

No. 683,886.

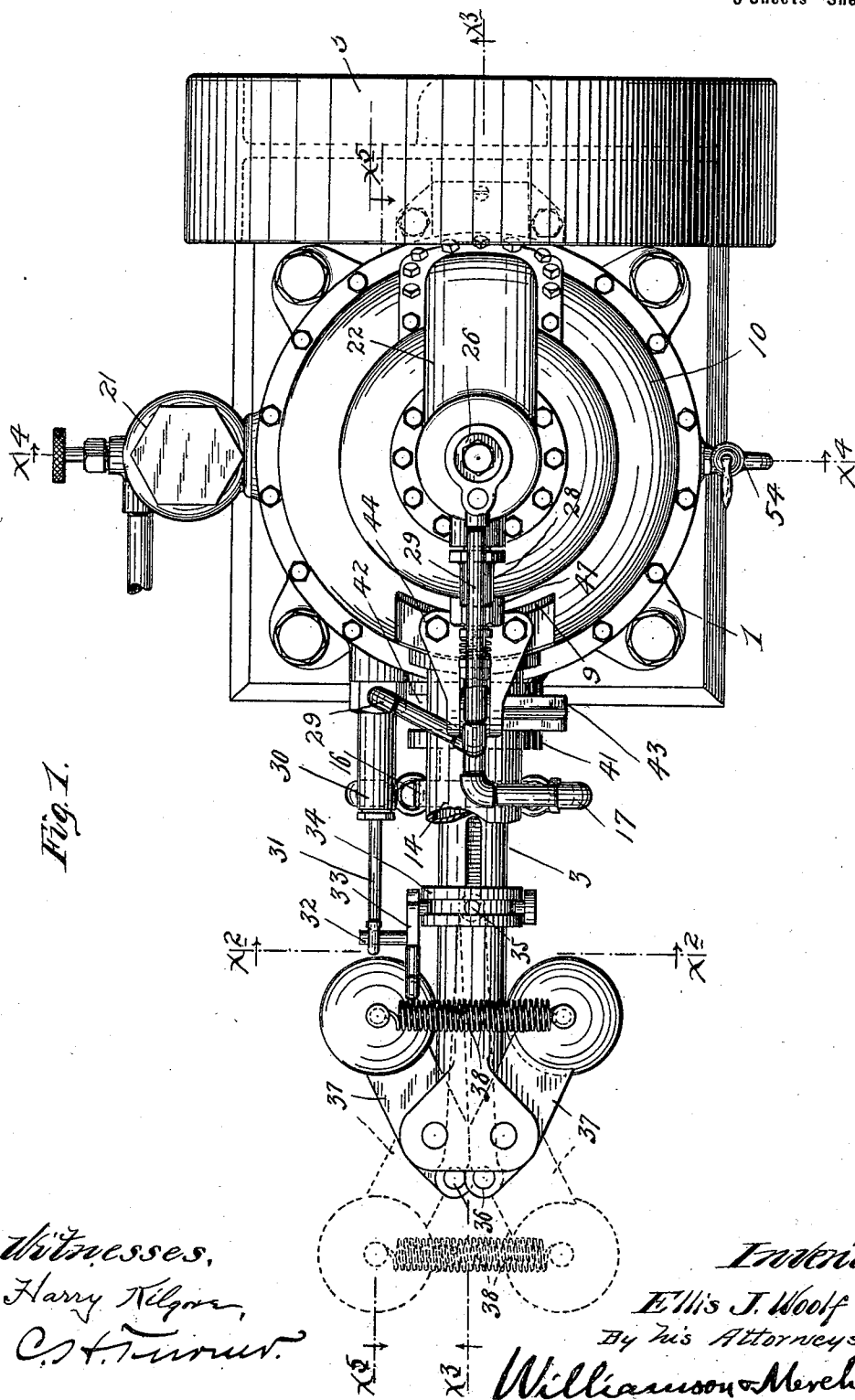
Patented Oct. 1, 1901.

E. J. WOOLF.
EXPLOSIVE ENGINE.

(Application filed Jan. 29, 1901.)

(No Model.)

6 Sheets—Sheet 1.



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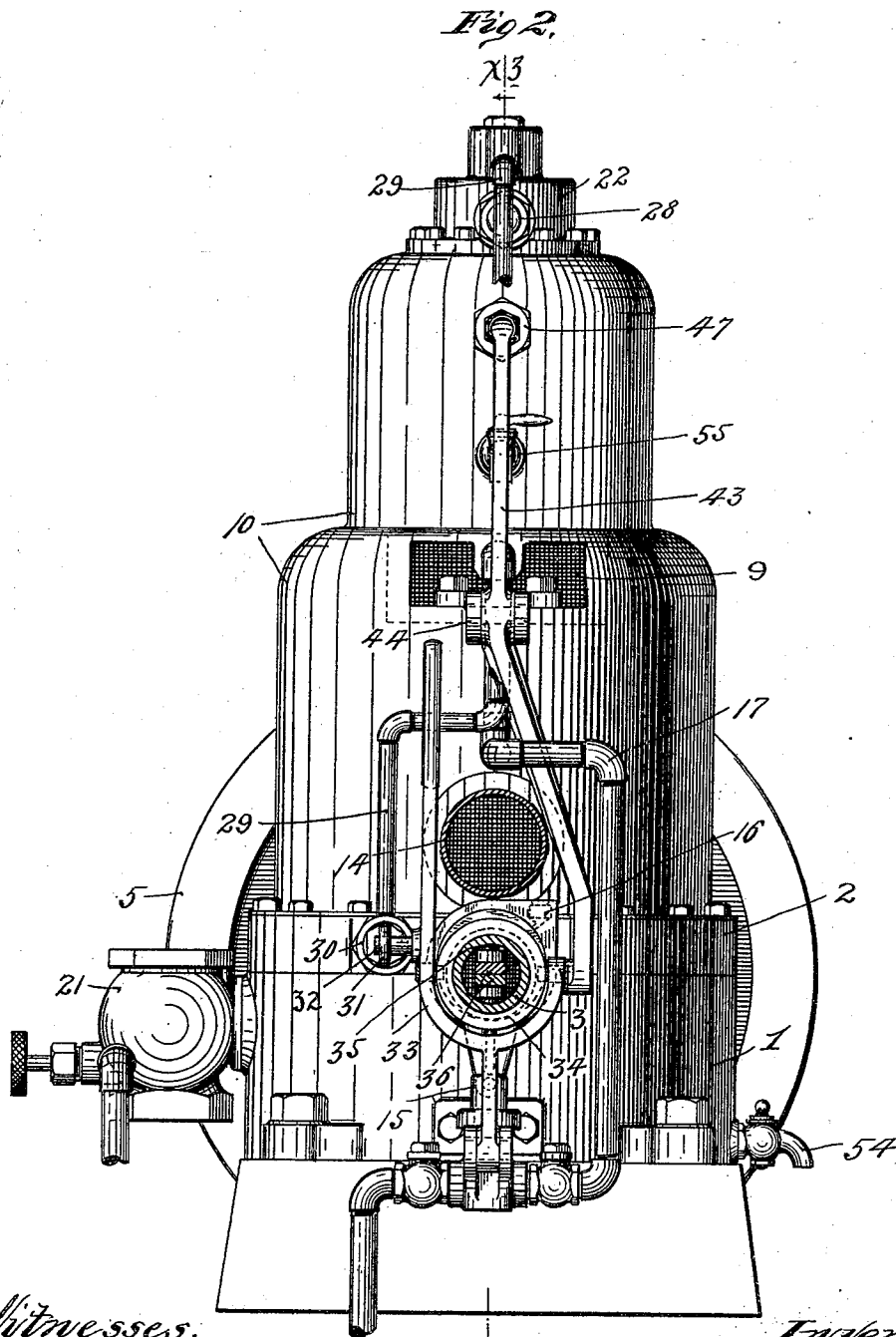
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6 Sheets—Sheet 2.



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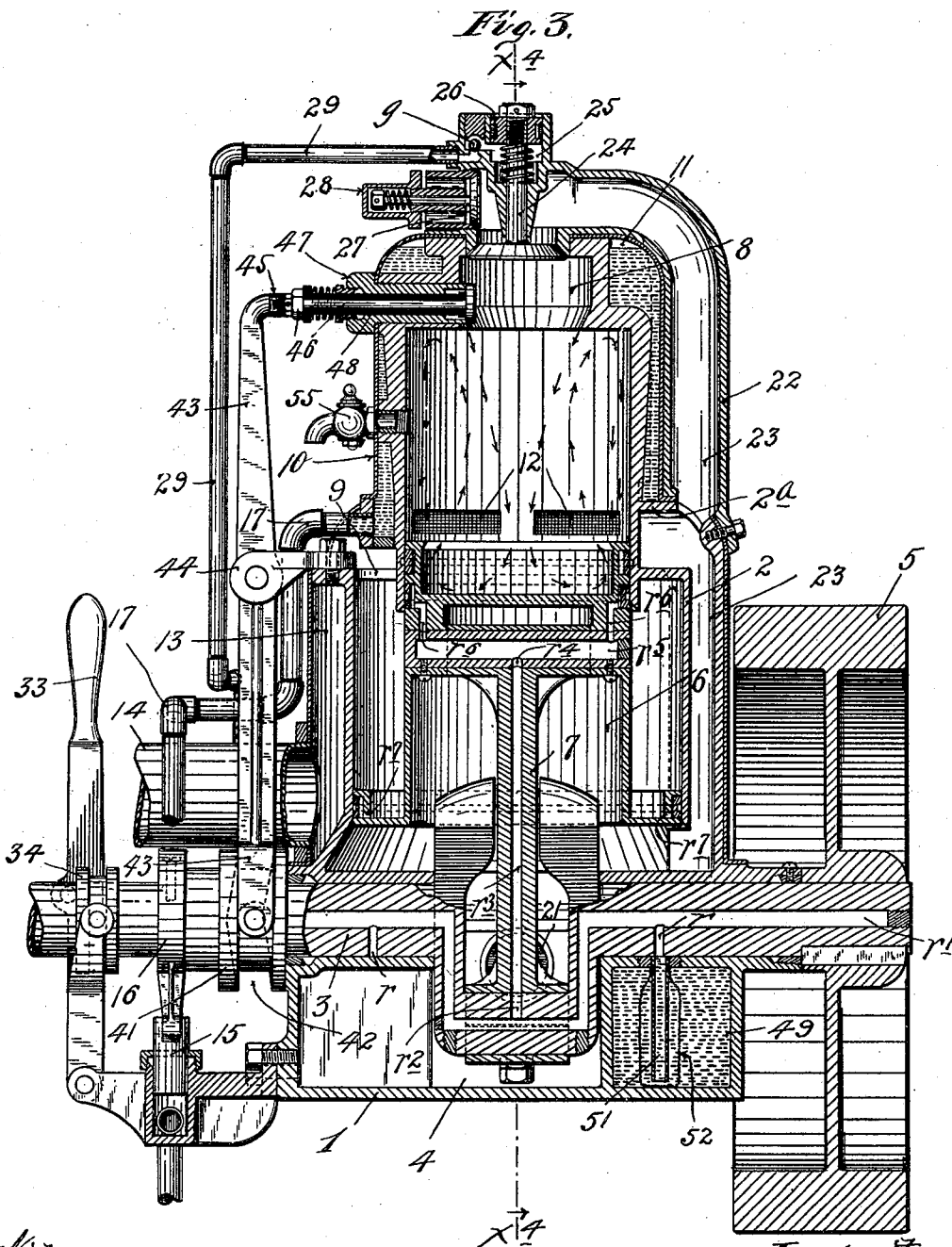
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6 Sheets—Sheet 3.



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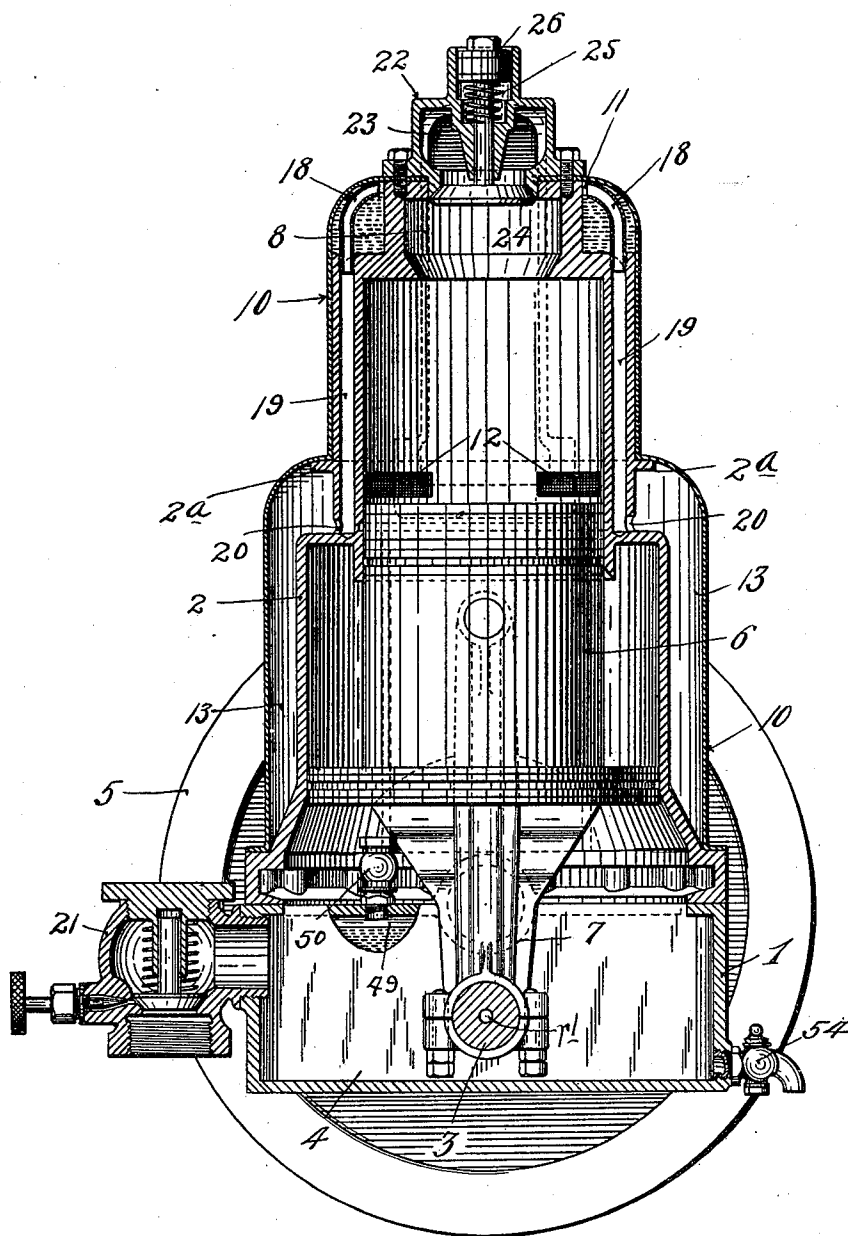
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Fig. 4.



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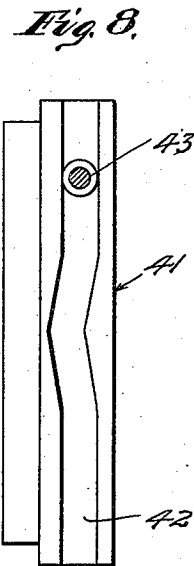
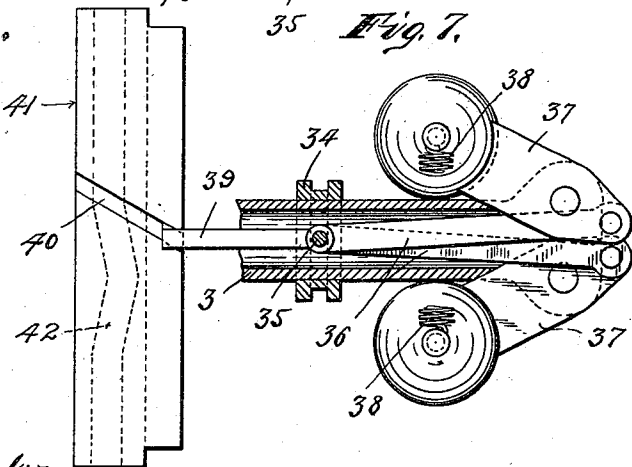
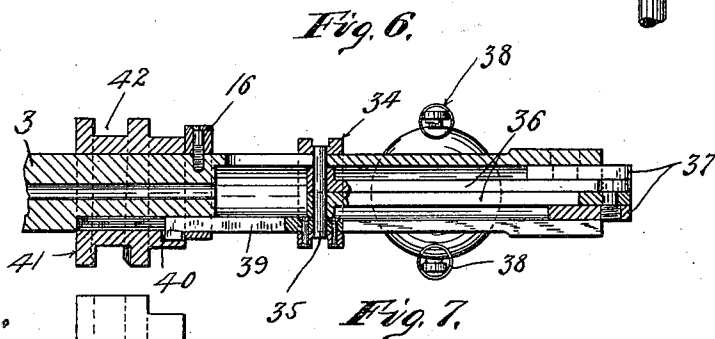
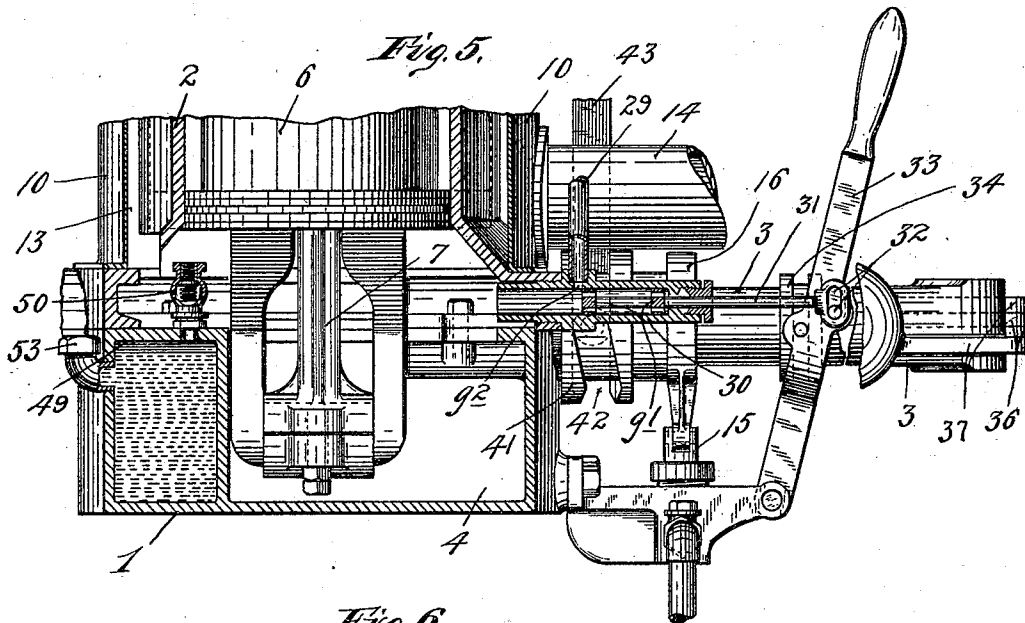
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Fig. 9.

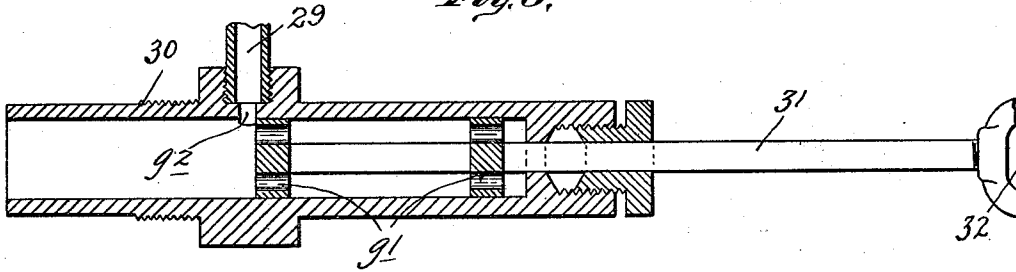


Fig. 10.

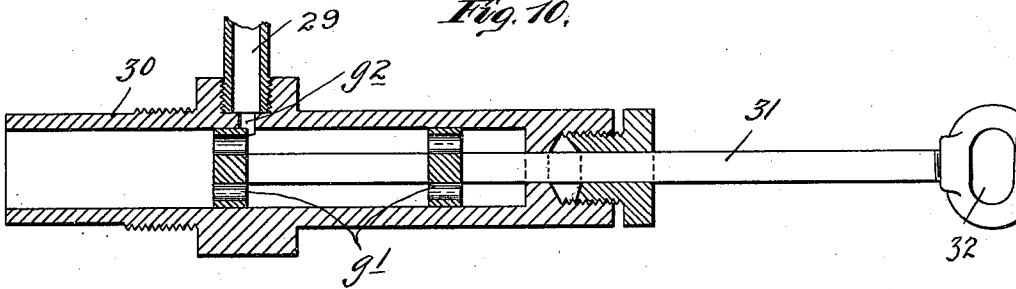


Fig. 11.

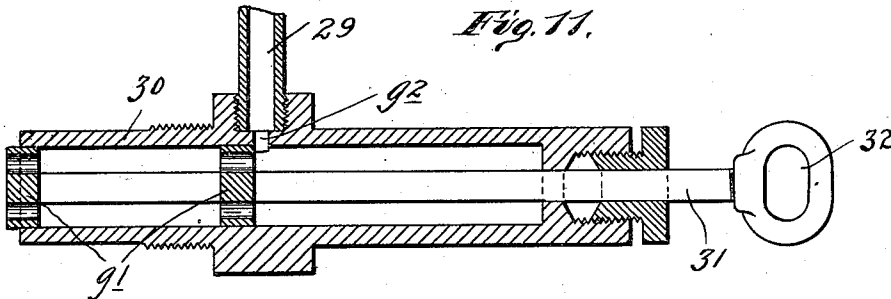
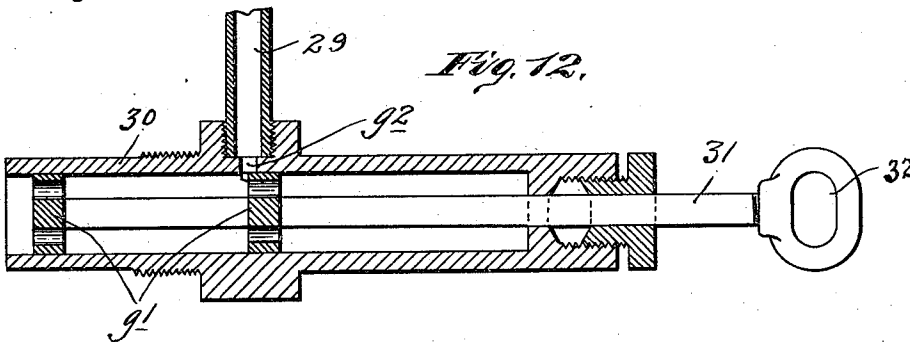


Fig. 12.



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UNITED STATES PATENT OFFICE.

ELLIS J. WOOLF, OF MINNEAPOLIS, MINNESOTA, ASSIGNOR TO THE WOOLF VALVE GEAR CO., OF SAME PLACE.

EXPLOSIVE-ENGINE.

SPECIFICATION forming part of Letters Patent No. 683,886, dated October 1, 1901.

Application filed January 29, 1901. Serial No. 45,244. (No model.)

To all whom it may concern:

Be it known that I, ELLIS J. WOOLF, 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-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 relates to explosive-engines, and has for its object to provide certain radical improvements therein with a view of securing increased efficiency.

To this end my invention consists of the novel devices and novel combinations of devices hereinafter described, and defined in the claims.

Some of the features of construction embodied in the engine herein disclosed were disclosed and are broadly claimed in my pending application, Serial No. 13,194, filed April 17, 1900, entitled "Explosive-engines."

The invention is illustrated in the accompanying drawings, wherein like characters of reference refer to like parts throughout the several views.

In said drawings, Figure 1 is a plan view of the engine with some parts broken away, the parts illustrated being as they would appear when the engine is idle. Fig. 2 is a view in vertical section on the line $x^3 x^3$ of Fig. 1, most of the parts of the engine being shown in elevation. Fig. 3 is a vertical central section on the line $x^3 x^3$ of Figs. 1 and 2, with some parts broken away. Fig. 4 is a vertical central section on the line $x^4 x^4$ of Figs. 1 and 3. Fig. 5 is a view in vertical section on the line $x^5 x^5$ of Fig. 1 with some parts broken away. Fig. 6 is a detail in vertical section lengthwise of the crank-shaft, taken through portions of the reversing mechanism and the governing mechanism. Fig. 7 is a view, partly in horizontal section and partly in diagram, to show the relation of the governor to the cam which controls the igniter, the cam being shown in diagram as it would appear if cut and laid out flatwise and looking at the interior surface thereof. Fig. 8 is a detail in diagram, showing the same cam as it would

appear when cut and laid out flatwise looking at the exterior or peripheral surface of the same; and Figs. 9 to 12, inclusive, are sectional diagrammatic views illustrating the actions of the governing-valve.

Some of the features of the invention are applicable to all kinds of explosive-engines and others are of special service only in explosive-engines of the two-stroke-cycle type. The engine illustrated is of the two-stroke-cycle type.

A base-casting 1 and a cylinder-casting 2 in the engine illustrated 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 3 and afford a space surrounding the same, which serves as the compression-chamber 4. The crank-shaft 3 is provided with a suitable fly-wheel 5. The casting 2 is of proper form to afford a differential cylinder the larger member of which opens into the compression-chamber 4. In this differential cylinder is mounted a corresponding differential piston 6, connected by rod 7 with the counterbalanced crank on the shaft 3. The smaller member of the differential piston 6 is of trunk form and the lower end thereof opens into the compression-chamber 4. The cylinder-casting 2 is of the proper form to afford an explosion-chamber 8 at its upper end opening into the explosion end of the cylinder. The differential space between the cylinders and pistons is not inclosed, but is open to the atmosphere at its upper end, as shown at 9 in Fig. 3. A suitable casing 10, preferably composed of brass or copper spun into shape, is of such form and is so applied to the cylinder-casting 2 as to afford a water-jacketing chamber 11 between the same and the cylinder-casting 2 above the horizontal flange 2^a on said casting and to afford between the same and said cylinder-casting 2 below said flange an exhaust-chamber 13, which is tapped by the exhaust-ports 12, leading from the smaller cylinder. An exhaust-pipe 14 taps the chamber 13 through the casing 6, as best shown in Figs. 3 and 5. A water-supply pump 15, operated from the crank-shaft 3 through eccentric-motion device 16, as best shown in Figs. 3 and 5, delivers circulating

water through pipe 17 to the lowest point of the water-jacketing chamber 11. The upper portion of the cylinder-casting 2 is tapped by a pair of return-flow water-pipes 18, located within the water-jacket, with their upper ends receiving from the highest point thereof, and the casting itself is provided with a passage-way 19, forming a continuation for the flow of the water from the pipes 18. The passages 19 are provided at their lower ends with outlet-ports 20, delivering to the exhaust-chamber 13. Hence the circulating or cooling water wastes or flows outward through the exhaust-chamber 13 and the exhaust-pipe 14.

The compression-chamber 4 receives its supply of explosive mixture under the control of an inlet-valve 21, which may be of any suitable form adapted to supply the commingled air and gasoline or other carbonizing agent therethrough. The larger portion of the cylinder-casting 2 is cored out to afford a section of a passage-way which coöperates with a pipe-casting 22 to afford a charging-passage 23, which leads from the compression-chamber 4 to the explosion-chamber 8, as best shown in Fig. 3. Said pipe-casting 22 is fitted to the cylinder-casting with a suitably-packed joint and is of such construction as to overreach the top of the jacket-casing 10 and afford a means of securely connecting said jacket to said cylinder-casting at their upper ends when bolted in place. Said pipe-casting 22 is also of such construction as to afford a seat for the charging-valve 24, a guide for its stem, and a governing-chamber 25, the upper portion of which is fitted with a small piston 26, carried by the stem of the charging-valve above said valve's retracting or closing spring, as best shown in Fig. 3. The fluid-pressure-governing chamber 25 is separated from the charging-passage 23 by the form of the casing for the charging-valve. The pipe-casting 22 is also of proper form to afford a suitable casing for a spring-seated air-inlet valve 27, located outward of the charging-valve and subject to a regulating-nut 28 for regulating the amount of the air-supply opening to said air-inlet valve. The fluid-pressure-governing chamber 25 is tapped by a pipe 29, which leads from the casing 30 of a governing-valve 31, as best shown in Figs. 3 and 5. The passage from the pipe 29 to the governing-chamber 25 is subject to a small check-valve g , so mounted with respect to the piston 26 on the charging-valve 24 that the downward or opening movement of the charging-valve 24 will cause the piston 26 to cage the fluid under pressure within the chamber 25 and render the same operative to oppose the opening movement of the charging-valve to govern the engine. The casing 30 of the governing-valve 31 taps the compression-chamber 4, and the governing-valve 31 is provided with a pair of small pistons g' for controlling the admission to the pipe 29 through the port g^2 , leading from the casing of the governor-valve. Said pistons g' on the governing-valve stem are perforated lengthwise thereof and are spaced apart from each other, as best shown in Figs. 5 and 9 to 12, for purposes which will later appear. The outer end of the stem of the governing-valve 31 has slot-and-pin connection, as shown at 32 in Fig. 5, with a reversing-lever 33 suitably pivoted to the fixed structure. The reversing-lever 33 takes hold of a shipper-sleeve 34, loosely mounted for sliding movement on the outwardly-extended end of the crank-shaft 3, as shown in Figs. 1, 2, 3, and 5. The shipper-sleeve 34 is provided with a pin 35, extending through slots in the walls of a hollow portion of the crank-shaft 3, as best shown in Fig. 6, the slots extending lengthwise of the shaft to permit the sliding movement of the sleeve 34 and its pin 35. A pair of rods 36 pivotally connect the pin 35 of the shipper-sleeve 34 with the inner ends of governor-levers 37, which are pivoted to projecting portions of the crank-shaft 3, as best shown in Figs. 1, 6, and 7. The governor-levers 37 are connected at their weighted ends by a pair of centripetal springs 38, which embrace the crank-shaft. The rods 36 and the governor-levers 37 are staggered in respect to each other, as best shown in Fig. 6, thereby affording the necessary clearance for the proper actions thereof. This construction affords a reversing-governor, wherein the governor-levers may be turned completely over on their fulcrums, and thereby bring the same into proper working positions for moving the shipper-sleeve 34 in the direction desired for controlling the motions of the engine in either direction of the crank-shaft's rotation, as will later more fully appear. The shipper-sleeve 34 has rigidly secured thereto a key 39, suitably seated for sliding movement on the crank-shaft 3 and formed with an outturned tip or hook-like end, which engages in a cam-channel 40, extending in an angular direction on a straight line crosswise of the inner surface of a cam-wheel 41, as best shown in Fig. 7. The cam-wheel 41 is loosely mounted on the crank-shaft 3, but held from sliding motion thereon by its position between the pump-eccentric and the castings, as best shown in Figs. 3 and 5. The cam-wheel 41 is provided on its periphery with a cam-channel 42, which is engaged by the roller-equipped lower end of the igniter-lever 43. The igniter-lever 43 is shown as pivoted to a bearing-bracket 44, removably secured to the cylinder-casting 2. At its upper end the igniter-lever 43 is provided with a tip 45, of rubber or other insulating material, which bears against the outer end of the spring-held plunger 46, constituting the movable member of the circuit-controller in the igniter-circuit. The other or fixed member 47 of said circuit-controller is tapped into the cylinder-casting, so as to project into the explosion-chamber 8, and the said two parts 46 and 47 of said circuit-controller are insulated from each other by a sleeve 48, of suitable insulating material. One of the leads from the source of electricity connects to the spring-

held plunger 46, and the other lead connects to any part of the machine, and the igniter-circuit is broken by the inward movement of the spring-held plunger 46 under the action 5 of the cam-wheel 41 and the igniter-lever 43, thereby producing a spark within the explosion-chamber 8 by the separation of the parts 46 and 47.

The base-casting 1 is of such construction 10 as to afford a chamber 49 for lubricating-oil, which chamber is in communication with the compression-chamber 4 through a check-valve 50, as shown in Fig. 5, thereby rendering the compression-chamber pressure avail- 15 able in the lubricating-chamber 49 for effecting a forced feed of oil to all the working parts of the engine. A feed-pipe 51, preferably encaged by a guard-screen 52, depends from the upper wall of the lubricating-chamber 49 to a point near the bottom of the same, 20 and the crank-shaft 3 is provided with radial ducts r , one of which registers with said pipe under the rotary motion of the crank-shaft for admitting oil to a central passage or duct 25 r' , extending throughout the entire length of the crank-shaft, but closed at its opposite ends, as best shown in Fig. 3. The crank-pin is provided with a radial duct r'' , leading from the central passage r' of the crank-shaft 30 and is adapted to register with a duct r^3 in the connecting-rod 7 under the rotary motion of the shaft. The oil-duct r^3 in the connecting-rod 7 is adapted to register at its upper end with a radial duct r^4 in the cross-head pin, 35 which is non-rotatively fixed to the piston and bored out to afford an oil duct or cavity r^5 , tapped by the duct r^4 and itself tapped by ducts r^6 at its opposite ends, leading to the seat of the lowermost packing-ring on the 40 smaller piston. The rim of the larger piston is of cup shape, and the cup-cavity is tapped by ducts r^7 , leading to the seat for the packing-ring of said larger piston. With this construction and disposition of the oil-ducts r to 45 r^7 , inclusive, the lubricating-oil will be forced under pressure from the chamber 49 throughout all of the said ducts and be delivered from said ducts under pressure to all the bearing and working surfaces of the engine. The oil- 50 chamber 49 is provided, of course, with a suitable filling-pipe 53, (shown in Fig. 5,) which is normally closed at its outer end.

The base portion of the compression-chamber 4 is provided at its lowest point with a 55 suitable drain-cock 54. The explosion-cylinder is shown as provided with a hand-action relief-valve 55 for relieving the compression within the explosion-cylinder, if so desired, for facilitating the starting of the engine. 60 The key 39, carried by the shipper-lever 34, moves on a straight line parallel with the crank-shaft, and as its outturned tip works in a straight camway 40, running in an angular direction crosswise of the inner surface 65 of the cam-wheel 41, it follows that said cam-wheel will be rotated under the sliding motion of the shipper-sleeve and said cam, as

required, to vary the actions of the igniter-cam.

Operation: All the parts have now been 70 specified. Some of the actions are also probably clear from the detailed description. It will be serviceable, however, to summarize the main actions of the engine, first considering the distribution and then the governing 75 and reversing actions of the engine. Under the upward or suction stroke of the large piston it is obvious that the explosive mixture will be drawn in through the inlet-valve 21, thereby filling the compression-chamber 4 80 with the explosive mixture, and that air will be drawn into the charging-passage 23 through the air-inlet valve 27, thereby filling the charging-passage with a column of air and encaging the same therein between the ex- 85 plosive mixture and the charging-valve. On the downward stroke of the large piston it is equally obvious that the explosive mixture within the compression-chamber 4 will be compressed and forced upward behind the 90 encaged air-column within the charging-passage 23, thereby also compressing said encaged column of air to the same pressure. Under the downward or explosion stroke of the smaller piston the exhaust-ports 12 will 95 be uncovered at the proper time, and as soon as the pressure within the explosion-cylinder has been sufficiently reduced by the exhaust the charging-valve 24 will open under the pressure from the compression-chamber and 100 the charging-passage 23, thereby first admitting the encaged column of air from the charging-passage 23 in advance of the explosive mixture which follows from the compression-chamber 4. With the parts in the 105 positions as shown in Fig. 3 the exhaust from the last previous explosion will have taken place down to a pressure which is less than the charging pressure above the charging-valve 24. The instant that the charging- 110 valve 24 opens the inrushing column of air from the charging-passage 23 will expel the remainder of the spent gases from the explosion-cylinder in advance of the incoming charge of explosive mixture. The explosion- 115 chamber 8 is of the proper shape to deflect the incoming air and explosive mixture downward and inward toward the axis of the cylinder. The head of the small piston is recessed to the proper form to make the same 120 act as a redelector, so as to redelect the incoming air and explosive mixture back upward and inward close to the incoming column. When the redelected column of the incoming charge reaches the upper end of the 125 explosion-cylinder, it will be again redelected outward and downward through the outer zone of the cylinder. The course of the incoming charge, made necessary by the deflecting and redelecting surfaces, above 130 noted, is roughly indicated by the arrows in Fig. 3, and in virtue of the course taken it follows that the spent gases must be driven out through the exhaust-ports 12 ahead of

the incoming charge. The intrushing column of air admitted from the charging-passage 23 to the explosion-chamber in advance of the explosive mixture, as described, scavenges the cylinder, forces out the spent gases, cools off the cylinder and piston, and affords an intervening body of air between any burning gases which may remain in the cylinder and the incoming column of the explosive mixture which follows behind the air, thereby preventing premature explosions. Under the return or upward stroke of the smaller piston the charge will be compressed and ignited at the proper time to produce the explosion, thereby imparting the working stroke to the piston. The upward or compression stroke of the smaller piston is of course the suction-stroke of the larger piston, which by its action fills the compression-chamber 4 with the explosive mixture supplied from the inlet-valve 21, as described, and fills the charging-passage 23 with air supplied through the air-inlet valve 27, as described, with the air column encaged within said charging-passage at the time when the compression-stroke of the smaller piston has been completed, thereby surrounding the charging-valve with air alone with the column of air extending throughout the entire length of the charging-passage 23. This body of encaged air is therefore available to widely separate the explosive mixture from the charging-valve 24 during the working stroke of the piston, thus making back explosions impossible from any flame leakage into the charging-passage 23. The differential cylinder and piston are of large importance where the large piston is used to draw into the compression-chamber the supply of mixture and into the charging-passage the supply of air to afford the encaged column of air in advance of the mixture, for the reason that thereby an excessive quantity of air is rendered available to the explosion-cylinder, together with an abundantly sufficient quantity of explosive mixture following up behind the same to secure powerful explosions at high speed. A most radical increase of efficiency is thereby secured. Owing to the presence of this large column of air, rendered available to the explosion-chamber in advance of the explosive mixture, it is obvious that if any portion of the incoming charge passes out through the exhaust-ports it will be air and not explosive mixture. Hence economy in the use of the gas is secured.

Attention will now be given to the governing and reversing action. In this engine the governing devices and the reversing devices cooperate with each other and are under the control of a common reversing-lever.

In explosive-engines it has been found in practice that it is highly desirable, and, in fact, is probably a practical necessity, first to reduce the power of the explosions, thus incidentally also lowering the speed of the engine before

attempting to use adversely-timed explosions to reverse the engine. The devices disclosed in this application enable that result to be readily secured. The centrifugal governor regulates the speed of the engine when in service according to load in either direction of motion. Then when it is desired to reverse the engine while in motion the manipulation of the reversing-lever will adjust the governing devices and the variable igniter, as required for that purpose. By reference to Figs. 5 to 12, inclusive, these actions can be readily traced. In Figs. 5 and 9 the governing-valve 31 and all the parts shown are as they would appear when the engine is in idle position and ready to start. As shown in said views, the governing-valve 31 being in its outermost position, or nearly so, the admission-port g^2 to the pipe 29 is uncovered, thereby rendering the fluid-pressure from the compression-chamber 4 available to the fluid-pressure or governing-chamber 25 in the casing of the charging-valve 24 and operative to oppose the opening movement of the charging-valve. The charging-valve 24 will therefore not open as widely as it otherwise would, thus reducing the quantity of the charge admitted to the explosion-cylinder. At the same time the igniter-cam 41 will be in such position that ignition will not occur until the smaller piston has completed its compression-stroke. This insures a comparatively weak and late explosion. The parts being in this position, the engine is ready to start. Let it be assumed that the engine has started. Then as soon as the engine is under way the centrifugal governor will begin to act and will first move the governing-valve 31 inward, (in the direction of motion assumed,) thereby cutting off admission to the pipe 29 by closing the port g^2 , and hence no further fluid-pressure will be available from the compression-chamber 4. The stem of the charging-valve has a loose fit in its guide, thus permitting whatever fluid may have been in the governing-chamber 25 to have wasted back into the charging-passage 23. Hence no pressure is available under the small piston 26 of the charging-valve 24. The charging-valve 24 will therefore open to its maximum extent under the charging pressure, thus admitting a maximum charge to the explosion-cylinder, and hence the engine will quickly gain its full working speed. At the same time that the centrifugal governor had the above-described effect on the governing-valve 31 it also moved the igniter-cam 41 by shifting the key 39, thereby varying the point of ignition, so as to cause the explosion to occur before the smaller piston has completed its compression stroke. As the speed of the engine increases the governing parts will come into the position shown in Fig. 10, and the igniter-cam 41 will come into the proper corresponding position for igniting the charge to produce the explosion at the proper point for the predetermined speed. The inner member of the

pistons g' of the governing-valve 31 having thus been thrown inward under the action of the governor to a point beyond the admission-port g^2 to the pipe 29 is in governing position for maintaining the predetermined speed and will then govern from the outer edge of said inner member of the pistons g' . Hence more or less fluid will come under pressure into said governing-chamber 25 in the casing of the charging-valve, thus variably opposing the opening movement of said charging-valve 24. Now assume that it is desired to reverse the engine while in motion. The operator taking hold of the reverse-lever 33 will throw the same inward to its limit, thereby bringing the governing-valve 31 into the position shown in Fig. 11 and the governor-levers into the position shown in dotted lines in Fig. 1. This inward movement of the reversing-lever 33 also shifts the igniter-cam 41 to its limit, so as to bring the same into position to produce adversely-timed explosions. As soon as the admission-port g^2 to the pipe 29 was opened by said hand manipulation of the reverse-lever 33, it is of course obvious that the maximum amount of fluid-pressure became available to the governing-chamber 25 in the casing of the charging-valve 24, thus minimizing the opening of the charging-valve 24 and admitting a minimum charge to the explosion-chamber for use under the adversely-timed ignition for reversing the engine. To insure this result while moving the reversing-lever inward, the two pistons g' on the governing-valve 31 are spaced apart from each other, as described. The engine having been thus reversed, the governing-valve 31 again comes under the control of the centrifugal governor, with the weighted levers hanging in the proper direction to move the governing-valve 21 in the reverse directions as compared with the movements thereof when the engine is running in the opposite direction. The governing-valve 31 will then shift from the position shown in Fig. 11 to the position shown in Fig. 12 and will govern from the inner edge of the outer member of its pistons g' .

It will be understood that many of the features of the invention are capable of a wide range of modification in construction and application and that the details may be widely varied without departing from the principles of the invention.

The drawings forming part of this case were taken from construction drawings and are one-third full size throughout. The engine illustrated is designed as a ten-horse-power engine of the weight two hundred and ten pounds.

What I claim, and desire to secure by Letters Patent of the United States, is as follows:

1. In an explosive-engine, the combination with a compression-chamber having an inlet-valve for the explosive mixture, a charging-port leading from the compression-chamber to the explosion-chamber and a charging-

valve controlling said charging-port, of a differential cylinder having its enlarged end in communication with said compression-chamber and a corresponding differential piston working in said differential cylinder, which valves operate under the action of the crank-shaft end of the larger piston, substantially as and for the purposes set forth.

2. In an explosive-engine, the combination with a crank-shaft compression-chamber having an inlet-valve for the explosive mixture, and an air-inlet valve, a charging-port leading from said compression-chamber to the explosion-chamber and a charging-valve controlling said charging-port, of a differential cylinder having its enlarged end in communication with said compression-chamber and a corresponding differential piston working in said differential cylinder, all of which valves operate under the action of the crank-shaft end of the larger piston, substantially as and for the purposes set forth.

3. In an explosive-engine, the combination with a crank-shaft compression-chamber having valve-controlled inlet for the explosive mixture, of a differential cylinder having its large end in communication with said compression-chamber, a corresponding differential piston therein, and a valve-controlled charging-passage leading from said compression-chamber to the explosion-chamber and provided with an air-inlet valve near the charging-valve, all of which valves operate under the action of the crank-shaft end of the larger piston, whereby an excessive body of air will be drawn into the charging-passage, coincidentally with the drawing in of the explosive mixture to the compression-chamber, and will afford a large column of air encaged in said passage, which will be forced into the explosion-chamber, in advance of the explosive mixture, substantially as and for the purposes set forth.

4. In an explosive-engine, the combination with a compression-chamber having an inlet-valve for the explosive mixture and a charging-port leading therefrom to the explosion-chamber of the engine, a charging-valve controlling said port, a differential cylinder having its enlarged end in communication with said compression-chamber, a corresponding differential piston, working in said cylinder, whereby the enlarged end of said differential piston operates to draw into said compression-chamber, an excessive charge of explosive mixture and to render the same available to the explosion-chamber, as described, and a governing device rendering fluid-pressure from said compression-chamber operative on said charging-valve to oppose the opening movement of the same for governing the engine, substantially as described.

5. In an explosive-engine, the combination with a compression-chamber, of a valve-controlled charging-passage leading from said compression-chamber to the explosion-chamber, a charging-valve subject to pressure in

opposite directions, from said compression-chamber; and a governing-valve controlling the supply of fluid for opposing the opening movement of said charging-valve, substantially as described.

6. In an explosive-engine, the combination with a compression-chamber, of a charging-valve subject to fluid-pressure in opposite directions, a casing for said charging-valve constructed to afford a governing-chamber separated from the charging-chamber, and a check-valve controlling the admission to said governing-chamber, whereby a body of fluid will be caged in said governing-chamber, under pressure, to oppose the opening movement of the charging-valve, substantially as described.

7. In an explosive-engine, the combination with a compression-chamber, of a charging-valve subject to fluid-pressure in opposite directions, a casing for said charging-valve constructed to afford a governing-chamber separated from the charging-chamber, a passage from said compression-chamber to said governing-chamber provided with a governing-valve, and a check-valve for caging the fluid-supply under pressure, in said governing-chamber, substantially as described.

8. In an explosive-engine, the combination with a charging-valve subject to fluid-pressure in opposite directions, of a governing-valve controlling the supply of fluid to oppose the opening movement of said charging-

valve, a variable electric igniter and a common controller for said governing-valve and said igniter.

9. In an explosive-engine, the combination with a charging-valve subject to fluid-pressure in opposite directions, of a governor-valve controlling the supply of fluid to oppose the opening movement of said charging-valve, a variable electric igniter and a reversing-controller for said governing-valve and said igniter, substantially as described.

10. In an explosive-engine, the combination with a charging-valve subject to fluid-pressure in opposite directions, of a governor-valve controlling the supply of fluid to oppose the opening movement of said charging-valve, and a reversible centrifugal governor controlling the actions of said valve, in either direction of the engine's motion.

11. In an explosive-engine, the combination with a variable igniter adapted to produce adversely-timed explosions, for use in reversing the engine, while in motion, of a reversible centrifugal governor for controlling said variable igniter in either direction of the engine's motion, substantially as described.

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

ELLIS J. WOOLF.

Witnesses:

MABEL M. MCGRORY,
F. D. MERCHANT.