber 74. Let it be now assumed that steam has been admitted to the cylinders A B and C D, and that the pistons 98 99 of the cylinders A B are commencing their stroke toward the water-cylinders. When the parts are in this position, the cylinders 40 and their pistons and rods will be in position to act in opposition to the main piston-rod 25, as shown in Fig. 1. As the pistons 98 99 advance the pistons 38 will be forced back into the cylinders 40, so as to expel the water therefrom and force it back into the chamber 74 against the pressure of the air in the tank 103. The opposition thus

offered by the pistons 38 will, however, owing to the constant change in the angles of the rods 39, gradually decrease, until the pistons 98 99 arrive at the middle of their stroke, at which point the pistons 38 will act in opposition to each other, as shown in Fig. 4, and offer no opposition to the rod 25. During the remainder of the stroke the operation is reversed, the water in the chamber 74, acted upon by the compressed air in the tank 103, is forced back into the cylinders 40, and the pistons 38, instead of offering a gradually-decreasing opposition, offer a gradually-increasing assistance to the pistons 98 99. During this operation the link 78, acted upon by the rod 29, will be moved so as to rock the shaft 76, and through the arm 21 move the rod 24 and the valves of the cylinders C D, so that just as the pistons 98 99 of the cylinders A B complete their stroke toward the water-cylinders steam will be admitted to the cylinders C D to start the pistons of those cylinders upon their stroke in the same direction. During this stroke the cylinders 50 and pistons 48 will act, first, in opposition to and then in conjunction with the pistons of the cylinders C D, the same as just described in connection with the cylinders A B, and just at the end of the stroke the other link, 78, acted upon by the other rod, 29, will rock the other shaft, 76, and through its arm 21 move the rod 23 and the valves of the cylinders A B, so as to start the pistons 98 99 upon their return-stroke, and so the operation will continue to be repeated, all as more fully set forth in my former Letters Patent, No. 292,525. If from any cause the pressure of the air in the tank 103 should become reduced below the proper point, the rod 47 of the compressor 83 will be connected to the crank-arm 45, so as to set the compressor in operation and force more air into the tank, and thus raise the pressure. If at any time either one of the piston-rods 25 or 26 should break at any point, so as to disconnect the rod 29 from the steam-pistons, this rod will, of course, be arrested either immediately or at the end of the stroke of the pistons 38 or 48, to which it is connected. As soon as either of the rods 29 is thus arrested the link 78, to which it is connected, will also be arrested, thus stopping the valves of the opposite side of the engine, and consequently bringing that side of the engine to rest at the end of the stroke which it is then making. As soon as one side of the engine is thus brought to rest the valves of the other side (the one having the broken rod) will of course receive no further movement, and the steam will thus be prevented from entering the cylinders. This is a feature of great importance, as if the valves were operated so as to allow the steam to act upon the pistons after the rod was broken the pistons, being relieved of their load, would be moved violently in the cylinders, and would be liable to cause great damage to the engine. In pumping water or other liquid through a long line of horizontal or nearly horizontal pipe—as, for example, in the petroleum-oil pipe-lines, where the main part of the power of the engine is expended not in raising the liquid but in overcoming the friction of the liquid against the sides of the pipe—the pressure in the pipe, and, as a consequence, the load upon the engine, depends to a very great degree upon the velocity with which the liquid is moved through the pipe. From this it results that when the engine is moving slowly, as in starting, and the liquid is consequently moving slowly in the pipe, the pressure in the pipe and the load upon the engine are comparatively light, but gradually increases as the speed of the engine increases until the maximum is reached. In those cases also where the pressure in the pipe and the load upon the engine are due to the height to which the water or other liquid is forced it sometimes happens that it is necessary to start the engine with little or no load upon it. This is the case when, for any reason, the force or discharge main has become emptied while the engine is at rest. In such case the pressure in the main and the load gradually increase as the main is filled until the maximum is reached. In any of these cases it is of course necessary, in order to prevent the engine from acting violently and causing damage, to graduate the power which the engine is permitted to develop to the load which is to be moved, the power developed being allowed to gradually increase as the speed of the engine and the load increases. In ordinary engines this can be done by operating the throttle-valve so as to properly regulate the amount of steam admitted to the steam-cylinders, and so far as the available power which is developed by the main cylinders is concerned this can be readily done in the present engine; but as to the power developed by the compensating-cylinders the case is different. The power developed by these cylinders, as will readily be seen, is always the same, regardless of the quantity of steam admitted to the main cylinders, and cannot be regulated or controlled by the operation of the throttle-valve. When, therefore, the engine is to be started, or run with little or no load, there must of course be sufficient steam admitted to the main cylinders to overcome the resistance offered by the pistons of the compensating-cylinders up to the middle of the stroke. As soon, however, as the middle of the stroke is reached the main pistons are not only relieved of this resistance or load, but are assisted by the pistons of the compensating-cylinders, so that, unless means were provided for preventing it, the last half of the stroke would be made with great violence, which would be liable to cause damage. In pumping against heavy pressure there is also of course some danger that the force-main may burst, which, in case it should happen, would suddenly relieve the engine of the whole or a large part of its load, thus allowing the speed of the engine to become suddenly accelerated to such an extent as to be liable to

occasion damage. In order to avoid all of these difficulties, and to prevent the engine from damaging itself under any of these circumstances, there is provided a governor valve or cock and connections, which are so arranged that when the engine is started or run without its load, or with considerably less than its full load, or when suddenly relieved of the whole or a large part of its load, the valve or cock will operate to shut off or regulate the admission of the motor-fluid to the compensating-cylinders, and thus prevent the engine from acting violently, so as to cause damage. This governor cock or valve may be arranged to be operated in a variety of ways, either by the speed of the engine or by the direct action of the load. In the case of a pumping-engine it will preferably be controlled and operated by the pressure of the liquid in the force-main. For this purpose, therefore, the pipe 37, through which the water flows in passing from the chamber 74 to the cylinders 40 50, is provided with the governor-valve 42, the rod of which is provided with the spring 44, and the piston 16, working in the cylinder 17, which communicates through the pipe 82 with the force-main, as hereinbefore described. The piston 16 is of such area that when the ordinary working-pressure exists in the force-main the pressure upon the piston, communicated from the main through the pipe 82, will raise the piston against the tension of the spring 44, and hold the valve 42 in its raised position, as shown in Fig. 5, so as to permit the water to flow freely from the chamber 74, through the pipes 37 36, to the compensating-cylinders. When, however, from any cause the pressure in the main, and consequently the load upon the engine, is reduced to any considerable extent, a corresponding reduction will take place in the pressure upon the piston 16, so that the tension of the spring 44 will be sufficient to move the rod 43 and the piston downward and close the valve 42, and thus prevent any of the water in the chamber 74 from being forced into the compensating-cylinders. As soon as this takes place the pistons 38 48, instead of working in conjunction with the main pistons during the last half of the stroke, will either be in equilibrium, or work against a partial vacuum, so as to either exert no power or offer a constantly-increasing resistance to the main pistons. If the valve 42 should be thus closed at a time when either pair of the compensating-cylinders are moving toward the center of the stroke, the water in the cylinders will be forced past the valve back into the chamber 74, but will then be prevented by the valve from passing in the opposite direction.

From what has been said it will be seen that the governor-valve 42 serves two purposes: First, when the engine is started or run with little or no load, it prevents the pistons of the compensating-cylinders from acting, and thus avoids the violence which would be occasioned by allowing these pistons to act when there was no load upon the engine. As soon, however, as the load upon the engine, or the pressure in the main 101 becomes sufficient to render the assistance of the pistons of the compensating-cylinders desirable, the valve permits these pistons to be brought into action; and, second, when for any reason, as by the bursting of the main 101, the engine is suddenly relieved of a large part or the whole of its load, this valve at once prevents the compensating cylinders and pistons from acting further and causing damage.

The construction and arrangement of the governor-valve 42 and the connections for operating the same, which have been described, are regarded as the best for the purpose; but the form of the valve and of the connections for operating it may be varied within wide limits without departing from the invention.

When the engine is used for pumping, it is preferable, as before stated, that the governor valve or cock should be operated by the pressure of the liquid in the force-main; but it is not essential that it should be so operated. In the case of an engine which is not used for pumping, or even in the case of a pumping-engine, it may be operated by any ordinary form of governor which is connected to some moving part of the engine, and so arranged that whenever the engine attains an undue speed it will operate the valve or cock so as to prevent the pistons of the compensating-cylinders from acting.

Even when the valve 42 is operated by the pressure in the force-main many modifications may be made in the connections between the valve and the piston 16 without departing from the essential features of the invention. Several of the many modifications which may be thus made are illustrated in Figs. 7, 8, 9, and 10.

In the construction shown in Fig. 7 the spring 44 is omitted and a pivoted lever, 85, provided with an adjustable weight, 86, is used for forcing the piston 16 downward to close the valve 42 when the pressure is removed from the piston. In this case also the rod 43 is provided with a telescopic connection, 54, having a light spring, 55, which will permit the valve 42 to to be raised, after the piston 16 has been lowered, to allow the water to be forced from the pipe 37 into the chamber 74 without raising the piston 16. In this case also the pipe 37 is provided with a by-pass, 87, having a cock or valve, 56, by which the water can, when desired, be allowed to flow from the chamber 74 to the pipe 37, and the compensating-cylinders when the valve 42 is closed. This by-pass affords means by which, when necessary, the water can be allowed to flow slowly into the compensating-cylinders, so that, in starting the engine, for example, the pistons of these cylinders can be allowed to act slowly before the pressure in the main 101 has become sufficient to open the valve 42. This by-pass can, of course, be

applied to any other arrangement of valve or cock.

The construction shown in Fig. 8 is the same as that shown in Fig. 7, except that the spring 55 is located above the valve 42, instead of in the telescopic connection 54.

In the construction shown in Figs. 9 and 10 the cylinder 17, instead of being located beneath the pipe 37, is arranged at the side of the pipe, and the piston 16, instead of being upon the end of the valve-rod 43, is connected by a short link, 15, with the lever 85, the lever in this case being connected to a short rock-shaft, 58, which passes through a stuffing-box in an offset, 59, of the pipe 37, and is provided with an arm, 60, the end of which enters an opening in the rod 43. The spring 55 in this case is arranged above the valve 42, the same as in the construction shown in Fig. 8. The rod 43 is not provided with the telescopic connection 54, the valve 42 being arranged to have a slight movement along the rod instead. In the construction shown in these last two figures the friction of the shaft 58, turning in the stuffing-box in the side of the pipe 37, is less than the friction of the rod 43, moving through the stuffing-box in the bottom of the pipe, and consequently the movement of the valve and rod is made more easy, and the apparatus is consequently rendered more sensitive to variations in the pressure of the water in the force-main.

The valve 42, instead of being of the form already described, may be of any other suitable form, or may be in the form of a cock, as shown in Fig. 11. In this case the plug 68 of the cock 42 is connected to the lever 85, and is so arranged that when the lever is rocked by the upward movement of the piston 16 it will be opened to permit the water to flow out of the chamber 74 to the compensating-cylinders, as shown in said figure. As soon, however, as the pressure is removed from the piston 16 the weight 86 will rock the lever 85 in the opposite direction, so as to close the cock. When a cock is used in place of the valve, there will be provided a by-pass, as 70, or some equivalent means, having an inwardly-opening check-valve, as 71, which will allow the water to flow from the compensating-cylinders when the cock is closed. This by-pass 70 and valve 71 may be made to also perform the function of the by-pass 87 and valve 56 by providing means for preventing the valve 71 from entirely closing. In any of these cases a spring may be used in place of the weight 86, or a spring may be combined with the weight, as shown in Figs. 9, 10, and 11. So, also, the rod 43 or link 15, instead of being connected to a piston, as 16, may be connected to a diaphragm which is acted on by the pressure in the force-main.

Many other modifications may be made in the connections for operating the valve 42, but those shown are deemed sufficient to impart a full understanding of the invention.

From what has heretofore been said it will be seen that during the first half of the stroke of each side of the engine only a part of the power exerted by the steam upon the pistons 98 99 is available for moving the load, the remainder being used to overcome the resistance offered by the pistons of the compensating-cylinders, but that during the last half of the stroke the whole power of the steam upon the pistons 98 99 is available for moving the load, and in addition thereto the power exerted by the pistons of the compensating-cylinders. This fact makes it possible to cut off the steam from the main cylinders after a part of the stroke has been made and yet obtain a practically-uniform propulsive power throughout the entire stroke. The cylinders A B and C D are therefore provided with suitable cut-off mechanisms, by which, after their pistons have advanced a certain distance, say one-half, or somewhat more or less than one-half, the stroke, the further admission of steam is cut off, the remainder of the stroke being accomplished by the expansive force of the steam already in the cylinders, aided by the power exerted by the pistons of the compensating-cylinders, the gradual falling off of power, due to the expansion of the steam in the main cylinders, being compensated for by the gradual increase of available power exerted by the pistons of the compensating-cylinders.

For the purpose of cutting off the admission of the steam to the cylinders A B and C D at the proper point in the stroke, the induction-ports 14 of these cylinders are provided with bushings 13, having plugs or rotary valves 12, which extend through the walls of the ports 14, and are provided with arms 11, which are connected by links 10 with two pairs of levers, 61, which are fulcrumed on studs 57, as shown. (See Figs. 1, 2, and 6.) The levers 61 are provided with arms 62, connected by links 63, so that the two levers of each pair are caused to move in unison. The arm 62 of the inner levers of the two pairs are extended and connected by links 64 with heads 65, which are arranged to slide in bearings 66, located at the sides of the cylinders A C. The heads 65 are provided with rods 67, which pass through stuffing-boxes in the ends of the cylinders B D, and are connected to their pistons 99. The bushings 13 are provided with ports 4, which open into the ports 14, and the valves 12, which are cut away at their centers, are provided with solid portions 5, which are so located that as the valves are turned they will pass over and close the ports 4. The ends of the levers 61 are connected to the links 10 by means of heads 6, which slide in slots 7 formed in the links, as best shown in Fig. 6, thus allowing an amount of lost motion between the levers and the arms 11. The parts 9 of the links 10 are tapped and provided with screw-bolts 8, which can be set in different positions, so as to change the amount of lost motion in the links 10, and thus vary the point of cut-off. The parts will be so proportioned and adjusted that when the pistons of the cylinders A B and

C D commence their strokes the ports 4 of the bushings at the ends of the cylinders which are receiving steam will be open and the ports 4 at the opposite ends will be closed, as shown in Fig. 6.

As the cut-off mechanisms for all four of the cylinders are exact duplicates the description of the operation of one will suffice for all four. During the first part of the stroke the heads 6 will move idly in the slots 7, and will, consequently, not move the valves 12. When, however, the piston arrives at the point where it is desired to cut off the further admission of steam behind the piston, the head 6 at the end of the cylinder which is receiving steam will come into contact with the bolt 8 and quickly turn the valve 12, so that the solid portions 5 will cover the ports 4 and shut off the further admission of steam behind the piston. After this takes place the head 6 will move back idly in the slot 7 during the remainder of the stroke. As the piston nears the end of its stroke, however, the head 6 at the other end of the cylinder, which has been moving idly in the slot 7 of its link 10, (first toward the arm 11 and then away from it,) will come into contact with the end of the slot and turn the valve 12 of that end of the cylinder from the position shown in Fig. 6, so as to uncover the ports 4 and permit steam to enter that end of the cylinder when the main valve is reversed. Upon the return-stroke of the piston the operation will be repeated. From this it will be seen that upon the stroke during which the valve is closed there is lost motion between the lever 61 and the arm 11, both before and after the closing of the valve, while upon the stroke during which the valve is opened the lost motion is all before it is opened.

By adjusting the bolts 8 the length of the slots 7 can be varied so as to cause the ports 4 to be closed sooner or later, and thus vary the point of cut off as may be desired.

The cut-off mechanism just described is regarded, all things considered, as the most desirable form for the purpose; but any other known form of mechanism for this purpose may be employed, if preferred.

In conclusion, it is to be remarked that although the invention is herein shown as applied to a duplex compound engine this form of engine has been selected merely for the purpose of illustration. The invention may be applied equally well to duplex engines which do not employ compound cylinders, or to single engines which are either simple or compound. In fact, as to its main features, the invention may be applied to any direct-acting engine for whatever purpose employed. In the case of a single engine the link 78 will, of course, be connected to its own piston-rod at the outer end of the water-cylinder, in the same manner that it is connected to the piston-rod of the opposite side of the engine in the case of a duplex engine.

Instead of providing two of the compensating-cylinders for each of the main piston-rods, only one such cylinder may be provided, and the compensating cylinder or cylinders, instead of being located at the outer end of the water-cylinders and arranged to oscillate, may be located between the water and steam cylinders, or at the outer ends of the steam-cylinders, and they may be arranged to operate upon the main piston-rods in any of the ways described and shown in my former Letters Patent, No. 292,525, or in any other way.

Instead of using a single governor valve or cock to control the admission of the motor-fluid to all of the compensating-cylinders, there may be one of these valves or cocks for each of the compensating-cylinders.

It is also to be remarked that parts of the invention may be used without the whole. The governor valve or cock 42 may be omitted, or this valve or cock may be used when the motor fluid is a liquid instead of a gas, with a liquid packing interposed between it and the pistons of the compensating-cylinders. So, also, the valve or valves of the main steam cylinder or cylinders may be operated in the ordinary manner, instead of from the end or ends of the main piston rod or rods; or the connections shown for operating the valve or valves of the main steam cylinder or cylinders may be applied with advantage to engines which do not employ the compensating-cylinders, or in which the compensating cylinder or cylinders are located in a different position from that shown. So, also, the cut-off mechanism herein shown may be applied with advantage to other forms of engines.

No claim is herein made to the mechanism, *per se*, shown and described for cutting off the admission of steam to the cylinders A B and C D, as the same forms the subject-matter of another application filed by me in the United States Patent Office November 10, 1885, Serial No. 182,330.

What I claim is—

1. The combination, with a main cylinder or cylinders and piston or pistons, of a compensating cylinder or cylinders provided with a piston or pistons and rod or rods, and supplied with a suitable motor-fluid and arranged to act in opposition to the main piston or pistons during the first part of the stroke, and in conjunction therewith during the last part of the stroke, and a governor valve or cock arranged to control the admission of the motor-fluid to the compensating cylinder or cylinders, substantially as described.

2. The combination, with the main cylinders and pistons forming the two sides of a duplex engine, and provided with connections by which the valve or valves of each side is or are operated by the other side, of a compensating cylinder or cylinders for each side of the engine, each provided with a piston and rod, and supplied with a suitable motor-fluid and arranged to act in opposition to the main piston or pistons to which they are connected during the first part of the stroke, and in conjunction therewith during the last part of the

stroke, and a governor valve or cock arranged to control the admission of the motor-fluid to the compensating-cylinders, substantially as described.

3. The combination, with a main cylinder or cylinders and piston or pistons, of a compensating cylinder or cylinders provided with a piston or pistons and rod or rods, and supplied with a suitable motor-fluid and arranged to act in opposition to the main piston or pistons during the first part of the stroke, and in conjunction therewith during the last part of the stroke, and a governor valve or cock controlled by the resistance of the load upon the engine and arranged to admit the motor-fluid to or shut it off from the compensating cylinder or cylinders, according to the resistance offered by the load, substantially as described.

4. The combination, with the main cylinders and pistons forming the two sides of a duplex engine and provided with connections by which the valve or valves of each side is or are operated by the other side, of a compensating cylinder or cylinders for each side of the engine, each provided with a piston and rod and supplied with a suitable motor-fluid and arranged to act in opposition to the main piston or pistons to which they are connected during the first part of the stroke, and in conjunction therewith during the last part of the stroke, and a governor valve or cock controlled by the resistance of the load upon the engine and arranged to admit the motor-fluid to or shut it off from the compensating-cylinders, according to the resistance offered by the load, substantially as described.

5. In a pumping-engine, the combination, with a main cylinder or cylinders and piston or pistons, of a compensating cylinder or cylinders provided with a piston or pistons and rod or rods and supplied with a suitable motor-fluid, and arranged to act in opposition to the main piston or pistons during the first part of the stroke, and in conjunction therewith during the last part of the stroke, and a governor valve or cock controlled by the pressure in the force-main and arranged to admit the motor-fluid to or shut it off from the compensating cylinder or cylinders, according to the pressure in the main, substantially as described.

6. The combination, with the main cylinders and pistons forming the two sides of a duplex pumping-engine and provided with connections by which the valve or valves of each side is or are operated by the other side, of a compensating cylinder or cylinders for each side of the engine, each provided with a piston and rod and supplied with a suitable motor-fluid, and arranged to act in opposition to the main piston or pistons to which they are connected during the first part of the stroke, and in conjuction therewith during the last part of the stroke, and a governor valve or cock controlled by the pressure in the force-main and arranged to admit the motor-fluid to or shut it off from the compensating-cylinders, according to the pressure in the main, substantially as described.

7. The combination, with a main cylinder or cylinders and piston or pistons, of a compensating cylinder or cylinders provided with a piston or pistons and rod or rods and supplied with a suitable motor-fluid, and arranged to act in opposition to the main piston or pistons during the first part of the stroke, and in conjunction therewith during the last part of the stroke, and a governor-valve arranged to control the admission of the motor-fluid to the compensating cylinder or cylinders and to permit it to flow freely out of said cylinder or cylinders, substantially as described.

8. The combination, with a main cylinder or cylinders and piston or pistons, of a compensating cylinder or cylinders provided with a piston or pistons and rod or rods and supplied with a suitable motor-fluid, and arranged to act in opposition to the main piston or pistons during the first part of the stroke, and in conjunction therewith during the last part of the stroke, and a governor-valve controlled by the resistance of the load upon the engine, and arranged to admit the motor-fluid to or shut it off from the compensating cylinder or cylinders, according to the resistance offered by the load, and to permit it to flow freely out of said cylinder or cylinders, substantially as described.

9. In a pumping-engine, the combination, with a main cylinder or cylinders and piston or pistons, of a compensating cylinder or cylinders provided with a piston or pistons and rod or rods and supplied with a suitable motor-fluid, and arranged to act in opposition to the main piston or pistons during the first part of the stroke, and in conjunction therewith during the last part of the stroke, and a governor-valve controlled by the pressure in the force-main and arranged to admit the motor-fluid to or shut it off from the compensating cylinder or cylinders, according to the pressure in the main, and to permit it to flow freely out of said cylinder or cylinders, substantially as described.

10. The combination, with a main cylinder or cylinders and piston or pistons and one or more compensating cylinders and pistons, of a governor valve or cock, as 42, for controlling the admission of the motor-fluid to the compensating cylinder or cylinders, the cylinder 17, communicating with the force-main, and the piston 16, connected to the governor valve or cock, substantially as described.

11. The combination, with a main cylinder or cylinders and piston or pistons and one or more compensating cylinders and pistons, of a governor valve or cock, as 42, for controlling the admission of the motor-fluid to the compensating cylinder or cylinders, the cylinder 17, communicating with the force-main, the piston 16, connected to the governor valve or cock, and the by-pass 87, substantially as described.

12. The combination, with the main cylinder or cylinders and piston or pistons, of one

or more compensating cylinders and pistons, said compensating cylinder or cylinders being provided with a volume of liquid which fills it or them behind the piston or pistons and is acted upon by a gas under pressure, substantially as described.

13. The combination, with the main cylinder or cylinders and piston or pistons, of one or more compensating cylinders and pistons, said compensating cylinder or cylinders being provided with a volume of liquid which fills it or them behind the piston or pistons and is acted upon by a gas under pressure, and a governor valve or cock which controls the pressure of the liquid upon the piston or pistons of the compensating cylinder or cylinders, substantially as described.

14. The combination, with the main cylinder or cylinders and piston or pistons, and one or more compensating cylinders and pistons, of a tank, as 103, communicating with the compensating cylinder or cylinders and containing a volume of gas under pressure, and a volume of liquid interposed between said gas and the piston or pistons of the compensating cylinder or cylinders, substantially as described.

15. The combination, with the main cylinder or cylinders and piston or pistons, and one or more compensating cylinders and pistons, of a tank, as 103, communicating with the compensating cylinder or cylinders and containing a volume of gas under pressure, a volume of liquid interposed between said gas and the piston or pistons of the compensating cylinder or cylinders, and a governor valve or cock which controls the pressure of the liquid upon the piston or pistons of the compensating cylinder or cylinders, substantially as described.

16. The combination, with the main cylinder or cylinders and piston or pistons, and one or more compensating cylinders and pistons, of a tank, as 103, communicating with the compensating cylinder or cylinders and containing a volume of gas under pressure, a volume of liquid interposed between said gas and the piston or pistons of the compensating cylinder or cylinders, and a compressor, as 83, for maintaining the proper pressure in the tank, substantially as described.

17. The combination, with the main cylinder or cylinders and piston or pistons, and one or more compensating cylinders and pistons, of a chamber, as 74, which communicates with the compensating cylinder or cylinders behind the piston or pistons and contains a volume of liquid under pressure of a gas, substantially as described.

18. The combination, with the main cylinder or cylinders and piston or pistons, and one or more compensating cylinders and pistons, of a chamber, as 74, which communicates with the compensating cylinder or cylinders behind the piston or pistons and contains a volume of liquid under pressure, and a governor valve or cock, as 42, for controlling the flow of the liquid from the chamber, substantially as described.

19. The combination, with the main cylinder or cylinders and piston or pistons, and one or more compensating cylinders and pistons, of a chamber, as 74, which communicates with the compensating cylinder or cylinders behind the piston or pistons and contains a volume of liquid under pressure, and a governor-valve, as 42, arranged to control the flow of the liquid from the chamber to the cylinder or cylinders and to permit it to flow freely back into the chamber, substantially as described.

20. In a direct-acting pumping-engine, the combination, with the piston-rod extending through and beyond the water-cylinder, of connections between the end of the rod at the outer end of the water-cylinder and the steam valve or valves for operating the latter, substantially as described.

21. In a direct-acting duplex pumping-engine, the combination, with the piston-rods 25 26, extending through and beyond the water-cylinders, of connections, as the links 78, rock-shafts 76, &c., between the end of the rod at the outer end of the water-cylinder of each side of the engine and the valve or valves of the opposite side of the engine for operating the latter, substantially as described.

22. The combination, with the steam cylinder and piston and its piston-rod extending through and beyond the water-cylinder, of connections between the end of the rod at the outer end of the water-cylinder and the steam valve or valves for operating the same, the cut-off valves at the opposite ends of the steam-cylinders, and the rod 67, secured to the piston and passing through the end of the cylinder and having connections for operating the cut-off valves, substantially as described.

23. The combination, with the main cylinder or cylinders and piston or pistons, and one or more compensating cylinders and pistons, of a chamber, as 74, which communicates with the compensating cylinder or cylinders behind the piston or pistons and contains a volume of liquid, a tank, as 103, which communicates with said chamber and contains a gas under pressure, and a cock or valve, as 52, arranged to shut off communication between said tank and chamber, substantially as described.

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

CHARLES C. WORTHINGTON.

Witnesses:
STILLMAN H. STORY,
T. H. PALMER.