No. 881,214. PATENTED MAR. 10, 1908.

E. J. WOOLF.

EXPLOSIVE COMPOUND ENGINE.

APPLICATION FILED MAR. 2, 1907.

4 SHEETS—SHEET 1.

Fig. 1.

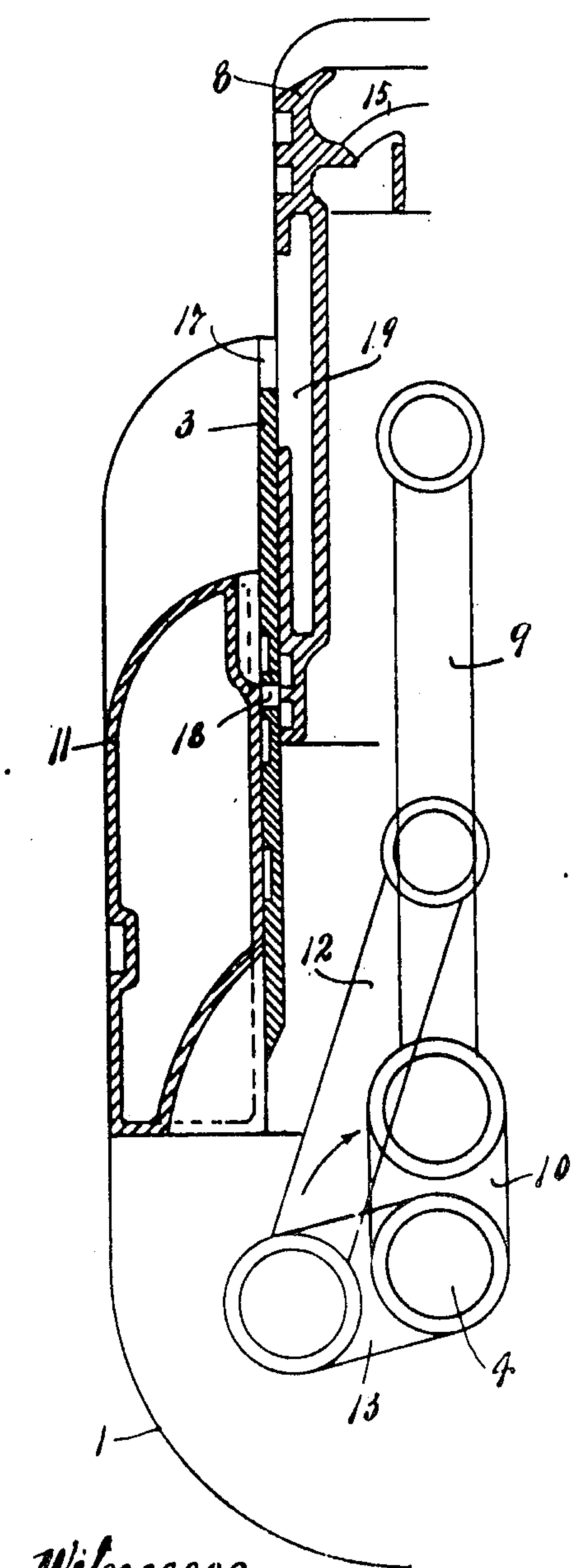
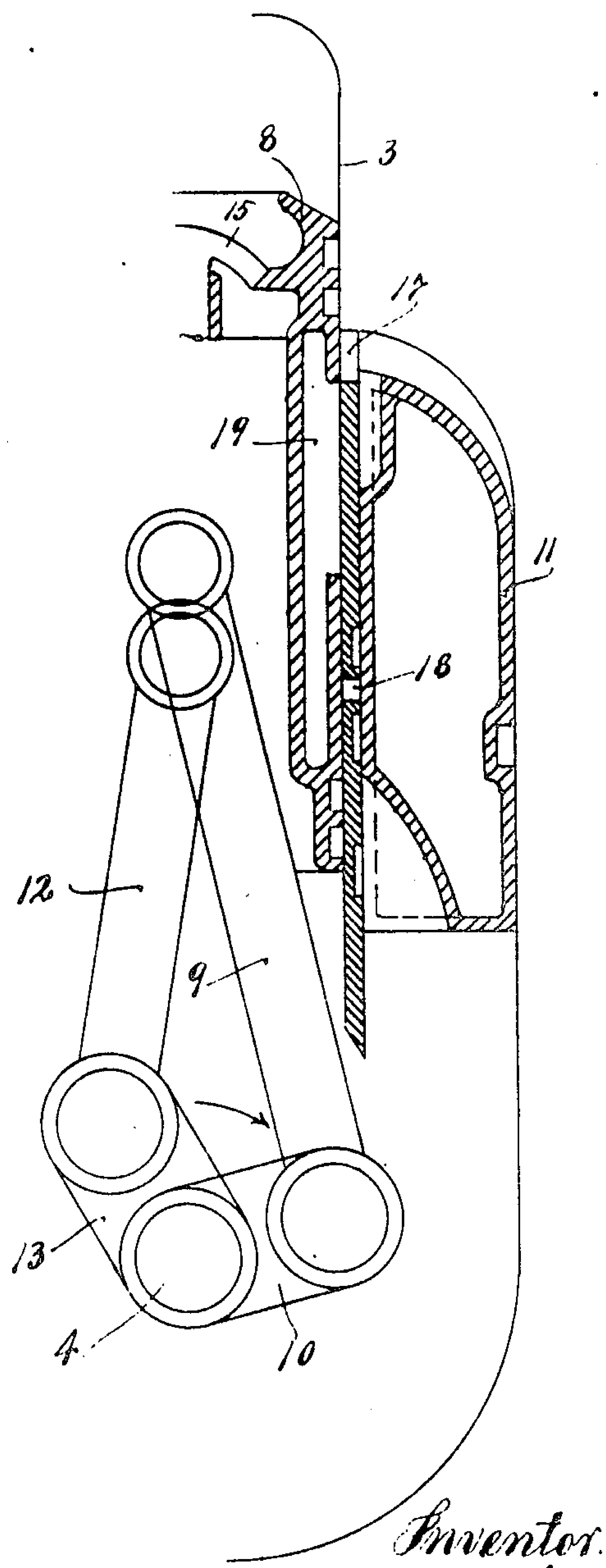


Fig. 2.



Witnesses.
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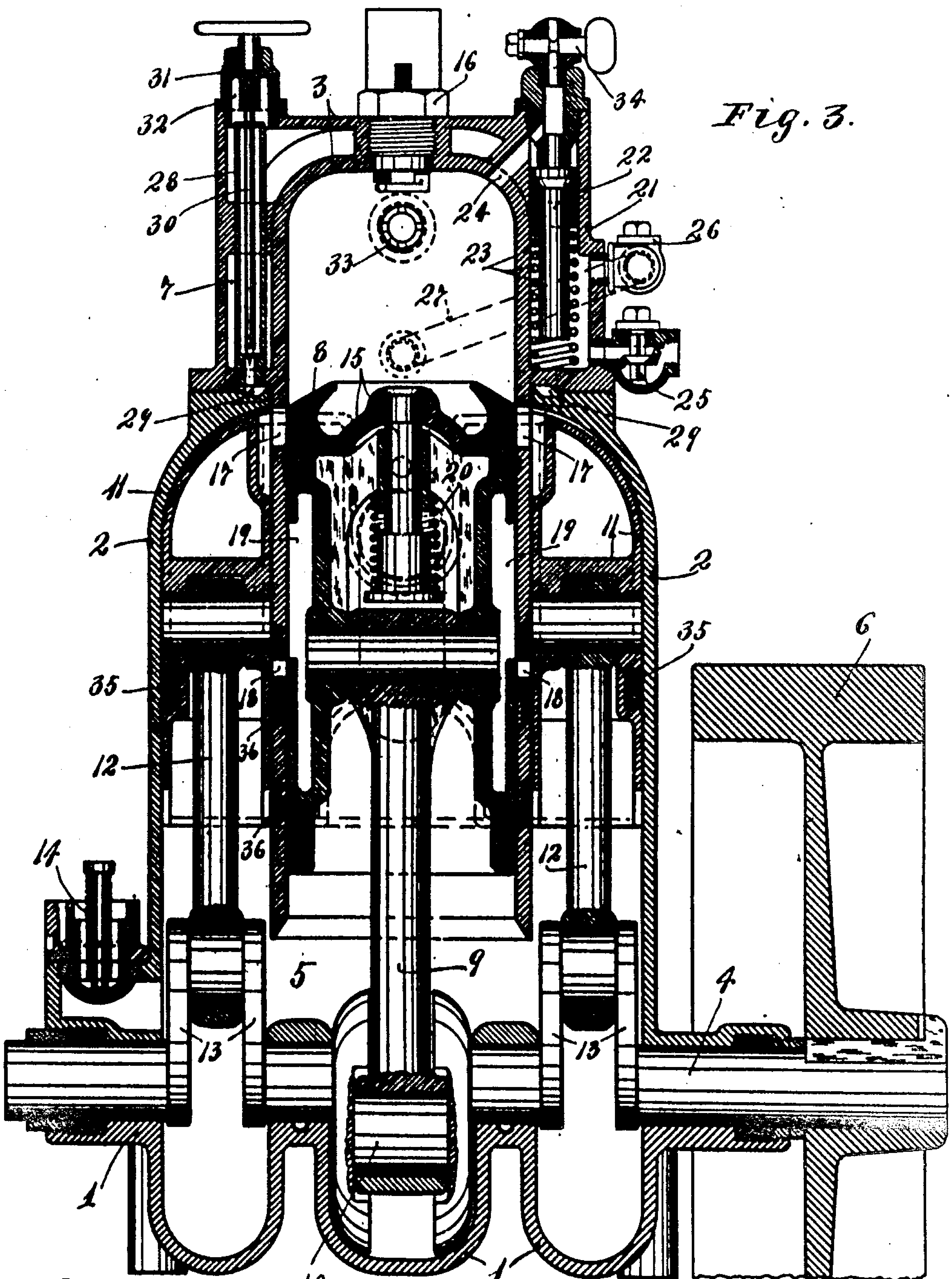
4 SHEETS—SHEET 2.

Fig. 3.



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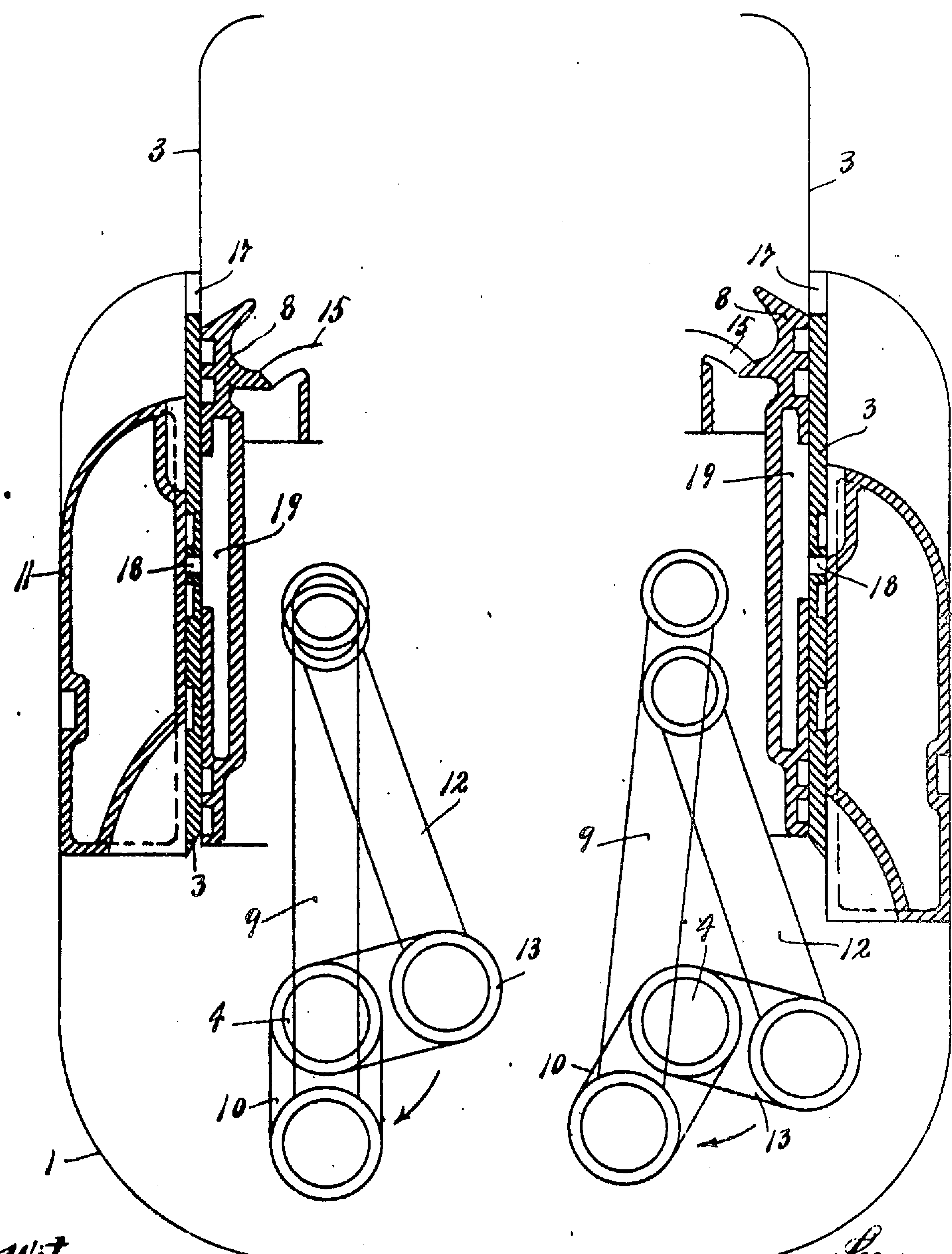
4 SHEETS—SHEET 3.

Fig. 4.

Fig. 5.



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4 SHEETS—SHEET 4.

Fig. 6.

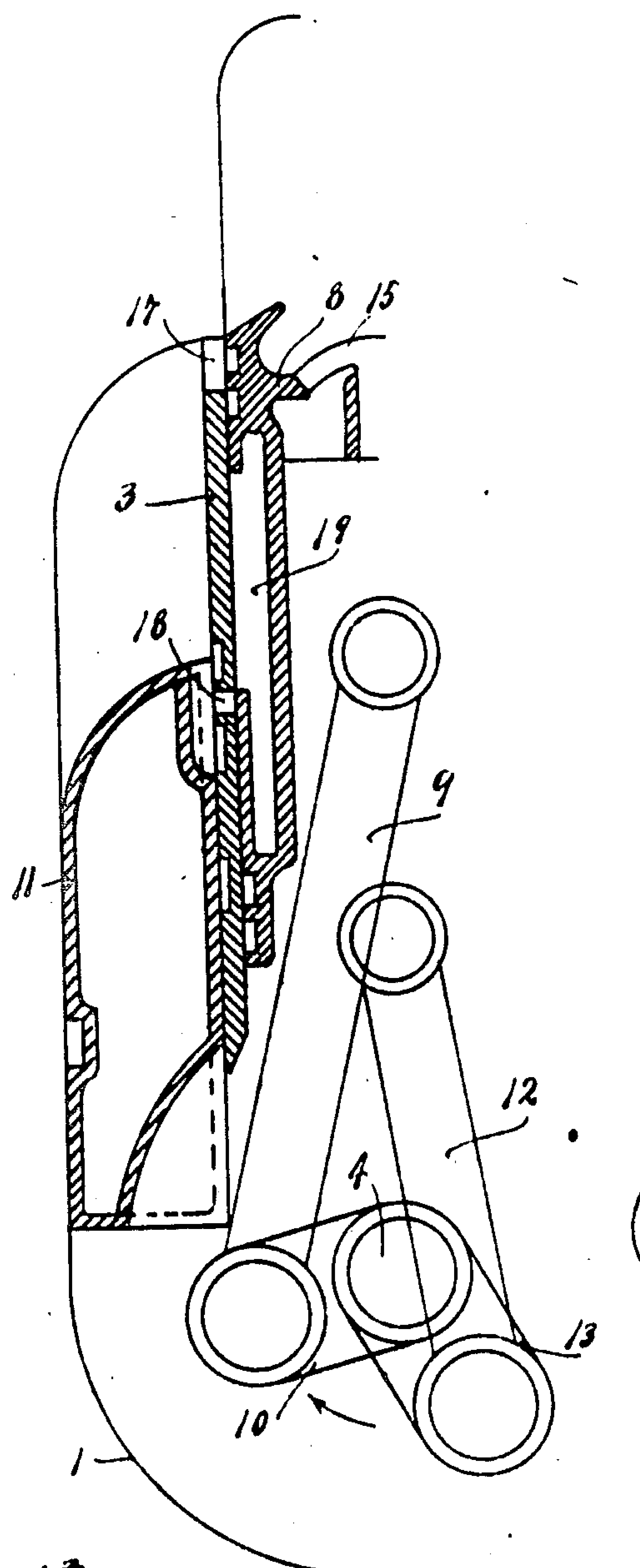
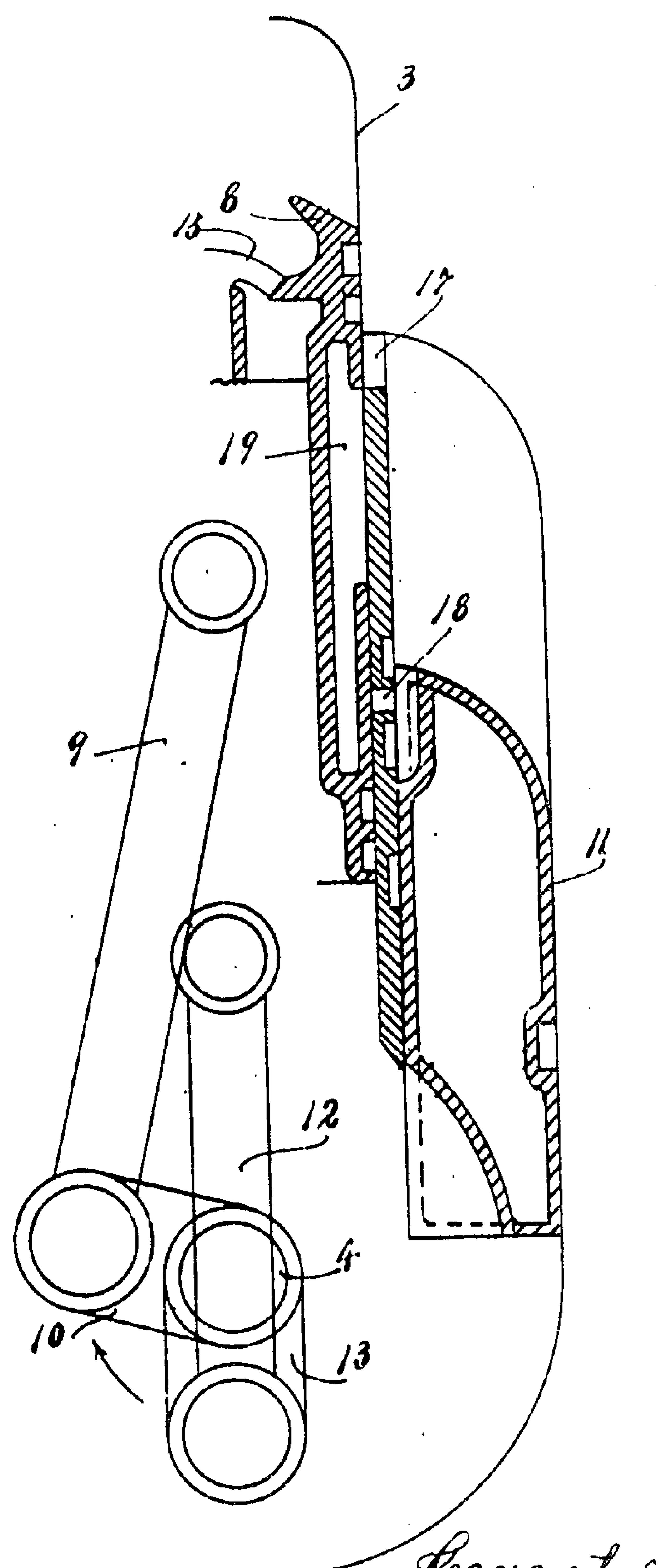


Fig. 7.



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UNITED STATES PATENT OFFICE.

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EXPLOSIVE COMPOUND ENGINE.

No. 881,214. Specification of Letters Patent. Patented March 10, 1908.

Application filed March 2, 1907. Serial No. 360,148.

To all whom it may concern:

Be it known that I, ELLIS J. WOOLF, of Minneapolis, Minnesota, a citizen of the United States, residing at Minneapolis, in the county of Hennepin and State of Minnesota, have invented certain new and useful Improvements in Explosive Compound Engines; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

My invention has for its especial object to provide an improved explosive compound engine of the kind or class wherein the elastic fluid becomes available for coincident expansion of the common volume thereof in the coöperating cylinders, all rendered effective on the cranks.

To this end, my invention consists of the novel features of construction hereinafter described and pointed out in the claims.

The invention is illustrated in the accompanying drawings, wherein like notations refer to like parts throughout the several views. It must be understood, however, that the said drawings are for illustration only, as the structure may take manifold forms and nevertheless embody and utilize the invention.

Referring to said drawings;—Figures 1, 2, 4, 5, 6 and 7 are views partly in section but chiefly in diagram, illustrating different positions of the parts for tracing the cycle of actions. Fig. 3 is a view in vertical section throughout the entire engine, in the plane of the crank shaft, serving to illustrate the structure ano showing the position of the moving parts as they would appear when the compounding of the gases begins, this being position 3 with respect to the several positions illustrated in the diagrams.

A base casting 1, low pressure cylinder casting 2 and high pressure cylinder casting 3 are rigidly secured together with suitably packed joints. Said castings 1 and 2 are of such construction that, when joined together, they inclose the crank shaft 4 and afford a space, surrounding the crank shaft, which serves as the compression or charging chamber 5 properly packed at the joints between the castings and the crank shaft to prevent the escape of the explosive mixture. The crank shaft 4 has a suitable fly wheel 6. The high pressure cylinder casting 3 is of the proper form to afford a water jacket 7 surrounding the explosion section of the high pressure cylinder. The high pressure cylinder wall is extended into the low pressure casting 2, thereby dividing the same into outer and inner differential spaces both opening to the charging chamber 5 at their inner or crank shaft ends.

In the high pressure cylinder, is mounted the high pressure piston 8 connected by a rod 9 with the central crank 10 of the crank shaft 4. The outer or annular space surrounding the part of the high pressure cylinder casting 3, which projects into the low pressure cylinder casting 2, affords the low pressure cylinder space, and in the same is mounted the low pressure piston 11 of corresponding annular form. The low pressure piston 11 is connected by rods 12 to cranks 13 located respectively on opposite sides of the crank 10. The high pressure piston 8 is connected to travel in advance of the coöperating low pressure piston 11. As shown, the high pressure piston crank 10 is located 105 degrees in advance of the low pressure piston cranks 13. The crank shaft compression or charging chamber 5 is provided with a suitable intake valve 14, for admitting the explosive mixture into said chamber. The high pressure piston 8 is of trunk form and opens at its inner end into the charging chamber 5; and in its head, there is mounted a spring seated charging valve 15 controlling the passage of the charge from the chamber 5 into the explosion section of the high pressure cylinder.

The explosion section of the high pressure cylinder is provided with suitable means for exploding the charge. The igniter may, of course, be of any suitable kind. I prefer to have the sparking plug 16 thereof centrally located in the head of the explosion cylinder, as shown in Fig. 3 of the drawing. The part of the high pressure cylinder casting 3 which projects into the low pressure cylinder casting 2 is provided with a series of alined openings 17 separated by bridge walls, which openings afford the low pressure admission port properly located for control by the high pressure piston 8. The said part of the high pressure cylinder casting 3 projecting into the low pressure cylinder casting 2 is also provided with a series of openings affording a preliminary exhaust port 18 properly located for control by the low pressure piston 11, to afford a preliminary exhaust from the high pressure cylinder, at the time when the charge is being admitted to the explosion section thereof under the compressing action of the low pressure piston. The high pressure piston 8 is of the proper construction to afford a port 19 encircling the trunk portion of the piston and always in communication with an exhaust pipe 20; and which port 19 is adapted to coöperate with said preliminary exhaust port 18 to afford said preliminary exhaust from the high pressure cylinder through the low pressure cylinder and to coöperate with the said low pressure admission or cylinder connecting port 17 to afford the final exhaust from the low pressure cylinder.

The casting 3 is of suitable construction to afford therein a pump cylinder 21 in which is mounted a pump plunger 22 normally held in its outermost position by a spring 23. The pump cylinder 21 is in communication with the explosion chamber of the high pressure cylinder through a small port 24 tapping the pump cylinder, at a point above the head of the pump plunger 22, thereby rendering the explosion pressure available to actuate the plunger against the spring 23. The pump cylinder 21 is provided with suitable intake check valve 25 and outlet check valve 26, the latter being connected by pipe 27, or otherwise, to the water jacket 7.

The water overflow or outlet pipe 28 is located inside the water jacket and is open to receive the water from its highest level in the jacket space and communicates, at its lower end, with an annular port 29, afforded between the castings 2 and 3 by the form thereof, and which port 29, as shown, is partly in the horizontal plane and partly in the vertical plane between the said castings and opens, at its inner end, into the low pressure cylinder, directly at the point where the port 17 connects the two cylinders. The overflow pipe 28, at its delivery end, is fitted with a throttle valve 30. The throttle valve 30 is adjustably held by a cap 31 which is recessed to afford an air chamber 32 opening into the water jacket space above the water level.

The high pressure cylinder is shown as tapped, near its upper end, by a valve controlled admission pipe 33, through which compressed air may be rendered available for starting the explosive engine or through which air or steam, under pressure, might be admitted, under the proper control, for operating the engine by air or steam instead of using the same as an explosive engine. The high pressure cylinder casting 3 is shown as fitted with an ordinary relief valve 34. The high pressure piston has its packing rings applied in the ordinary way. The low pressure piston 11 has its outer packing ring 35 also applied in the ordinary way; but the additional packing rings 36 for the low pressure piston 11 are seated in the intervening cylinder wall or downward extension of the high pressure cylinder casting, which disposition of these packing rings 36 enables them to be of the ordinary snap ring type. The lubrication is effected in any suitable way.

Operation. All the parts of the illustrated engine have now been specified. The operation will now be traced, with a view of rendering more distinct the new actions which result from the invention herein disclosed. Let it be assumed that an explosive mixture has been admitted, compressed and ignited, in the explosion section of the high pressure cylinder, and that the high pressure piston is about to begin its working stroke. Then, all the parts will be in the position illustrated in the diagram Fig. 1; from an inspection of which it will be seen that the low pressure admission or cylinder connecting port 17 will now be in communication with the exhaust port 19 of the high pressure piston, with the final exhaust in progress from the low pressure cylinder, the low pressure piston 11 being 105 degrees of its cranks' travel behind the crank of the high pressure piston; and this relationship will continue, with the final exhaust still in progress, until the piston cranks have traveled 75 degrees, whereupon all the parts will be in the position shown in diagram Fig. 2. In this position, shown in diagram 2, the high pressure piston has cut off the connecting port 17, thus closing the low pressure cylinder to compression therein. This compression in the low pressure cylinder then continues for 30 degrees more of the cranks' travel, which will bring the parts into the position shown in Fig. 3, or the point, at which the low pressure piston 11 has completed its compression stroke and the high pressure piston 8 is about to uncover the low pressure admission or cylinder connecting port 17, thereby permitting the gases to begin to operate expansively on both pistons. This coincident expansion of the common volume of the gases in both cylinders will then continue for 75 degrees of the cranks' travel from the position shown in Fig. 3, thereby bringing the parts into the position shown in the diagram Fig. 4, at which time the high pressure piston has completed its working stroke and is about to begin its return stroke. The expansion will then continue in the low pressure cylinder for 30 degrees more of the cranks' travel, thereby bringing the parts into the position shown in the diagram Fig. 5, at which instant the low pressure piston is about to uncover the preliminary exhaust port 18, for coöperation with the exhaust port 19 in the high pressure piston 8 to afford a preliminary exhaust from the high pressure cylinder. During this time, that the parts are moving from the position shown in Fig. 4 to the position shown in Fig. 5, only the differential area between the two is effective on the crank shaft, but owing to the way in which the two pistons are connected up, as hitherto noted, and the effect of the angularities of their connecting rods, the high pressure piston will, during this interval, be moving at substantially its lowest rate of speed, and the low pressure piston at substantially its highest rate of speed; so that the 30 degrees of the cranks' travel, during which time the differential area only of the pistons is effective, is only about 5% of the high pressure piston's return stroke.

The preliminary exhaust which begins when the parts are in the position shown in Fig. 5, continues for substantially 45 degrees of the cranks' travel, or until the parts are brought into the position shown in diagram Fig. 6; and, during the same time, the charging valve 15 is opened and a new charge forced into the explosion section of the high pressure cylinder, under the compressing action of the low pressure piston on the mixture within the crank shaft compression or charging chamber 5. When the parts have reached the position shown in the diagram Fig. 6, the connecting port 17 will be cut off, from the low pressure cylinder, by the high pressure piston 8, thus closing the high pressure cylinder to compression therein; and, during the next 30 degrees travel of the cranks, the low pressure piston 11 completes its working stroke and the high pressure piston comes into position where it is about to open the connecting port 17 to the piston port 19, for effecting the final exhaust, or in other words the parts will be in the position shown in diagram Fig. 7. During the next 75 degrees of the cranks' travel from the position shown in Fig. 7, the final exhaust from the low pressure cylinder and the compression in the high pressure cylinder continues, until the parts reach the original or starting position shown in diagram No. 1.

The explosive mixture is drawn through the intake valve 14 into the charging chamber 5, during the return or upward strokes of the two pistons. In view of the way in which the two pistons are connected up to their respective cranks, and the relative areas of the two pistons, this suction action on the chamber 5 will have been completed and the compression therein be about to begin when the parts have reached the position shown in Fig. 3 of the drawing. In the further downward movement of the two pistons, under the effect of the expanding gases thereon, the two pistons coöperate to compress the mixture in the charging chamber 5 until the parts come into the position shown in Fig. 4; and then, the compression in the charging chamber 5 will continue, under the action of the low pressure piston 11, after the high pressure piston begins its return stroke, and so continue until the parts come into the position shown in Fig. 5. When the parts reach the position shown in Fig. 5, the preliminary exhaust port 18 begins to open, as hitherto noted, and remains open until the parts come into the position shown in Fig. 6, and during this interval, while the parts move from the position shown in Fig. 5 to that shown in Fig. 6, the continued downward movement of the low pressure piston 11 forces the charge through the charging valve 15 into the explosion section of the high pressure cylinder; and, as this occurs at the time when the displacement within the low pressure cylinder equals its compression on the mixture in the charging chamber 5, it is possible to force the charge into the explosion cylinder at a comparatively low pressure. It follows that a maximum charge can be secured in the explosion chamber with slight base compression losses.

Having regard now to the injection of water into the partially expanded gases, let it be assumed that the pump cylinder, the water jacket and all the water circulating connections are loaded with a charge of water. Then let it further be assumed that the parts are in the position shown in Fig. 1, or in other words, that an explosion has just taken place. Then under the effect of said explosion, the pump plunger 22 is forced downward, against its retracting spring 23, thereby forcing the water from the pump cylinder into the water jacket 7, where it absorbs the heat units radiated from the explosion cylinder and, under the same impulse from the pump, a portion of the upper strata or highest temperature water will be forced into the air chamber 32, and another portion thereof into the overflow pipe 28 and past the throttle valve 30 and through the water port 29 into the low pressure cylinder and through the cylinder connecting port 17. Then, under the effect of the compressed air in the air chamber 32, the high temperature water will continue to be forced through the overflow pipe 28, past the throttle 30 and through the port 29, into the connecting port 17, after the parts have reached the position shown in Fig. 3 of the drawings, or, in other words, after the high pressure piston uncovers the connecting port 17 and the compounding action beg ns. The pressure stored in the air within the air chamber 32 was of course forced up to substantially that of the explosion pressure, under the action of the pump plunger; and, hence, it will be sufficient to continue the injection of the water into the gases against the back pressure therefrom. The pump, the air chamber and the throttle opening are so proportioned as to insure the injection of water into the gases, on their passage from the high to the low pressure cylinder, throughout the whole time that the connecting port 17 is uncovered during the working stroke of both pistons. It follows that the heat units radiated from the explosion cylinder into the water jacket will be reconverted into work and rendered effective on both pistons; or otherwise stated, the hot water which is injected into the gases, on their passage from the high to the low pressure cylinder, is there converted into steam, the elastic force of which is added to the force of the other gases. It will be seen that a portion of the water is injected into the low pressure cylinder and connecting port, before the high pressure piston uncovers the said connecting port; or otherwise stated, in the interval while the parts are moving from the position shown in Fig. 1 into the position shown in Fig. 3, or during the time that the low pressure piston is making its return or exhausting stroke. Hence it follows that the water which enters during this interval will spread all over the low pressure cylinder walls and piston and all over the high pressure piston or that portion thereof affording the exhaust cavity or port 19 and will thereby be brought against the inside surface of the high pressure cylinder wall, thus becoming effective to take up the heat units therefrom and cool all of these parts. The water thus thrown by the reciprocating action of the high pressure piston on the inside surface of the explosion cylinder wall will be largely carried back by the packing rings, but some thereof will adhere to the walls and come in contact with the intense heat within the explosion cylinder as it is uncovered by the movement of the high pressure piston during its explosion stroke, and the first water coming into contact with something like 3000 degrees of heat will either be decomposed, or be converted into highly superheated steam, and thereby be rendered more effective in its expansive action on the piston, and thereafter there will be continuously generated a layer of steam vapor interposed between the centrally inclosed intense heat and the said cylinder wall, thus preventing excessive radiation therethrough.

It will be recalled that when the parts are in the position shown in Fig. 7 of the diagrams, the high pressure piston is about to uncover the connecting port to the final exhaust pipe, and that the larger low pressure piston is about to begin its return or exhausting stroke. It is therefore evident that a condenser might be connected directly to this exhaust pipe, without valves or other mechanism, and be operative to make its partial vacuum effective throughout the larger portion of the low pressure piston's return or exhausting stroke, thus converting the heat units below atmospheric pressure and temperature into work.

What I claim is:

1. A compound explosive engine having its high pressure piston connected to travel in advance of the coöperating low pressure piston, and a charging chamber subject to compressing action of both of said pistons for forcing a charge into the explosion cylinder, substantially as described.

2. A compound explosive engine having its high pressure piston connected to travel in advance of the coöperating low pressure piston, a connecting port controlled by the high pressure piston to admit the gas from the high to the low pressure cylinder and to effect the final exhaust from the latter, a port controlled by the low pressure piston to effect a preliminary exhaust from the high pressure cylinder, and a charging chamber subject to the direct action of said low pressure piston for forcing a charge into said high pressure cylinder coincident with the preliminary exhaust therefrom.

3. A compound explosive engine having its pistons connected to a common crank shaft in a common charging chamber, with its high pressure piston connected to travel in advance of the coöperating low pressure piston, and means for admitting the charge from said charging chamber to the high pressure or explosion cylinder under the compressing action thereon of both of said pistons, substantially as described.

4. A compound explosive engine having its pistons connected to a common crank shaft in a common charging chamber, with its high pressure piston connected to travel in advance of the coöperating low pressure piston, means affording a preliminary exhaust from the high pressure explosion cylinder, and means for admitting the charge from the charging chamber to the explosion cylinder under the compressing action thereon of the low pressure piston coincident with said preliminary exhaust, substantially as described.

5. A compound explosive engine having its high pressure piston connected to travel in advance of the coöperating low pressure piston, a low pressure admission port controlled by the high pressure piston, a preliminary exhaust port controlled by the low pressure piston, and an exhaust port in the high pressure piston, which, under the movement of said piston, coöperates alternately with said preliminary exhaust port and with said low pressure admission port to effect a preliminary and a final exhaust, substantially as described.

6. A compound explosive engine having its pistons connected to a common crank shaft in a common charging chamber, with its high pressure piston connected to travel in advance of the coöperating low pressure piston, a low pressure admission port controlled by the high pressure piston, a pre-

liminary exhaust port controlled by the low pressure piston, an exhaust port in the high pressure piston which, under the movement of said piston, coöperates alternately with said preliminary exhaust port and with said low pressure admission port to effect a preliminary and the final exhaust, and a valve controlled charging port for admitting the charge to the explosion chamber under the pressure from said charging chamber coincident with said preliminary exhaust, substantially as described.

In testimony whereof I affix my signature in presence of two witnesses.

ELLIS J. WOOLF.

Witnesses:
JAS. F. WILLIAMSON,
F. D. MERCHANT.