(No Model.) 3 Sheets—Sheet 1.

C. C. WORTHINGTON.

STEAM ENGINE.

No. 341,534. Patented May 11, 1886.

Fig. 1.

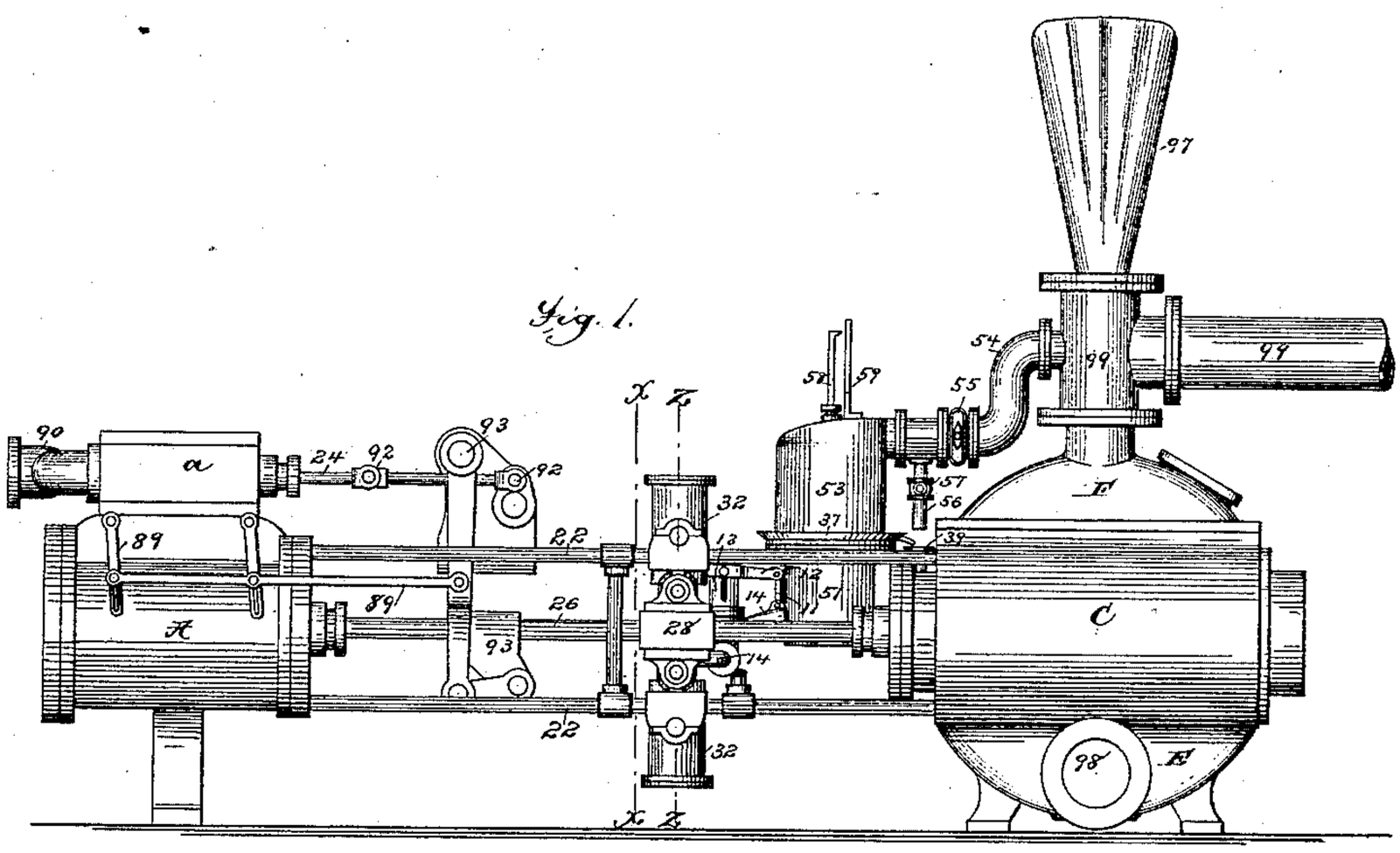
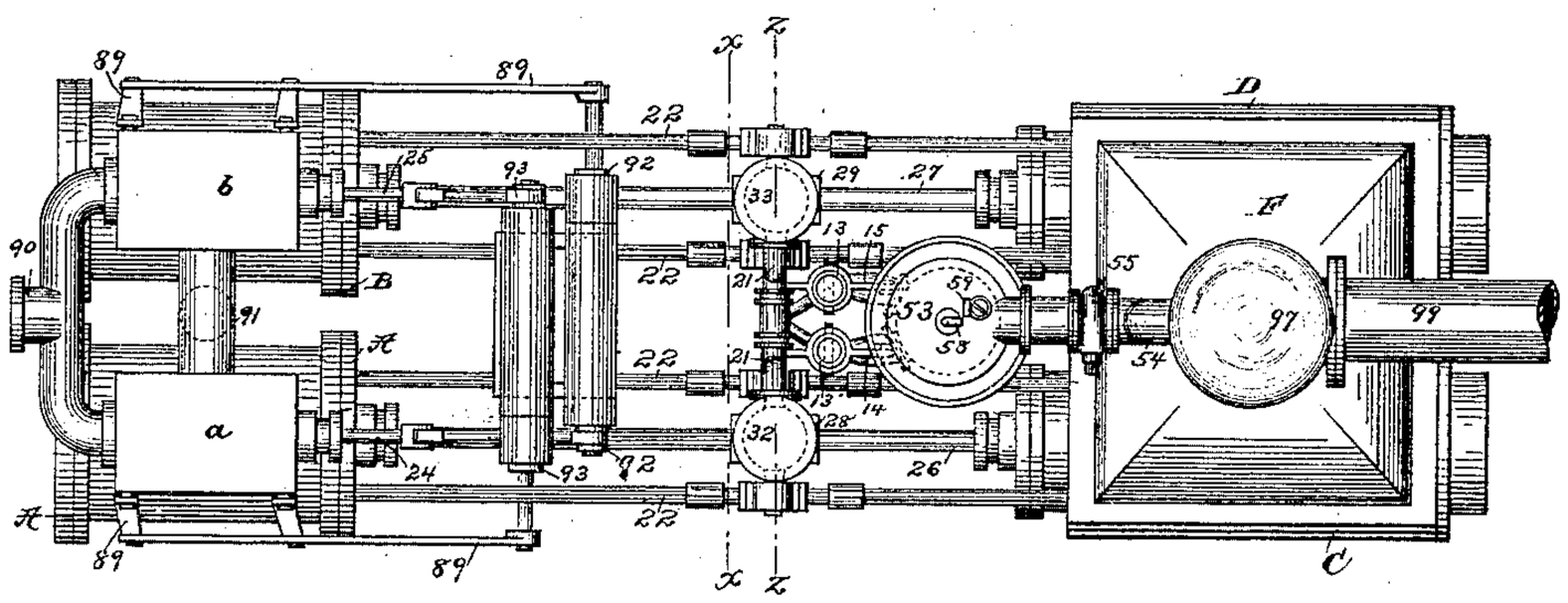


Fig. 2.



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J. A. Hovey

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Attys

(No Model.) 3 Sheets—Sheet 2.

C. C. WORTHINGTON.

STEAM ENGINE.

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Fig. 3.

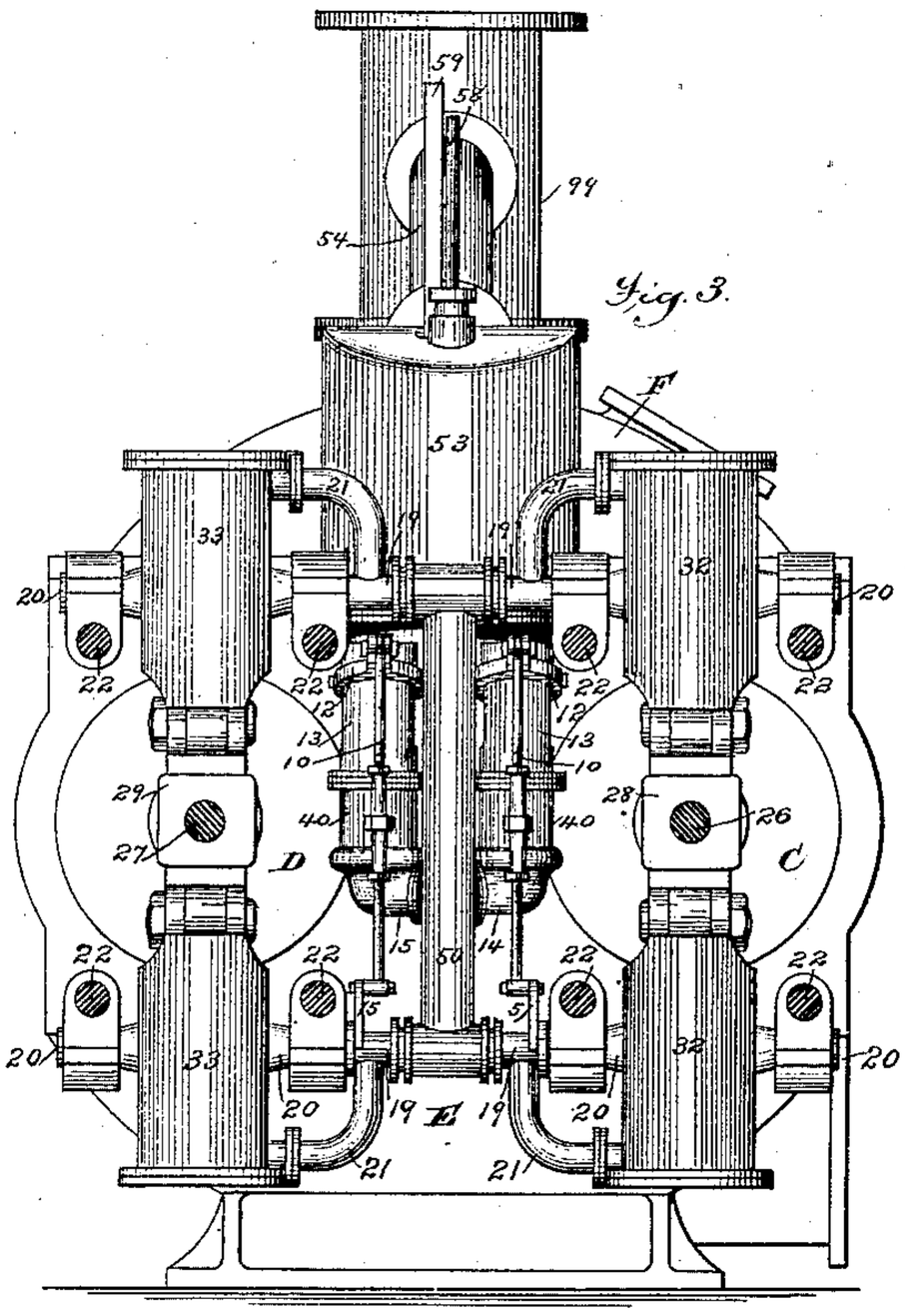


Fig. 4.

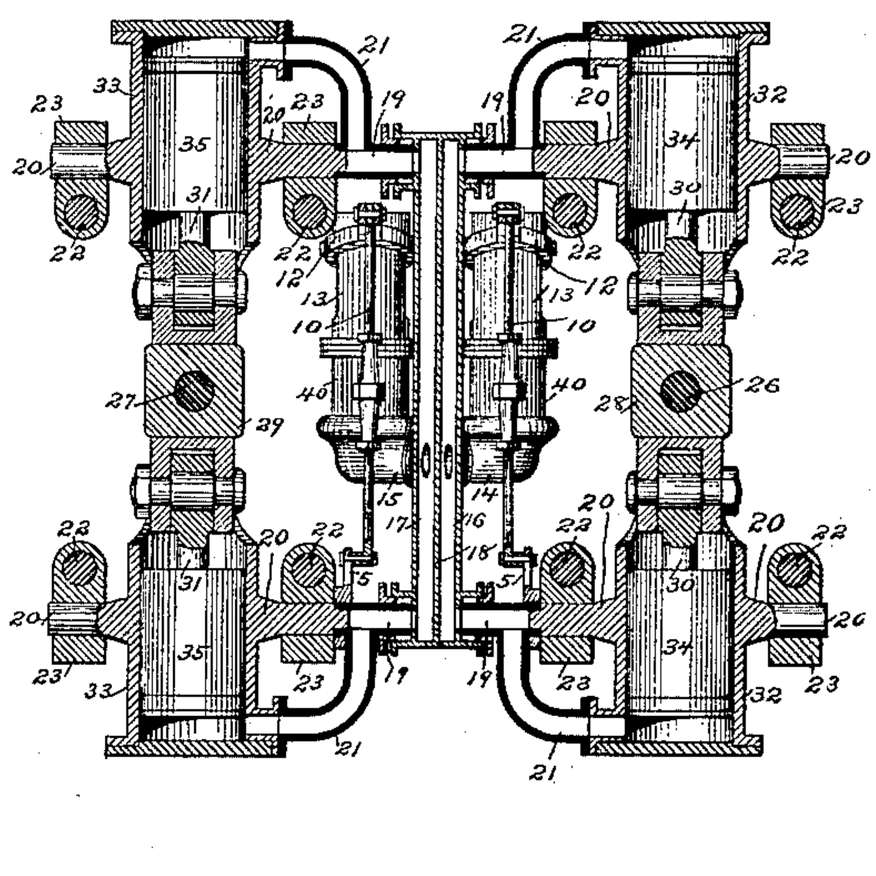
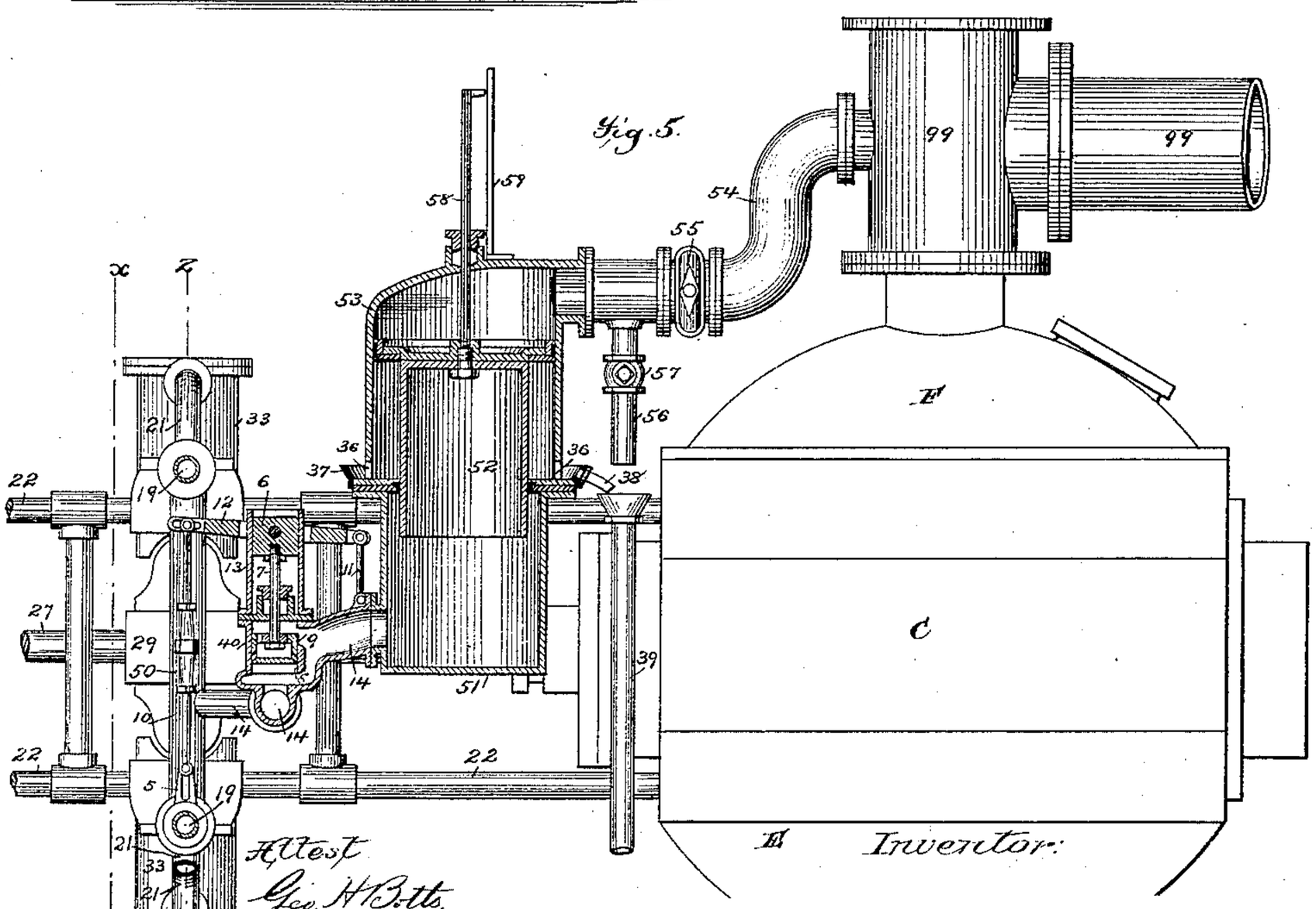


Fig. 5.



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(No Model.) 3 Sheets—Sheet 3.

C. C. WORTHINGTON.

STEAM ENGINE.

No. 341,534. Patented May 11, 1886.

Fig. 6.

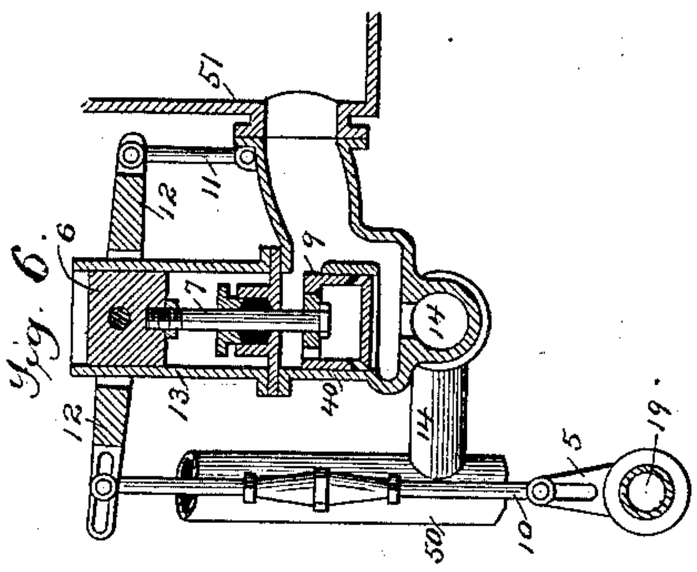


Fig. 7.

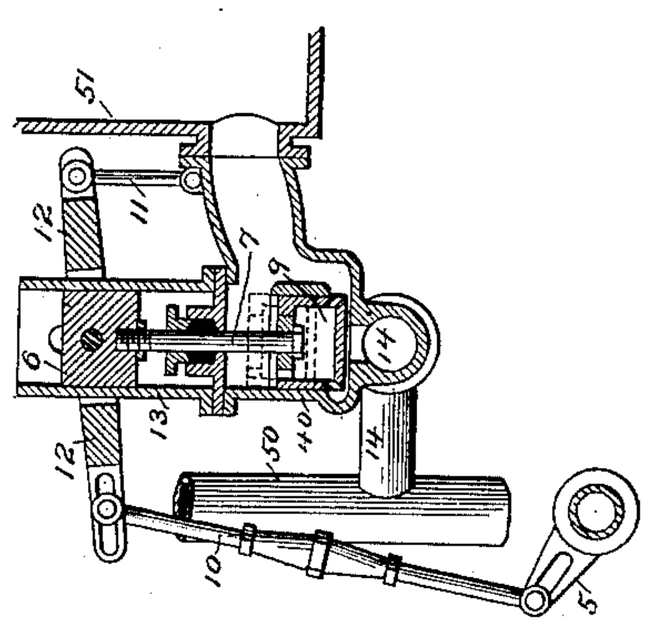
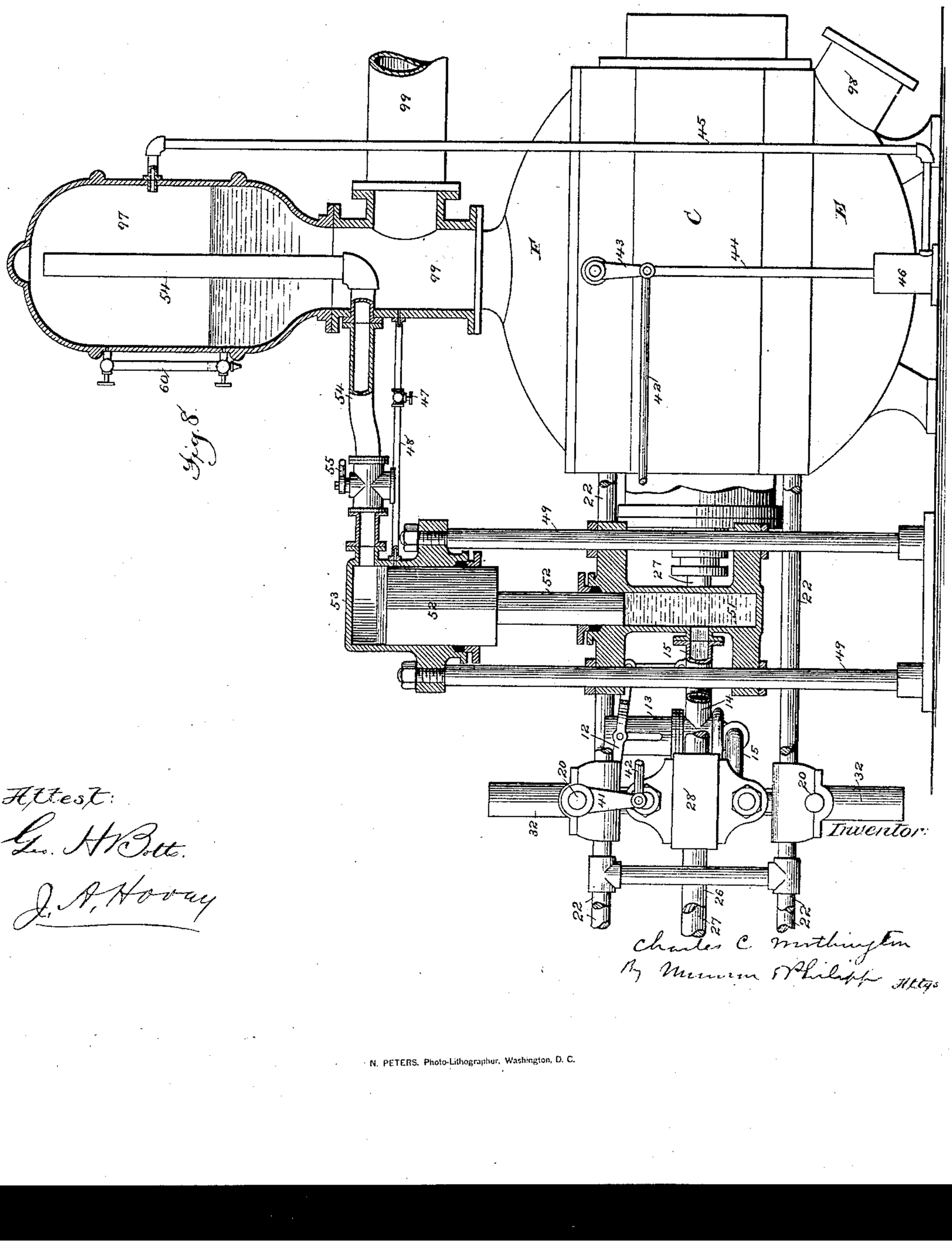


Fig. 8.



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Geo. H. Bolte.
J. A. Hovey

Inventor:
Charles C. Worthington
By Munn & Philipp Attys

UNITED STATES PATENT OFFICE.

CHARLES C. WORTHINGTON, OF IRVINGTON, NEW YORK.

STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 341,534, dated May 11, 1886.

Application filed February 6, 1886. Serial No. 191,014. (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 Steam-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 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 last part of the stroke, thereby permitting the admission of the 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, principally, in the employment of an accumulator for producing the required pressure upon the piston or pistons of the compensating cylinder or cylinders.

Another feature of the invention consists in deriving the pressure in the compensating cylinder or cylinders from the pressure in the force-main, and transmitting it to the cylinder or cylinders through a volume of air or other elastic gas.

The invention also includes a governor apparatus, which is arranged to control the pressure upon the piston or pistons of the compensating cylinder or cylinders in such manner as to prevent the engine from being subjected to a shock or strain at the end of the stroke, and from operating violently and being damaged in case it is attempted to start or run it with no load or with less than its full load, or in case it is suddenly relieved of the whole or a large part of its load, as by the breaking of a piston or plunger rod or the force-main.

As a full understanding of the invention can be best imparted by a detailed description of the organization and operation of the engine, all further preliminary description will be omitted and a full description given, reference being had to the accompanying drawings, in which—

Figure 1 is a side elevation of a duplex pumping-engine embodying the present invention, the parts being shown in the position they will occupy when the pistons of the main steam-cylinders are at the middle of their strokes. Fig. 2 is a top view of the same. Fig. 3 is an enlarged sectional elevation taken upon the line *x x* of Figs. 1, 2, and 5, looking toward the water end of the engine. Fig. 4 is a similar view taken upon the line *z z* of the same figures. Fig. 5 is an enlarged side elevation, partly in section, showing particularly the accumulator and the governor-valve for controlling the pressure in the compensating-cylinders of one side of the engine. Fig. 6 is an enlarged view of a portion of Fig. 5. Fig. 7 is a similar view showing the parts in a different position; and Fig. 8 is a view similar to Fig. 5, showing an accumulator of a different form, and also showing one way of deriving the pressure for the compensating-cylinders from the force-main and transmitting it to the cylinders through a body of air or other elastic gas.

Referring particularly to Figs. 1 and 2, it is to be understood that the steam end of the engine, or what may be termed the "engine proper," is of a common form, consisting of two steam-cylinders, A B, one for each side of the engine, which are provided with the usual steam-chests, *a b*, into which the steam is admitted from the boiler through the usual induction-pipe, 90. After performing its work in the cylinders the steam is exhausted through the usual exhaust-pipe, 91, into a condenser or into the open air. The steam-chests *a b* are provided with ordinary slide-valves, (not shown,) the rods 24 25 of which are provided with the usual connections, 92 93, by which the valve of each side of the engine is operated from the piston-rod of the other in the manner common in duplex engines.

The water end of the engine, or what may be termed the "pump proper," is also of a common form, consisting of two water-cylinders, C D, the plungers or pistons of which are connected directly to the piston-rods 26 27 of the steam-cylinders in the manner common in this class of engines. The water-cyl-

inders C D are provided with the usual suction and force chambers, E F, the former of which is connected to the suction main 98 and the latter to the force-main 99. The force-main 99 is provided with the usual air-compression chamber, 97, to equalize the flow of the water discharged from the pump. The organization thus briefly outlined is, as before stated, common, and will be readily understood by those familiar with this class of engines.

Referring now more particularly to Figs. 3, 4, and 5, it will be seen that the piston-rods 26 27 are provided between the steam and water cylinders with heads or bearings 28 29, to which are pivoted the piston-rods 30 31 of two pairs of oscillating compensating-cylinders, 32 33, which are supplied with a suitable motor-fluid, and are arranged so that their pistons 34 35 act in opposition to the main steam-pistons during the first part of the stroke of the latter, and in conjunction therewith during the last part of the stroke, in substantially the manner described in my former Letters Patent, hereinbefore referred to. The cylinders 32 33 are arranged to oscillate upon trunnions 20, which are mounted in bearings 23, supported upon the tie-rods 22, which connect the steam and water cylinders, or in any other suitable manner. It is to be remarked that the compensating-cylinders, instead of being located between the steam and water cylinders, may be located at the outer end of the water-cylinders, or at the outer end of the steam-cylinders. In such case the main piston-rods will be extended through the water-cylinders or the steam-cylinders, as the case may be; or, in fact, the compensating-cylinders may be located in any other convenient position. It is also to be remarked that one compensating-cylinder may be employed for each of the main piston-rods, instead of two, and also that the compensating cylinders or cylinder may be arranged to act on the main piston-rod in any of the ways shown in my Letters Patent before referred to, or in any other suitable way. The compensating-cylinders and pistons are, as before stated, arranged to act in opposition to the main steam-pistons during the first part of the stroke, and in conjunction therewith during the last part of the stroke, thereby permitting the steam to be cut off from the main cylinders before the end of the stroke without interfering with the proper operation of the engine. The engine shown in the present case is, therefore, provided with cut-off mechanisms 89, by which the steam is cut off from the main cylinders A B when their pistons have arrived at the proper point in their strokes, after which their pistons complete their strokes by the expansive force of the steam in the cylinders, aided by the power exerted by the pistons of the compensating-cylinders. These cut-off mechanisms are of the form shown and described in my Letters Patent No. 292,525, before referred to, and need not, therefore, be herein described in detail. It is to be remarked, however, that any other form of cut-off mechanism may be used, if preferred. The motor-fluid which acts upon the piston or pistons of the compensating cylinder or cylinders may, as set forth in my Letters Patent before referred to, be steam, air, or other gas, or it may be a liquid; but it has been found in practice that in those cases where steam, air, or other gas is employed as the motor-fluid it is desirable that a liquid packing should be interposed between the motor-fluid and the piston or pistons of the compensating cylinder or cylinders, which liquid packing will fill the cylinder or cylinders and transmit the pressure of the motor-fluid to the piston or pistons. The advantages of this liquid packing are fully set forth in my Letters Patent No. 332,857. It has also been found in practice that in order to develop the desired amount of power in the compensating cylinder or cylinders and yet avoid making it or them of an inconveniently large size, it is sometimes necessary that the pressure upon the piston or pistons of the compensating cylinder or cylinders should be greater than exists in the boiler or other source from which it is most convenient and desirable to derive the pressure for the motor-fluid. To overcome this difficulty I provide the engine with an accumulator, which is interposed between the compensating cylinder or cylinders and the source from which the pressure on the motor-fluid is derived, and by which the pressure is accumulated or concentrated upon a smaller area, thereby increasing the pressure in the compensating cylinder or cylinders to any desired extent. Other advantages are also gained by the employment of this accumulator, which will be hereinafter referred to. Two applications of the accumulator are illustrated in the present case. In one (see Figs. 1 to 5) the pressure in the compensating-cylinders is derived directly from the pressure of the column of water in the force-main, while in the other (see Fig. 8) the pressure is derived indirectly from the same source, but directly from the pressure of the air in the air-chamber 97.

Referring now to Figs. 1 to 5, the first of these applications of the accumulator and its connections with the compensating-cylinders and the force-main will be described. The inside trunnions of the compensating-cylinders are provided with tubular extensions 19, (see Fig. 4,) which communicate with a vertical pipe, 50, having a vertical partition or diaphragm, 18, by which it is divided into two compartments or ducts, 16 17, the tubular extensions 19 of the trunnions of the cylinders 32 communicating with the duct 16 and those of the cylinders 33 with the duct 17. It is to be remarked, however, that instead of using the single pipe 50, which is divided to form the two ducts 16 17, two separate pipes may be employed, one for each of the pairs of compensating-cylinders. The tubular extensions 19 are provided with pipes 21, (see Fig. 4,) which communicate with the ends of their

respective cylinders behind the pistons 34 35. The ends of the tubular extensions 19 enter stuffing-boxes formed on the sides of the pipe 50, which serve to form tight connections between the oscillating cylinders, trunnions, and tubular extensions and the stationary pipe. The ducts or pipes 16 17 are provided with branch pipes 14 15, which communicate with the chamber or cylinder 51 of the accumulator, which is of a capacity at least equal to the combined displacement of the pistons of the compensating-cylinders, and which, together with the connections just described, are filled with water, oil, or other liquid, which also fills the compensating-cylinders behind their pistons. The upper end of the cylinder 51 is provided with an opening, through which passes the smaller end of the differential plunger 52, the larger end of which works in a cylinder, 53, which is located above the cylinder 51, and is provided at a point above the end of the plunger with a pipe, 54, which communicates with the force-main 99, and through which the water from the main enters and fills the cylinder 53, and communicates the pressure of the main directly to the larger end of the plunger 52. By reason of this arrangement it results, according to the well-known law of hydrostatics, that the pressure in the cylinder 51 and upon the pistons of the compensating-cylinders is to the pressure in the force-main as the area of the larger end of the plunger is to the area of its smaller end. By this means the pressure in the compensating-cylinders is increased above the pressure which exists in the force-main, and it will readily be seen that by properly proportioning the relative areas of the two ends of the plunger any desired degree of pressure can be obtained in the compensating-cylinders. It will of course be seen that if the pressure in the main should be greater than is desired in the compensating-cylinders, the pressure can be reduced by simply reversing the relative areas of the ends of the plunger. The lower end of the cylinder 53, which rests upon the cylinder 51, is provided with one or more openings, as 36, through which air is allowed to pass freely into and out of the cylinder below the enlarged part of the plunger, so as to prevent the plunger from being cushioned. The openings 36 also serve to allow any liquid which may leak past the plunger to escape into a trough, 37, formed upon the upper end of the cylinder 51, from which trough it flows through a spout, 38, to a drain-pipe, 39. The pipe 54 is provided with a valve or gate, 55, by which, when desired, communication between the cylinder 53 and the main 99 may be shut off, and the pipe is also provided with a small branch pipe, 56, which communicates with a drain-pipe, 39, and is provided with a cock or valve, 57, by which, when the gate 55 is closed, the liquid can be drawn out of the cylinder 53. The plunger 52 will preferably be provided with a small rod, as 58, which passes through a stuffing-box in the upper end of the cylinder 53, and extends by the side of a stationary scale, as 59, so as to indicate the position of the plunger 52, and enable the engineer to determine when the cylinder 51 contains the proper quantity of liquid.

In the second application of the accumulator illustrated—viz., that shown in Fig. 8—the general organization of the engine is substantially the same as that already described. The cylinder 51 and the smaller end of the plunger 52 are, however, as shown, much smaller in proportion to the cylinder 53 and the larger end of the plunger. The accumulation of the pressure in the cylinder 51 is, therefore, much greater, and, as a consequence, the compensating-cylinders 32 33 are of correspondingly reduced diameter. The cylinders 51 53 are in this case entirely independent of each other, and are supported upon vertical rods 49. The connections for conducting the liquid from the cylinder 51 to the compensating-cylinders are the same as already described. The pipe 54, however, instead of communicating directly with the force-main 99, extends upward through the air-chamber 97, and terminates at a point near its top, so that the pressure of the column of water in the force-main, instead of being transmitted directly to the plunger 52 through the column of water in the pipe 54, is transmitted indirectly to the plunger through the body of air in the chamber 97 and in the pipe 54 and cylinder 53. In order to keep the larger end of the plunger 52 properly packed and lubricated in the cylinder 53, the cylinder is provided with a small pipe, 48, which communicates with the main 99, and is provided with a cock, 47, through which a small amount of water can be allowed to enter the cylinder above the plunger. The proper amount of air can be maintained in the chamber 97 by means of a small air-compression pump, as 46, which communicates with the chamber by a pipe, 45. This pump, as herein shown, is operated from an arm, 41, extending from one of the trunnions, 20, of the compensating-cylinders, and connected by a rod, 42, to an arm, 43, which is pivoted on a stud extending from the side of the water-cylinder C, and is connected to the plunger-rod 44 of the pump. By this means the pump 46 is caused to make two strokes to each stroke of the engine, the advantages of which are fully set forth in my former Letters Patent No. 309,676. The pump 46 will need to be operated only occasionally, and at other times it will be disconnected from the engine. Instead of using the compressor 46, the proper amount of air can be supplied to the chamber 97 in any other suitable manner. The chamber 97 is provided with an ordinary glass gage, as 60, by which it can be determined when the chamber contains the proper quantity of air. The pipe 54 is provided with an ordinary three-way cock, 55, by which communication with the air-chamber can be cut off from the cylinder 53 and communication opened between the atmosphere and the cylinder.

The operation of the accumulator, when arranged in either of the ways described, is as follows: For the purpose of this description it will be assumed that the engine is in operation, and that the normal or ordinary pressure exists in the main 99, and also that the piston of the cylinder A is commencing its stroke toward the water-cylinders. During the first half of the stroke the liquid will be forced out of the compensating-cylinders 32, and through the pipes 21, duct 16, and pipe 14 into the cylinder 51, where it will act upon the smaller end of the plunger 52 and raise the plunger against the pressure of the water in the main 99. During the last half of the stroke the operation will be reversed, and the plunger 52, acted upon by the pressure from the force-main in the cylinder 53, will force the liquid out of the cylinder 51 back into the cylinders 32, thus giving back the power which was expended in raising the plunger. As the piston of the cylinder A approaches the end of its stroke the connections 93 will operate the valve of the cylinder B, so as to start the piston of that cylinder upon its stroke in the same direction. During this stroke the operation just described will be repeated in connection with the compensating-cylinders 33, and as the piston of the cylinder B approaches the end of its stroke the connections 92 will operate the valve of the cylinder A, so as to start the piston of that cylinder upon its return-stroke, and so the operation will continue to be repeated.

In addition to its function of accumulating or concentrating pressure in the cylinder 51, the accumulator is important in another respect. It sometimes happens, owing to a change in the character or amount of the work which the engine is to perform, that it is desirable to cause the compensating cylinder or cylinders to develop a greater or less amount of power without changing the pressure at the source from which the pressure in the cylinder or cylinders is derived. When the pressure in the compensating cylinder or cylinders is communicated directly to it or them from the source at which it is derived, such change can only be effected by changing the diameter of the cylinder or cylinders; but by the use of the accumulator this change can be effected by simply changing the area of the smaller end of the plunger 52, which can be readily and cheaply done.

It will readily be seen that so far as concentrating or accumulating the pressure in the cylinder 51 is concerned, and also so far as changing the pressure in the compensating cylinder or cylinders is concerned, the operation of the accumulator will be the same whether the pressure upon the larger end of the plunger 52 is derived from the force-main, as shown in the present case, or from any other source—as the steam-boiler, or a tank containing air or other gas under pressure, or a standpipe containing a column of liquid, or even a weight or spring arranged upon or to act upon the plunger. In any of these cases the pressure upon the upper end of the plunger is in effect nothing more than so much weight placed upon the plunger, and it is therefore to be understood that my invention embraces the combination of the accumulator with one or more of the compensating-cylinders, regardless of the source from which the pressure upon the plunger of the accumulator is derived. There are, however, several important advantages gained by having the pressure in the compensating cylinder or cylinders derived either directly or indirectly from the force-main. By this means the power developed by the compensating cylinder or cylinders is controlled by and conforms to the pressure in the main, or, in other words, conforms to the load upon the engine. This is a feature of particular importance, as there are many cases in which the full pressure in the main, or, in other words, the full load upon the engine, is not attained until it has been operating for some time or has acquired a considerable degree of speed. This is the case in raising liquids when for any reason the force-main has become empty or partly empty while the engine is at rest. It is also the case in pumping through a long line of pipe, when the pressure in the pipe, and as a consequence the load upon the engine, is due to the friction of the fluid, depending on its velocity, and not to the height of the column. In these and other like cases, if the compensating cylinder or cylinders is or are allowed to develop its or their full power when the engine is started and when the load is light, it will cause the engine to act violently and be liable to occasion damage; but by having the pressure in the compensating cylinder or cylinders derived from the pressure in the main the power developed by the former gradually increases as the pressure in the latter increases, so that all violent action of the engine is avoided. In pumping against a heavy pressure there is also some danger that the force-main may burst, and thus suddenly relieve the engine of all or a large portion of its load. In this case, also, the compensating cylinder or cylinders will at once cease to develop any power, and the danger of damage from the sudden acceleration of the speed of the engine which would otherwise ensue is avoided. The results just stated will be the same, whether the pressure in the compensating cylinder or cylinders is derived directly from the force-main, as shown in Figs. 1 to 5, or indirectly, as shown in Fig. 8. When, however, the pressure is derived directly from the main, the flow of the liquid into and out of the cylinder 51, and the consequent reciprocating movement of the plunger 52, will cause pulsations in the main, owing to the non-compressibility of the liquid in the main, which in some cases will be objectionable; but these pulsations will be wholly or nearly wholly avoided when the pressure is derived indirectly from the main through the air in the chamber 97, as shown

in Fig. 8, because these pulsations will be absorbed by the elasticity of the air in the chamber 97, and will not be communicated, excepting, perhaps, in a slight degree, to the water column.

It will readily be seen that although it is most convenient to utilize the air in the chamber 97 for transmitting the pressure in the main to the compensating cylinder or cylinders, a special air-chamber may be provided for containing the air for that purpose, such chamber being located in any convenient position and made to communicate with the main and the cylinder 53. It will also be seen that the advantage due to transmitting the pressure in the main to the compensating cylinder or cylinders indirectly through a body of air or other elastic fluid will be the same in those cases where no accumulator is employed.

It is often desirable, even when the engine is running at its normal speed and under its ordinary working conditions, that the pressure upon the piston or pistons of the compensating cylinder or cylinders should be reduced or entirely removed just at the end of the stroke of the engine, as otherwise the shock occasioned by arresting these pistons while they are subjected to their full working pressure, and at the time when, by reason of their position, they are exerting their maximum power upon the main piston-rod, is straining to the engine. In order to avoid this strain upon the engine, the compensating-cylinders for each side of the engine are provided with a governor or cut-off valve or cock which operates to regulate the flow of the liquid to these cylinders, and to greatly reduce or entirely cut it off just at the end of the stroke of the main steam-piston, and thus deprive the compensating-cylinders of all or nearly all their power at that time. For this purpose the pipes 14 15, which connect the ducts 16 17 with the cylinder 51, are provided with enlargements 40, which form chambers for a pair of piston-valves, 9, which reciprocate in bearings 8, formed in the chambers 40, and are provided with rods 7, which pass through stuffing-boxes in the tops of the chambers, and are connected to heads 6, which move in guides 13, and are connected to levers 12, which are fulcrumed to links 11, pivoted upon the pipes 14 15, and are connected by rods 10 with crank-arms 5, extending from the trunnions 20 of two of the cylinders, 32 33. The valves 9 are so connected to the rods 7 (see Figs. 5, 6, and 7) that they are capable of a small amount of motion independent of the rods, the purpose of which will be made clear when the operation of these valves is explained.

The operation of this part of the engine is as follows: As either of the main steam-pistons moves in either direction from the middle of its stroke, thereby oscillating its pair of compensating-cylinders and allowing the liquid in the cylinder 51 to flow out through the pipe 14 or 15, as the case may be, and into the compensating-cylinders behind their pistons, the arm 5 will be rocked, thereby rocking the lever 12 and permitting the valve 9 of that side of the engine to move downward toward its seat. As the main piston approaches the end of its stroke the valve 9 will fall below its guide 8 and commence to close the pipe 14 or 15, as the case may be, and cut off the flow of the liquid to its pair of compensating-cylinders, and this movement will continue until the main piston arrives at the end of its stroke, at which time the valve 9 will have nearly or quite reached its seat, as shown in Fig. 7, and consequently have cut off all or nearly all flow of the liquid to the compensating-cylinders and deprived them of all or nearly all power. As the main piston starts upon its return-stroke and the liquid in the compensating-cylinders is forced back into the cylinder 51, the valve 9 will be raised from its seat in advance of the movement of the rod 7, as shown by dotted lines in Fig. 7, so as to offer no obstruction to the flow of the liquid. As the main piston arrives at the middle of its return-stroke, the parts will be restored to the position shown in Fig. 6, and as it makes the last half of its return-stroke the arm 5 will be rocked in the opposite direction, and the operation just described will be repeated. By reason of these governor-valves the whole or nearly the whole pressure is removed from the pistons of the compensating-cylinders just at the end of the stroke of the engine, thus relieving the engine of the strain which might result from arresting these pistons when subjected to full pressure. It will also be seen that these governor-valves operate to control the rate at which the liquid is permitted to enter the compensating-cylinders. This latter is a feature of great importance, because it allows the compensating-cylinders to develop their full power only when the engine is operating at its normal speed, and thus prevents the engine from acting violently in case it is suddenly relieved of its load in such manner as not to affect the pressure in the force-main—as by the breaking of a piston-rod. This function of the governor-valves is of especial importance in those cases where the pressure in the compensating cylinder or cylinders is not derived from the pressure in the main, as in such case the power developed by the compensating cylinder or cylinders does not vary to conform to variations in the pressure in the main. The rods 10 are made adjustable in length, and the arms 5 and levers 12 are slotted, as shown, so that the extent of the movement of the valves 9 and their time of closing can be regulated to conform to the different running conditions of the engine.

It is to be understood that any other form of valve which will perform the same function may be substituted for the valves 9 without departing from the substance of the invention, or that a rotary valve or cock combined with a check-valve may be used in place of each of the valves 9. In such case the rotary valve or cock will be operated to regulate the flow of the

liquid into the compensating cylinder or cylinders, while the check-valve will operate to permit the liquid to flow freely out of the cylinder or cylinders. Such an arrangement is therefore to be understood as the equivalent of that shown.

In conclusion, it is to be remarked that parts of the invention may be used without the whole. The accumulator may be used without the governor-valves, and in such case the cylinder 51 can be made to communicate with the compensating cylinder or cylinders in any convenient manner. The accumulator may also be used in connection with a governor valve or cock, such as shown in my Letters Patent No. 332,857. So also the governor-valves shown in the present case may be used without the accumulator—that is to say, when the pressure of the motor-fluid is transmitted directly to the compensating cylinder or cylinders, as in my Letters Patent Nos. 292,525 and 332,857.

The duplex engine shown in the present case has been selected for the purpose of illustration, because it is thought the invention is most useful in connection with the engines of this type. The invention is, however, applicable to any engine in which a compensating cylinder or cylinders is or are used.

What I claim is—

1. The combination, with a main cylinder or cylinders and piston or pistons, and a compensating cylinder or cylinders and piston or pistons 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, of an accumulator arranged between the compensating cylinder or cylinders and the source from which the pressure in said cylinder or cylinders is derived, substantially as described.

2. The combination, with the main cylinders and pistons forming the two sides of a duplex engine, and having connections by which the valve or valves of each side is or are operated by the other side, and a compensating cylinder or cylinders and piston or pistons for each side of the engine, which is or are 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, of an accumulator arranged between the compensating-cylinders and the source from which the pressure in said cylinders is derived, substantially as described.

3. The combination, with a main cylinder or cylinders and piston or pistons, and a compensating cylinder or cylinders and piston or pistons 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, of an accumulator consisting of two cylinders of different diameters, and a differential plunger arranged between the compensating cylinder or cylinders and the source from which the pressure in said cylinder or cylinders is derived, substantially as described.

4. The combination, with the main cylinders and pistons forming the two sides of a duplex engine, and having connections by which the valve or valves of each side is or are operated by the other side, and a compensating cylinder or cylinders and piston or pistons for each side of the engine, which is or are 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, of an accumulator consisting of two cylinders of different diameters, and a differential plunger arranged between the compensating-cylinders and the source from which the pressure in said cylinders is derived, substantially as described.

5. The combination, with the main cylinder or cylinders and piston or pistons of a pumping-engine, and a compensating cylinder or cylinders and piston or pistons 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, the pressure in said compensating cylinder or cylinders being derived from the force-main, of an accumulator arranged between the compensating cylinder or cylinders and the force-main, substantially as described.

6. The combination, with the main cylinders and pistons forming the two sides of a duplex pumping-engine, and having connections by which the valve or valves of each side is or are operated by the other side, and a compensating cylinder or cylinders and piston or pistons for each side of the engine, which is or are 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, the pressure in said compensating-cylinders being derived from the force-main, of an accumulator arranged between the compensating-cylinders and the force-main, substantially as described.

7. The combination, with the main cylinder or cylinders and piston or pistons of a pumping engine, and a compensating cylinder or cylinders and piston or pistons 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, the pressure in said compensating cylinder or cylinders being derived indirectly from the force-main through a body of air or other gas which is subjected to the pressure in the main, of an accumulator arranged between the compensating cylinder or cylinders and the force-main, substantially as described.

8. The combination, with the main cylinders and pistons forming the two sides of a duplex pumping-engine, and having connections by which the valve or valves of each side is or are operated by the other side, and a compensating cylinder or cylinders and piston or

pistons for each side of the engine, which is or are 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, the pressure in said compensating-cylinders being derived indirectly from the force-main through a body of air or other gas which is subjected to the pressure in the main, of an accumulator arranged between the compensating-cylinders and the force-main, substantially as described.

9. The combination, with the main cylinder or cylinders and piston or pistons of a pumping-engine, and a compensating cylinder or cylinders and piston or pistons 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, the pressure in said compensating cylinder or cylinders being derived indirectly from the force-main through the body of air or other gas in the chamber 97 of the pump, of an accumulator arranged between the compensating cylinder or cylinders and said chamber, substantially as described.

10. The combination, with the main cylinders and pistons forming the two sides of a duplex pumping-engine, and having connections by which the valve or valves of each side is or are operated by the other side, and a compensating cylinder or cylinders and piston or pistons for each side of the engine, which is or are 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, the pressure in said compensating-cylinders being derived indirectly from the force-main through the body of air or other gas in the chamber 97 of the pump, of an accumulator arranged between the compensating-cylinders and said chamber, substantially as described.

11. The combination, with the main cylinder or cylinders and piston or pistons of a pumping-engine, and a compensating cylinder or cylinders and piston or pistons which is or are 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, of connections by which the pressure in the force-main is transmitted indirectly to the compensating cylinder or cylinders through a body of air or other gas, substantially as described.

12. The combination, with the main cylinders and pistons forming the two sides of a duplex pumping-engine, and having connections by which the valve or valves of each side is or are operated by the other side, and a compensating cylinder or cylinders and piston or pistons for each side of the engine, which is or are 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, of connections by which the pressure in the force-main is transmitted indirectly to the compensating-cylinders through a body of air or other gas, substantially as described.

13. The combination, with the main cylinder or cylinders and piston or pistons of a pumping-engine, and a compensating cylinder or cylinders and piston or pistons 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, of connections by which the pressure in the force-main is transmitted indirectly to the compensating cylinder or cylinders through the body of air or other gas in the chamber 97 of the pump, substantially as described.

14. The combination, with the main cylinders and pistons forming the two sides of a duplex pumping-engine, and having connections by which the valve or valves of each side is or are operated by the other side, and a compensating cylinder or cylinders and piston or pistons for each side of the engine, which is or are 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, of connections by which the pressure in the force-main is transmitted indirectly to the compensating-cylinders through the body of air or other gas in the chamber 97 of the pump, substantially as described.

15. The combination, with a main cylinder or cylinders and piston or pistons, and a compensating cylinder or cylinders and piston or pistons 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, of a governor valve or valves arranged to gradually reduce or cut off the flow of the motor-fluid into the compensating cylinder or cylinders as the engine approaches the end of its stroke, substantially as described.

16. The combination, with a main cylinder or cylinders and piston or pistons, and a compensating cylinder or cylinders and piston or pistons 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, of a governor valve or valves arranged to gradually reduce or cut off the flow of the motor-fluid into the compensating cylinder or cylinders as the engine approaches the end of its stroke, and to allow it to flow freely out of the cylinder or cylinders as the engine commences its stroke, substantially as described.

17. The combination, with the main cylinders and pistons forming the two sides of a duplex engine, and having connections by which the valve or valves of each side of the engine is or are operated by the other side, and a compensating cylinder or cylinders and piston or pistons for each side of the engine, which is or are arranged to act in opposition to the main piston or pistons during the first part of the stroke, and in conjunction there-

with during the last part of the stroke, of governor-valves for each side of the engine, which are arranged to gradually reduce or cut off the flow of the motor-fluid into the compensating-cylinders as the engine approaches the ends of its strokes, substantially as described.

18. The combination, with the main cylinders and pistons forming the two sides of a duplex engine, and having connections by which the valve or valves of each side of the engine is or are operated by the other side, and a compensating cylinder or cylinders and piston or pistons for each side of the engine, which is or are 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, of governor-valves for each side of the engine, which are arranged to gradually reduce or cut off the flow of the motor-fluid into the compensating-cylinders as the engine approaches the ends of its strokes, and to allow it to flow freely out of the cylinders as the engine commences its strokes, substantially as described.

19. The combination, with a main cylinder or cylinders and piston or pistons, and a compensating cylinder or cylinders and piston or pistons 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, of an accumulator arranged between the compensating cylinder or cylinders and the source from which the pressure in said cylinder or cylinders is derived, and a governor valve or valves arranged to gradually reduce or cut off the flow of the motor-fluid into the compensating cylinder or cylinders as the engine approaches the end of its stroke, substantially as described.

20. The combination, with a main cylinder or cylinders and piston or pistons, and a compensating cylinder or cylinders and piston or pistons 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, of an accumulator arranged between the compensating cylinder or cylinders and the source from which the pressure in said cylinder or cylinders is derived, and a governor valve or valves arranged to gradually reduce or cut off the flow of the motor-fluid into the compensating cylinder or cylinders as the engine approaches the end of its stroke, and to allow it to flow freely out of the cylinder or cylinders as the engine commences its stroke, substantially as described.

21. The combination, with the main cylinder or cylinders and piston or pistons of a pumping-engine, and a compensating cylinder or cylinders and piston or pistons 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, the pressure in the compensating cylinder or cylinders being derived from the force-main either directly or through a body of air or other gas, of a governor valve or valves arranged to gradually reduce or cut off the flow of the motor-fluid into the compensating cylinder or cylinders as the engine approaches the end of its stroke, substantially as described.

22. The combination, with the main cylinder or cylinders and piston or pistons of a pumping-engine, and a compensating cylinder or cylinders and piston or pistons 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, the pressure in the compensating cylinder or cylinders being derived from the force-main either directly or through a body of air or other gas, of a governor valve or valves arranged to gradually reduce or cut off the flow of the motor-fluid into the compensating cylinder or cylinders as the engine approaches the end of its stroke, and to allow it to flow freely out of the cylinder or cylinders as the engine commences its stroke, substantially as described.

23. The combination, with the main cylinder or cylinders and piston or pistons of a pumping-engine, and a compensating cylinder or cylinders and piston or pistons 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, the pressure in the compensating cylinder or cylinders being derived from the force-main either directly or through a body of air or other gas, of an accumulator arranged between the compensating cylinder or cylinders and the force-main, and a governor valve or valves arranged to gradually reduce or cut off the flow of the motor-fluid into the compensating cylinder or cylinders as the engine approaches the end of its stroke, substantially as described.

24. The combination, with the main cylinder or cylinders and piston or pistons of a pumping-engine, and a compensating cylinder or cylinders and piston or pistons 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, the pressure in the compensating cylinder or cylinders being derived from the force-main either directly or through a body of air or other gas, of an accumulator arranged between the compensating cylinder or cylinders and the force-main, and a governor valve or valves arranged to gradually reduce or cut off the flow of the motor-fluid into the compensating cylinder or cylinders as the engine approaches the end of its stroke, and to allow it to flow freely out of the cylinder or cylinders as the engine commences its stroke, substantially as described.

25. The combination, with the main cylinder or cylinders and piston or pistons of a pumping-engine, and a compensating cylinder or cylinders and piston or pistons arranged to act in opposition to the main piston or pis-

tons during the first part of the stroke, and in conjunction therewith during the last part of the stroke, of connections by which the pressure in the force-main of the pump is transmitted indirectly to said compensating cylinder or cylinders through a body of air or other gas which is subjected to the pressure in the force-main, and means for supplying air to said body to maintain its volume, substantially as described.

26. In an engine constructed substantially as shown and described, the combination, with the accumulator-cylinder 53, of the pipe 54, communicating with the main and having the cock or gate 55, substantially as described.

27. The combination, with the accumulator-cylinder 53, of the pipe 54, communicating with the air-chamber 97, and the pipe 48, having the cock 47, through which a small amount of water can be admitted to the cylinder 53, substantially as described.

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

CHARLES C. WORTHINGTON.

Witnesses:
JAS. J. KENNEDY,
J. A. HOVEY.