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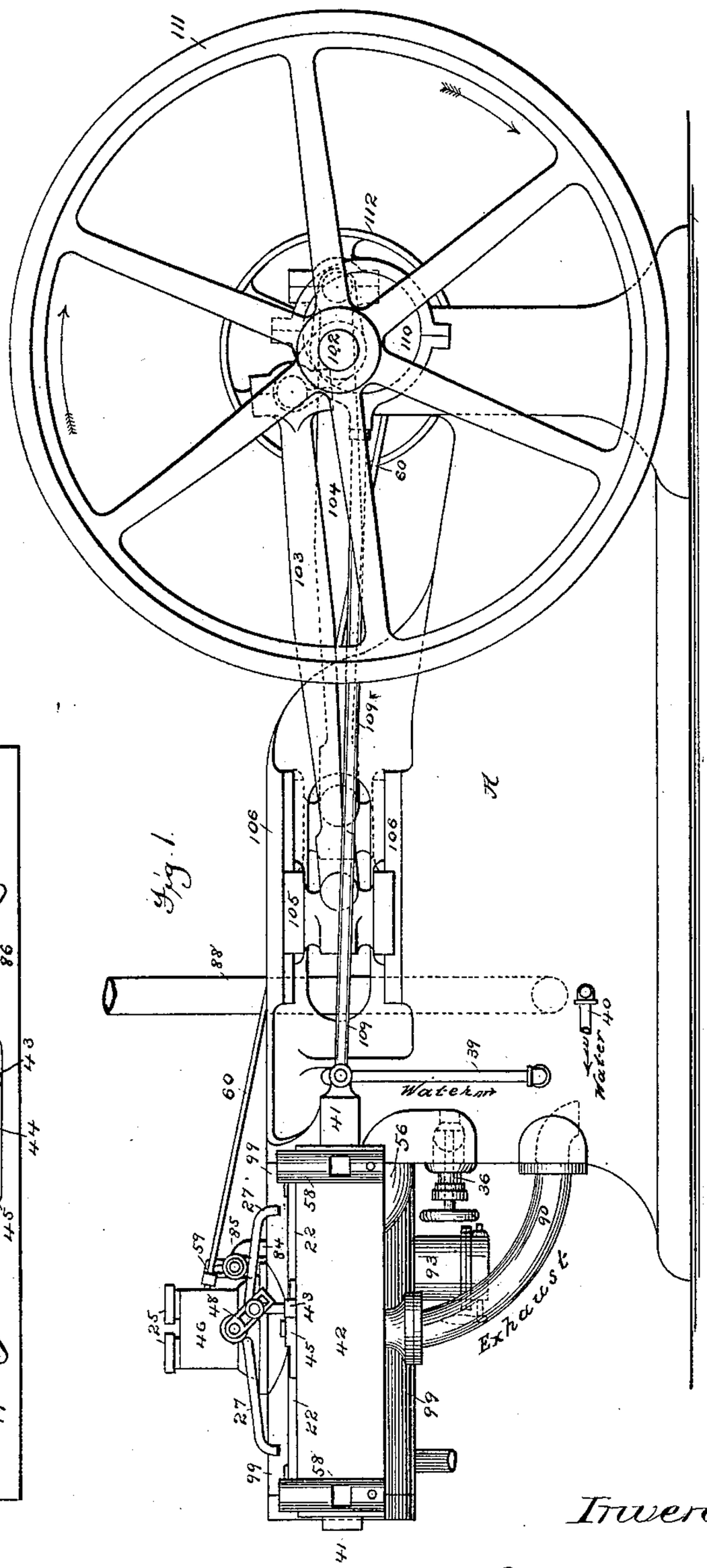
GAS ENGINE.

No. 351,395. Patented Oct. 26, 1886.



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Geo. H. Botts.
J. A. Hovey

Inventor:
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By Munn & Philipp
Attys.

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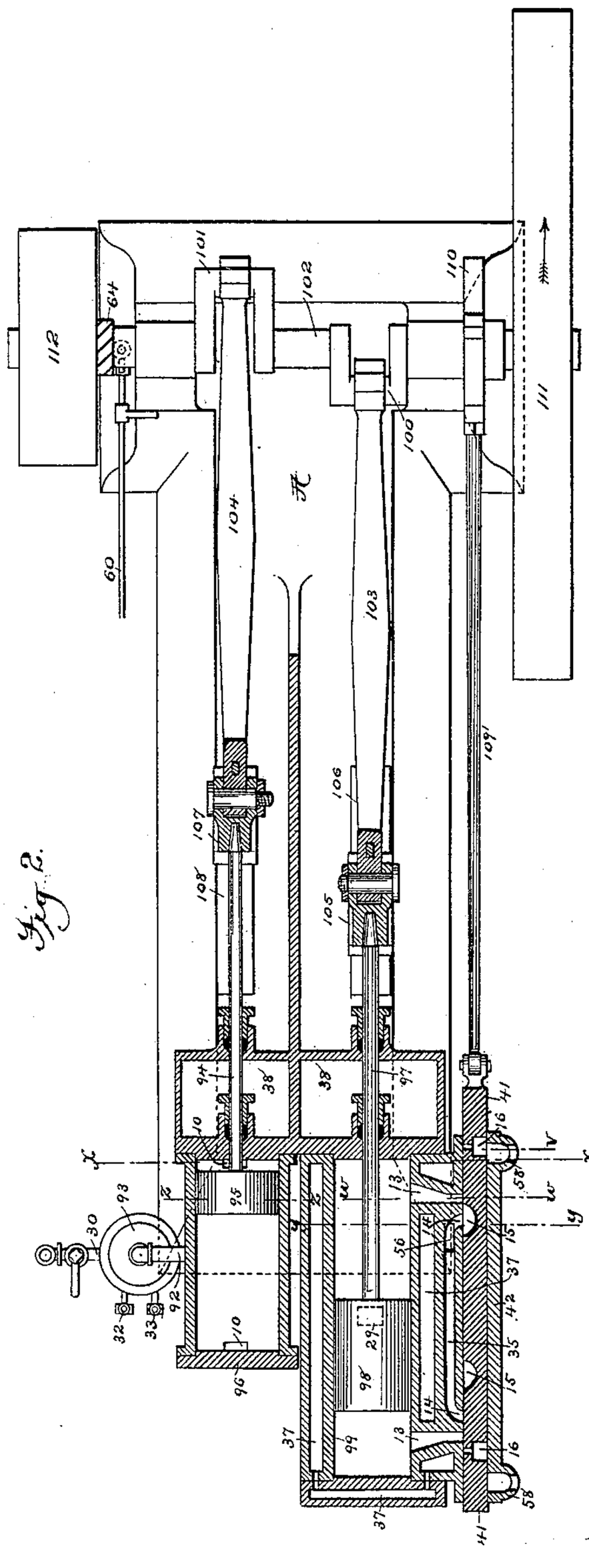

Fig. 2.

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Fig. 11.

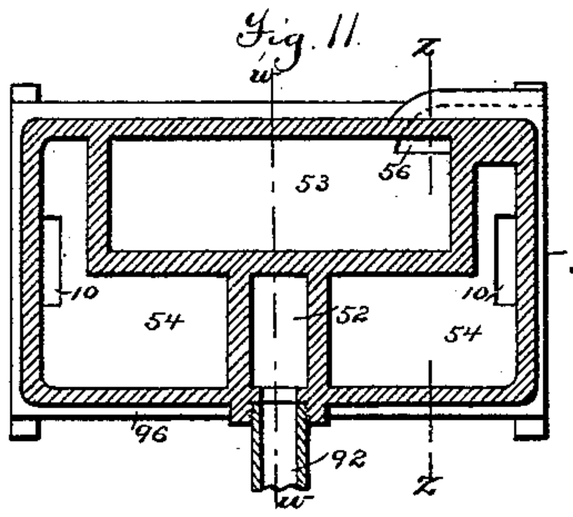


Fig. 12.

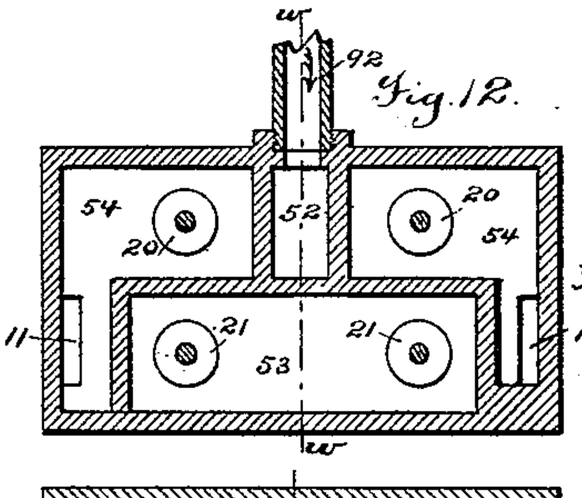


Fig. 13.

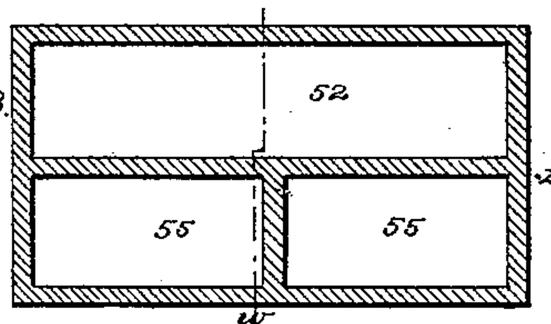


Fig. 14.

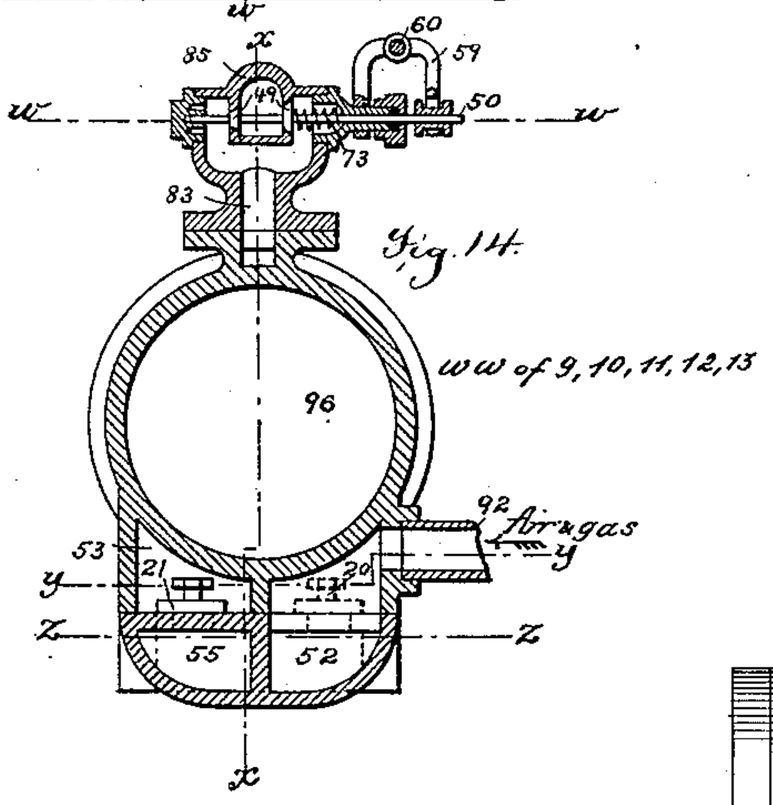


Fig. 15.

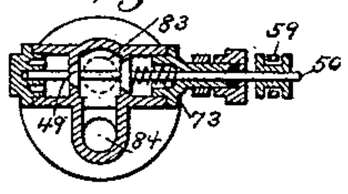


Fig. 9.

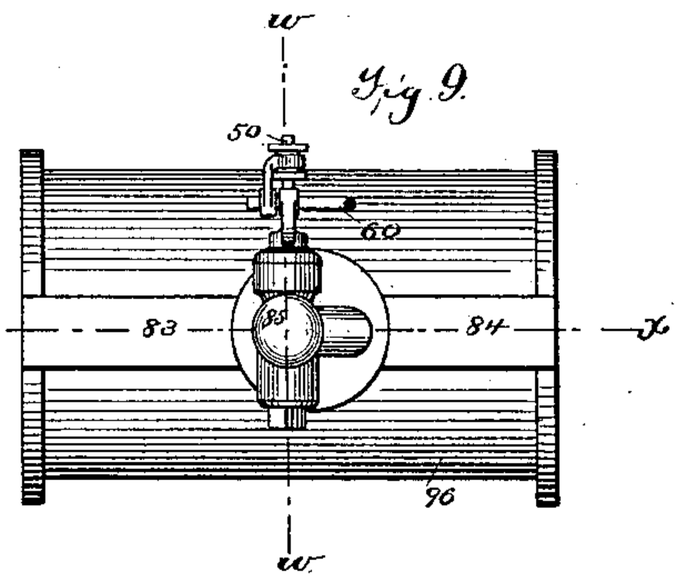


Fig. 10.

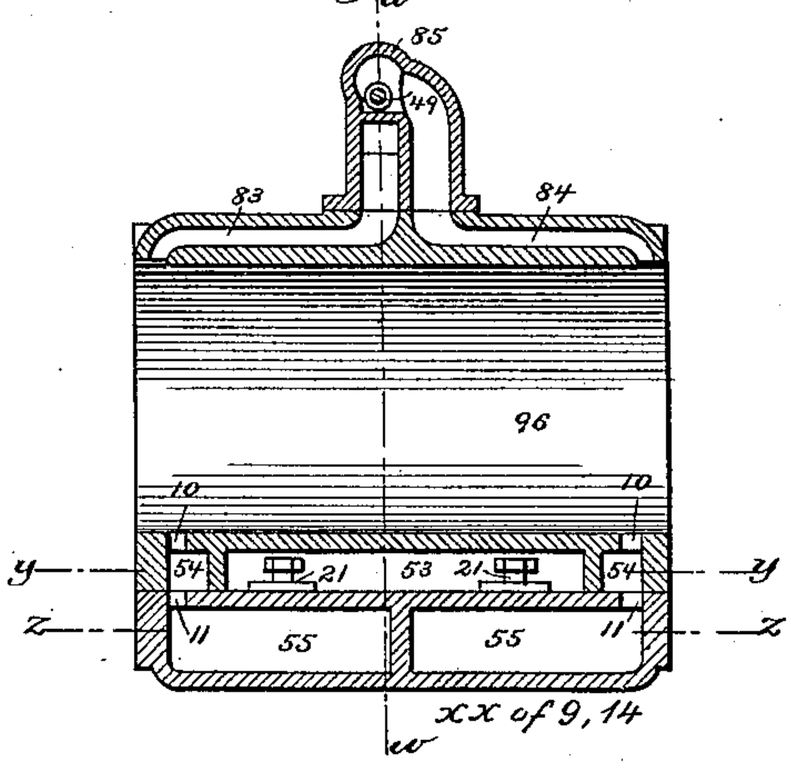
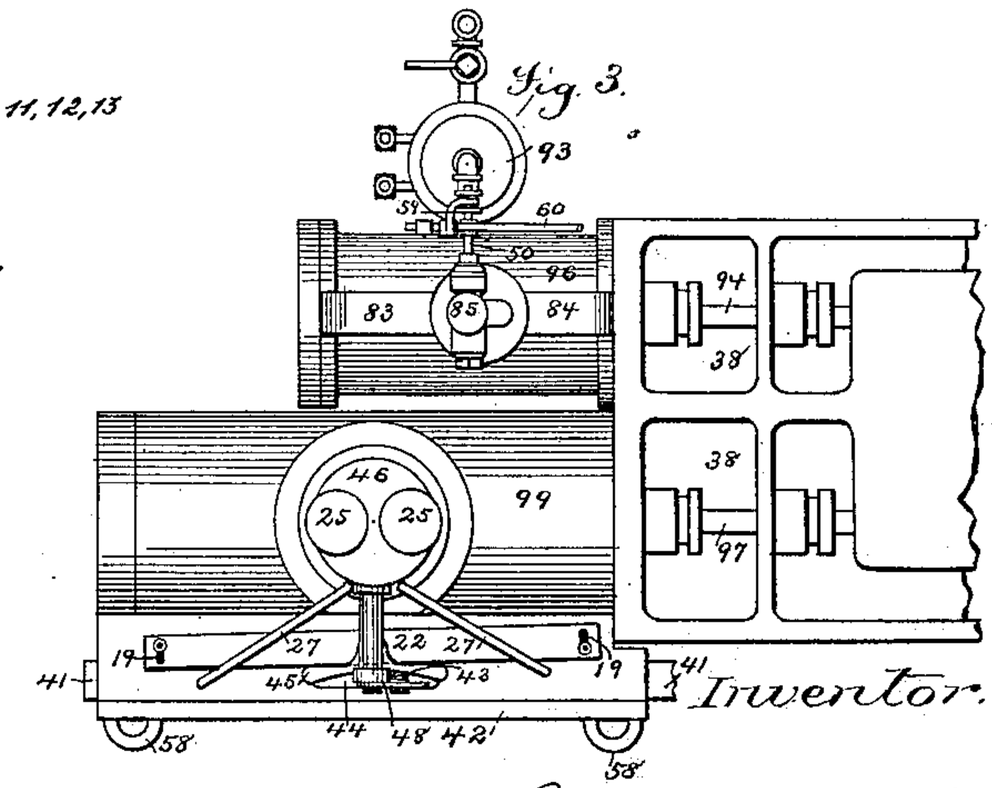


Fig. 3.



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GAS ENGINE.

No. 351,395. Patented Oct. 26, 1886.

Fig. 6.

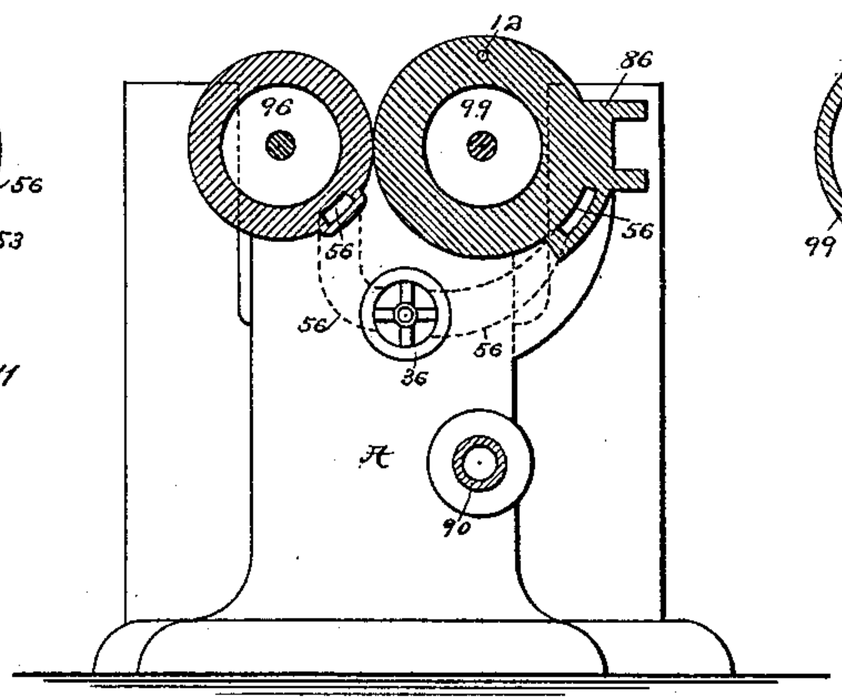

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Fig. 8.

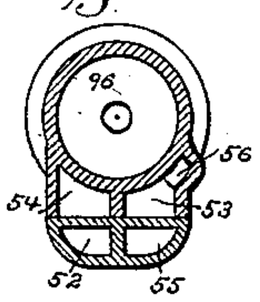

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Fig. 7.

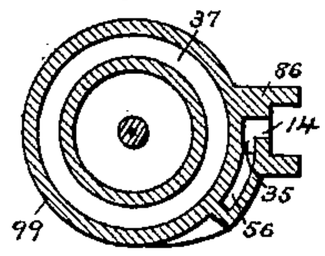

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Fig. 5.

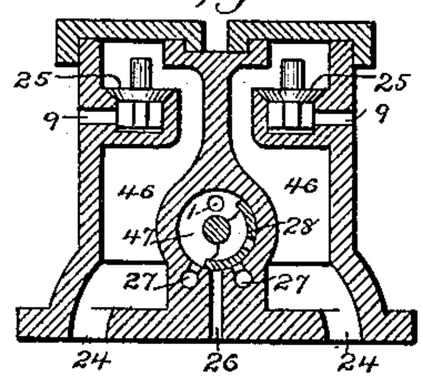
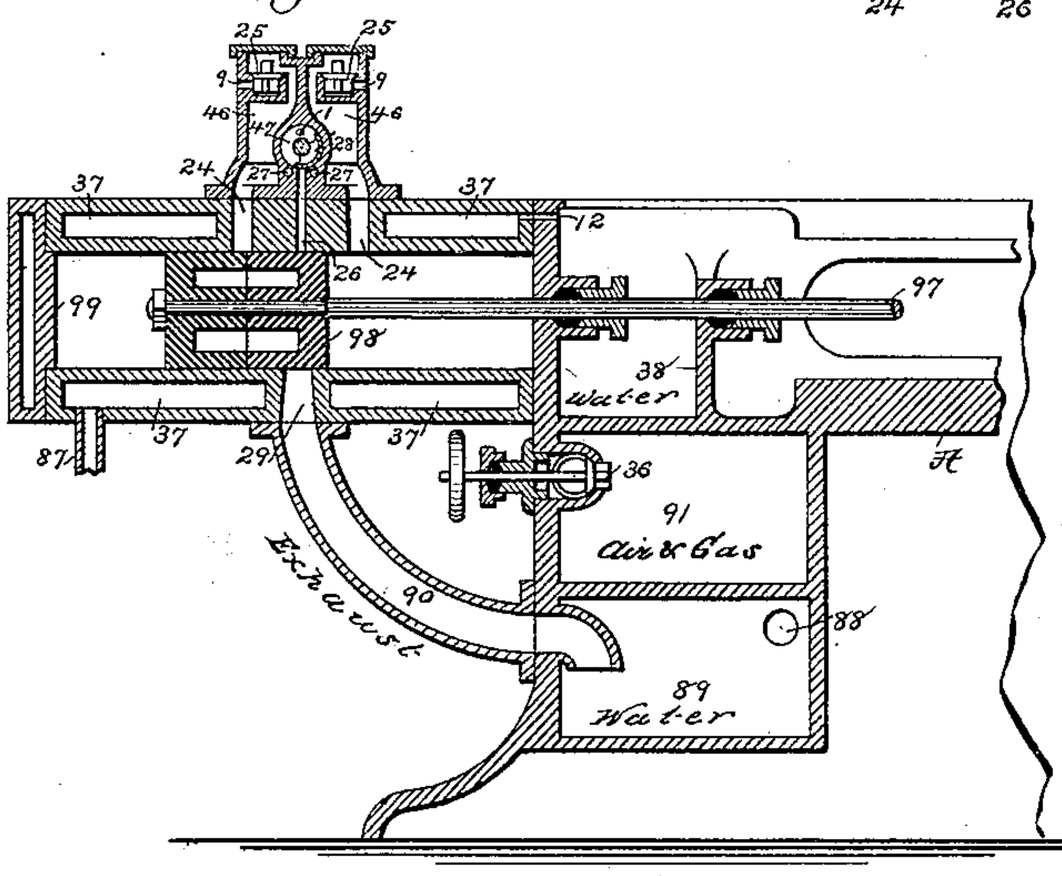


Fig. 4.



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GAS ENGINE.

No. 351,395. Patented Oct. 26, 1886.

Fig. 30. yy of 25

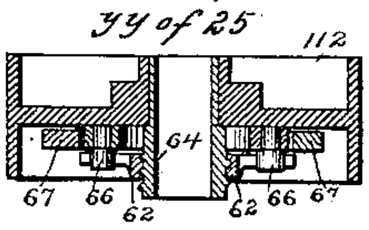

Fig. 31. ww of 25, 27

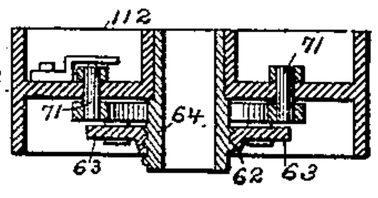

Fig. 32.

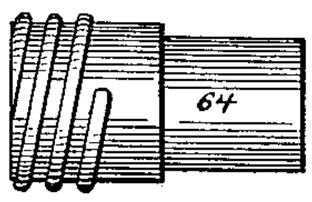

Fig. 28.

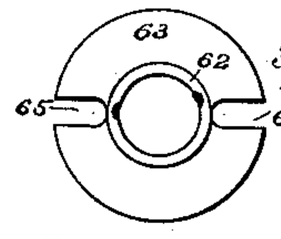

Fig. 25.

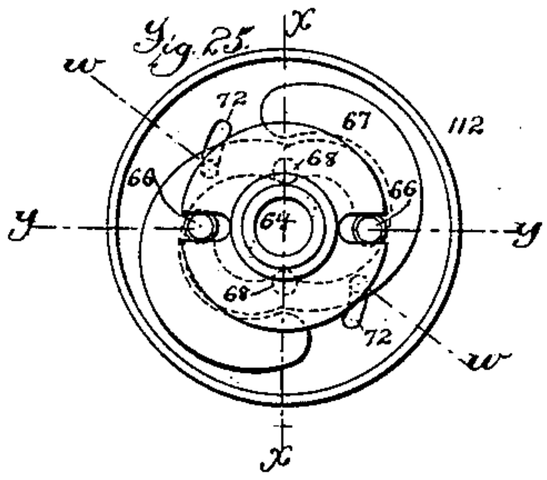

Fig. 27.

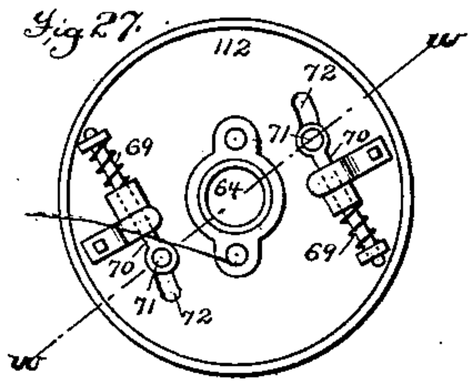

Fig. 29.

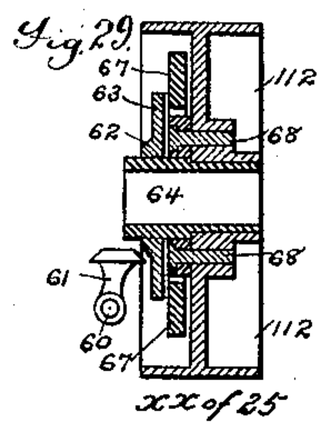

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Fig. 26.

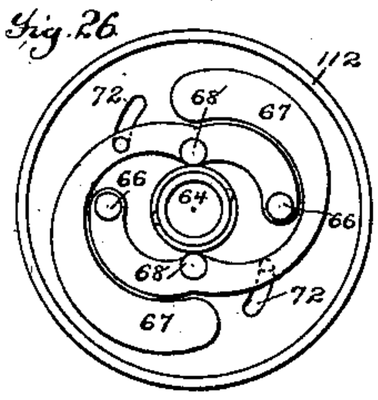


Fig. 22.

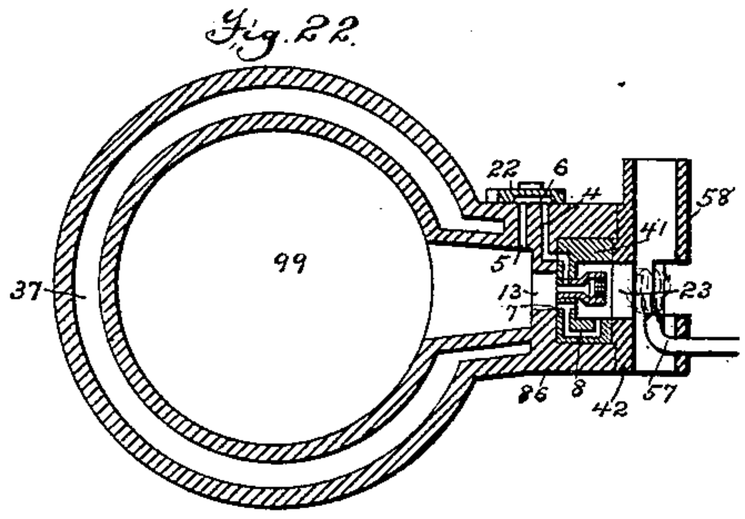


Fig. 19.

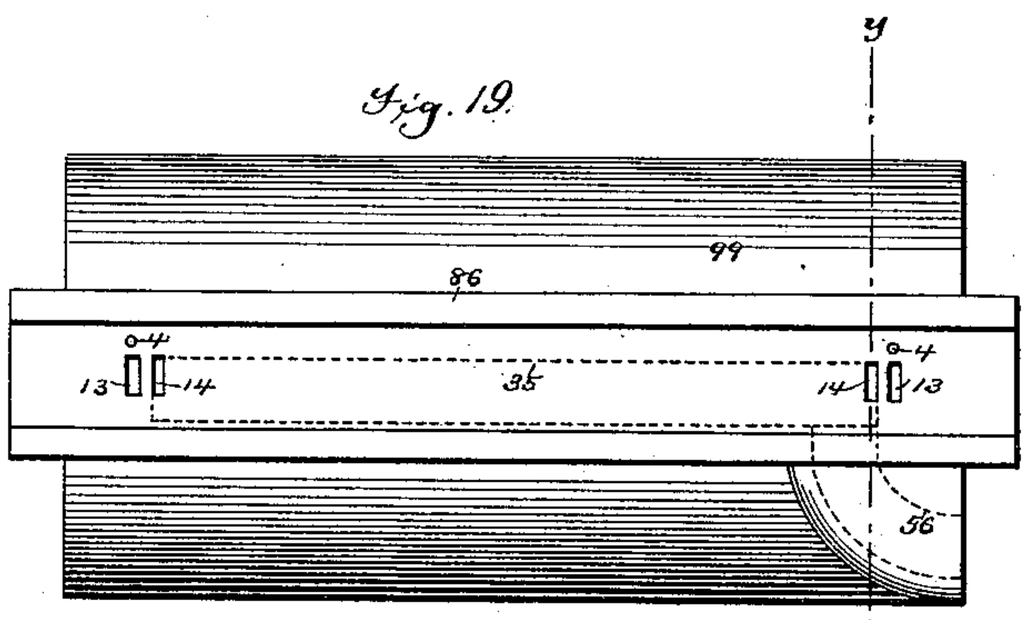


Fig. 21. ww of 2

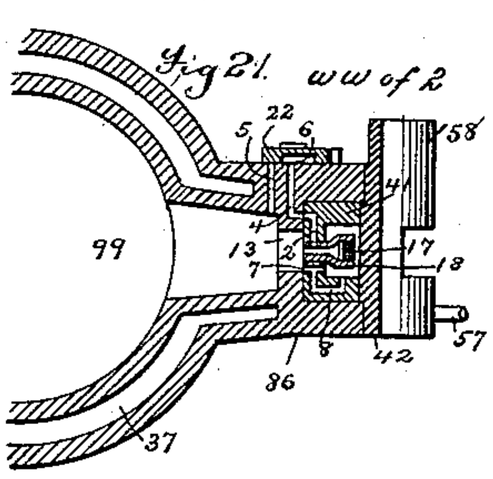


Fig. 20.

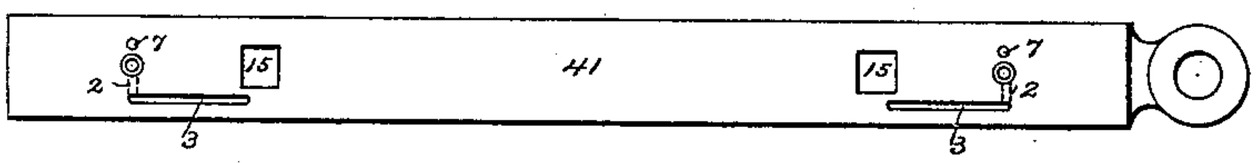


Fig. 16.

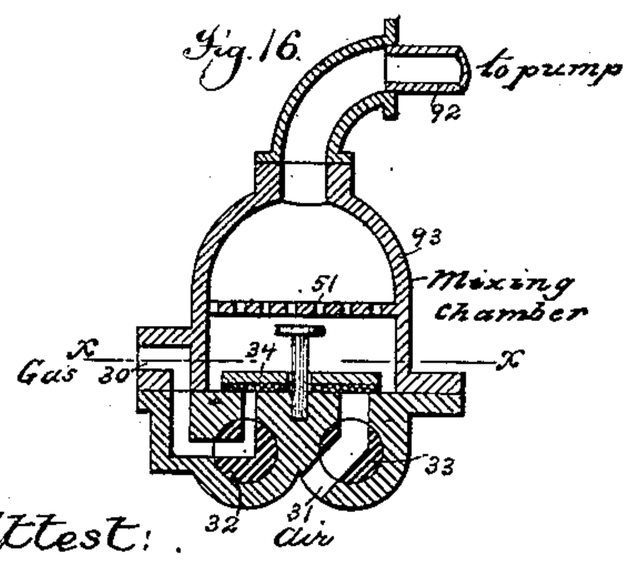


Fig. 23.

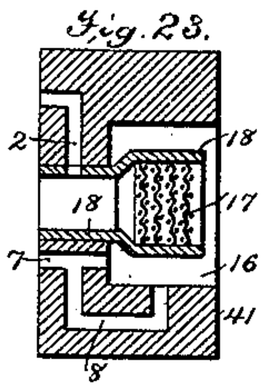


Fig. 24.

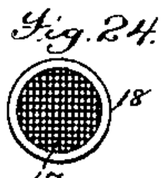
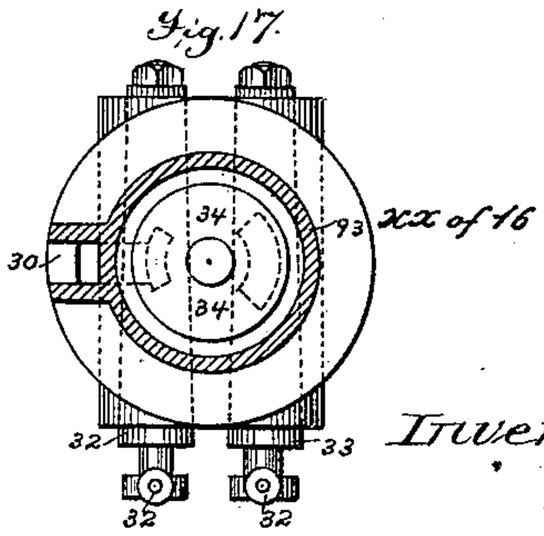


Fig. 17.



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J. A. Hoving

UNITED STATES PATENT OFFICE.

PETER MURRAY, JR., OF NEWARK, NEW JERSEY, ASSIGNOR TO THE MURRAY MOTOR MANUFACTURING COMPANY, OF SAME PLACE.

GAS-ENGINE.

SPECIFICATION forming part of Letters Patent No. 351,395, dated October 26, 1886.

Application filed February 6, 1886. Serial No. 191,011. (No model.)

To all whom it may concern:

Be it known that I, PETER MURRAY, Jr., a citizen of the United States, residing at Newark, county of Essex, and State of New Jersey, have invented certain new and useful Improvements in Gas-Engines, fully described and represented in the following specification and the accompanying drawings, forming a part of the same.

This invention relates, generally, to that class of gas-engines in which the power is obtained by the explosion of a mixture of gas and air in the cylinder of the engine, but more particularly to that class of these engines in which the explosive mixture is supplied to the engine by a pump and in which the explosive mixture is confined in the cylinder of the engine under a considerable degree of pressure previous to being exploded.

To aid in a more ready understanding of the invention, and of the details in the construction and organization of the engine, to be hereinafter described, a brief description of the general organization and operation of the engine will be first given.

The air and gas which form the explosive mixture are first admitted, in suitable proportions, into a chamber containing a mixing apparatus. This chamber is connected by a pipe with the suction-chamber of a double-acting force-pump, which operates to draw the air and gas through the mixing apparatus, so as to form these two fluids into a homogeneous mixture and then force the mixture thus formed into the opposite ends of the power-cylinder. The pipe or passage leading from the force-chamber of the pump to the power-cylinder also communicates with a tank or reservoir, and is provided with a cock or valve by which the communication between the tank and the pipe may be opened or closed at pleasure. The purpose of this will be hereinafter fully explained.

The power-cylinder is provided at its opposite ends with induction-ports which communicate with the pipe or passage leading from the pump, and these ports are controlled by a reciprocating charging and firing valve which operates to open the ports at the proper times to admit the charges and then close them, so as to confine the charges in the cylinder. The power-cylinder is provided with a single exhaust-opening, which is located at or near the middle of the length of the cylinder, and in such position as to be uncovered by the power-piston as it arrives at the end of its stroke in either direction. The exhaust-opening is provided with an exhaust-pipe which communicates with a chamber containing a quantity of water which operates to condense the products of combustion and thus aid in exhausting these products from the cylinder. The movements of the power-piston and the charging and firing valve which controls the induction-ports are so timed with relation to each other that the induction-port at either end of the cylinder is opened to admit the charge to that end of the cylinder just before the power-piston completes its stroke toward the opposite end of the cylinder, and is closed to confine the charge in the cylinder just after the power-piston commences its return-stroke and has covered the exhaust-opening, thereby allowing the charge to be compressed by the return-stroke of the piston. The movement of the pump-piston is so timed with relation to the movement of the valve that it will complete its stroke in either direction, by which the charge is forced into the cylinder simultaneously with the closing of the induction-port by the valve. The charges thus forced into the power-cylinder and confined and compressed therein are fired at the proper time by means of igniting-burners which are carried by the charging and firing valve, and which are brought into communication with the charges by the continued movement of the valve after the induction-port has been closed to confine the charge in the cylinder, as just explained. These burners are fed from the charges in the cylinder through suitable ducts formed in the valve and the walls of the valve-chest, and are relighted, after each charge has been fired, by permanent burners or master-lights located in the side of the valve-chest. The ducts through which the igniting-burners are fed are provided with means by which they are closed and the supply of the mixture to the burners cut off just as or just before the charges are fired, and by which the ducts are kept closed until the power-piston has proceeded far enough upon its stroke to open or partly open the exhaust-opening. The purpose of this arrangement will also be hereinafter explained.

The power-cylinder is provided with two air ports or openings, which are controlled by suitable valves, and are so arranged that after each charge is fired and after the power-piston has made a part of its stroke, a quantity of air is admitted to the cylinder behind the piston, so as to hasten the complete combustion of the charge and prevent the flame from lingering in the cylinder so long as to cause a premature explosion of the next charge as it is admitted.

The engine is provided with a governor apparatus, which is constructed upon the same general plan as that described in my former Letters Patent No. 305,464, and which operates, if the speed of the engine is accelerated beyond what is desirable, to reduce the volume of the charges forced into the power-cylinder, and thus bring the engine back to its normal speed.

The invention consists, principally, in the organization or relative arrangement of the pump and power piston and the charging and firing valve, in the construction of the charging and firing valve, in the means for controlling the supply of the explosive mixture to the igniting-burners, and in means for supplying air to the power-cylinder to hasten the complete combustion of the charges. The invention also embraces various other features of construction and combinations of parts, all of which will be hereinafter described and pointed out.

The details in construction and operation of the organization, thus briefly outlined, will now be described, reference being had to the accompanying drawings, in which—

Figure 1 is a side elevation of the engine. Fig. 2 is a horizontal section of the same, parts being shown in plan view. Fig. 3 is a plan view of the power and pump cylinders. Fig. 4 is a longitudinal vertical section of the power-cylinder, showing also the apparatus for introducing air into the cylinder after the explosion of the charges takes place. Fig. 5 is an enlarged view of a part of Fig. 4. Fig. 6 is a vertical cross-section of the pump and power cylinders, taken upon the line *x x* of Fig. 2. Fig. 7 is a cross-section of the power-cylinder, taken upon the line *y y* of Figs. 2 and 19. Fig. 8 is a cross-section of the pump-cylinder, taken upon the line *z z* of Figs. 2 and 11. Fig. 9 is an enlarged plan view of the pump-cylinder, showing particularly a portion of the governor apparatus. Fig. 10 is a longitudinal vertical section of the same, taken upon the line *x x* of Figs. 9 and 14. Fig. 11 is a horizontal section looking upward, taken upon the line *y y* of Figs. 10 and 14. Fig. 12 is a similar view, taken upon the same line, looking downward. Fig. 13 is a similar view looking downward, taken upon the line *z z* of the same figures. Fig. 14 is a vertical cross-section taken upon the line *w w* of Figs. 9, 10, 11, 12, and 13. Fig. 15 is a horizontal section taken upon the line *w w* of Fig. 14. Fig. 16 is a vertical section, upon an enlarged scale, of the mixing apparatus. Fig. 17 is a horizontal section taken upon the line *x x* of Fig. 16. Fig. 18 is an enlarged view of a portion of Fig. 3, showing particularly the apparatus for controlling the ducts through which the igniting-burners are fed. Fig. 19 is an enlarged side elevation of the power-cylinder, the covering-plate of the valve-chest and the charging and firing valve being removed. Fig. 20 is an inside view of the charging and firing valve removed from its seat. Fig. 21 is an enlarged cross-section of the power-cylinder and the charging and firing valve, taken upon the line *w w* of Fig. 2, the valve, however, being shown in position to fire the charge. Fig. 22 is a similar view taken upon the line *w v* of the same figure, showing the valve in position to bring the igniting-burner into communication with the master-light. Fig. 23 is a still more enlarged cross-section of the charging and firing valve, showing particularly the construction of the igniting-burners. Fig. 24 is an outside view of one of the burners. Fig. 25 is an inside view of the driving-pulley, showing the weighted levers and their connections for operating the governor-valve. Fig. 26 is a similar view with the revolving disk removed. Fig. 27 is an outside view of the driving-pulley, showing particularly the springs and their connections for operating the weighted levers of the governor apparatus. Fig. 28 is a view of the revolving disk removed from the other parts. Fig. 29 is a cross-section of the driving-pulley, taken upon the line *x x* of Fig. 25. Fig. 30 is a similar view taken upon the line *y y* of the same figure. Fig. 31 is a similar view taken upon the line *w w* of Figs. 25 and 27, and Fig. 32 is an enlarged view of the threaded sleeve upon which the revolving disk turns.

Referring to said drawings, it is to be understood that the power-cylinder 99 is arranged in a horizontal position upon a suitable frame-work, A, which at a proper distance in front of the cylinder is provided with bearings for the main crank-shaft 102. The power-piston 98 is provided with the usual piston-rod, 97, which passes through a stuffing-box in the end of the cylinder, and is connected to the main crank 100 by means of a pitman, 103. The piston-rod and pitman are provided at their point of connection with the usual cross-head, 105, which reciprocates between bearings 106 formed in the frame-work.

In the organization herein shown, the charges of the explosive mixture, instead of being drawn into the power-cylinder by the piston 98, are forced into each end of the cylinder after the piston has nearly completed its stroke toward the opposite end and just as it is commencing its return-stroke, thereby allowing the charges to be compressed in the cylinder to a considerable degree by the return-stroke of the piston. The supplying of the charges to the power-cylinder is effected by means of a double-acting pump, 96, which is located at the side of the power-cylinder, and has its piston 95 connected by a rod, 94,

and pitman 104 with a second crank, 101, upon the main shaft 102, the point of connection between the piston-rod 94 and the pitman being provided with a cross-head, 107, which moves between bearings 108 in the frame-work, the same as in the case of the piston-rod 97 and its pitman. The cranks 100 101 are so positioned that the pump-piston will complete its stroke and thus complete the forcing of the charge into the power-cylinder just after the power-piston has commenced its stroke toward the end of the cylinder into which the charge is forced. The purpose of this relative arrangement of the two pistons will more fully appear when the operation of the engine is explained.

In order to effect the rapid and complete combustion of the explosive mixture in the cylinder of the engine, which must be accomplished in order to secure the best results, it is important that the air and gas which form the mixture should be thoroughly commingled before they enter the cylinder. This is effected by means of a mixing apparatus, through which the air and gas are drawn as they enter the pump. This apparatus, as herein shown, consists of a chamber, 93, (see Figs. 16 and 17,) having a partition, 51, which is provided with a large number of small perforations through which the air and gas are drawn and which serves to divide these fluids into a large number of small streams and thus thoroughly agitate and mix them. The chamber 93 is provided, upon one side of the partition 51, with two openings, 30 31, through which the gas and air are admitted to the chamber, the proper proportions of these fluids being regulated by cocks or valves 32 33, which control the openings. These openings are also controlled by an inwardly-opening check-valve, 34, which prevents the escape of any of the mixture from the chamber through the air-opening. The chamber 93 is connected, upon the side of the partition 51 opposite to the openings 30 31 by a pipe, 92, with the suction-chamber 52 (see Figs. 10 to 14) of the pump 96. The pump 96 is provided with ordinary suction-valves, 20, which control the communication between the suction-chamber and two chambers, 54, located at opposite ends of the pump, and which communicate with the pump-cylinder by means of ports 10. The chambers 54 communicate by ports 11 with two chambers, 55, which in turn communicate with the force-chamber 53, the passage between the chambers 55 and the force-chamber being controlled by ordinary force-valves, 21. The force-chamber 53 of the pump communicates by means of a pipe or passage, 56, (see Figs. 11, 8, 6, 4, 19, and 2,) with what may be termed a small "induction-chamber," 35, located in the side of the power-cylinder and extending a considerable portion of the length of the cylinder. As shown in the present case, the passage 56 is formed in the frame-work A and the wall of the power-cylinder; but it may of course be an independent pipe, if preferred. The passage 56 also communicates (see Fig. 4) with a tank or reservoir, 91, which, as shown in the present case, is formed in the base of the frame-work A, though of course it may be independent of the frame-work. The passage 56, at the point where it communicates with the tank 91, is provided with a cock or valve, 36, by which the communication between the tank and the passage may be cut off, when desired. From this arrangement it will be seen that the quantity of the explosive mixture drawn through the mixing apparatus and into the pump upon either side of its piston upon one stroke, is upon the next stroke forced out of the pump and into the tank 91 and the passage 56 and chamber 35, or into the passage and chamber alone, depending upon the position of the valve 36. The cylinder of the pump is of such size with relation to the power-cylinder that the amount of the explosive mixture which is drawn into the pump upon each stroke is just sufficient to form one charge for the power-cylinder when the engine is running under its ordinary working conditions.

The power-cylinder 99 is provided with a single exhaust-opening, 29, (see Figs. 2 and 4,) consisting of one or more ports which is or are located at or near the middle of the length of the cylinder, and in such position as to be uncovered by the power-piston as it arrives at the end of its stroke in each direction. The exhaust-opening 29 is provided with an exhaust-pipe, 90, which opens into a condensing-chamber, 89, from which a chimney-pipe, 88, conducts the exhaust products to the open air. The condensing-chamber 89 is supplied with water, which acts to take up more or less of the heat of the exhaust products, so as to partially condense them and thus aid in exhausting the cylinder. The chamber 89 and the water therein also perform another important function, in that they serve to very materially reduce the noise caused by the exhaust, which sometimes is so great as to be objectionable.

The chamber 89 may be supplied with water in any convenient manner; but as here shown the water which is supplied through the pipe 87 (see Fig. 4) to the usual water-spaces, 37, of the power-cylinder, after circulating through these spaces passes through an opening, 12, into a trough, 38, formed on the inner ends of the pump and power cylinders, where it serves to keep the piston-rods 94 97 cooled, after which it flows through a pipe, 39, (see Fig. 1,) to the chamber 89, from which chamber it is drawn by a waste-pipe, 40. By this means a constant flow of water is maintained through the spaces 37, trough 38, and chamber 89 in a very simple manner. It will be observed that the waste-pipe 40 is so positioned that the water is not permitted to rise in the chamber 89 to a sufficient height to close or submerge the end of the exhaust-pipe 90. The constant flow of the water through the chamber 89, produced either in the manner just stated or in any other suitable manner, is also important,

as it serves to carry away the non-gaseous products exhausted from the cylinder, which would otherwise accumulate in the chamber.

The charges of the explosive mixture which are forced into the tank 91 and the passage 56 and chamber 35, or the passage and chamber alone, are admitted to the power-cylinder as follows: The power-cylinder is provided at its opposite ends with induction-ports 13, (see Figs. 2 and 19,) which open outward through the walls of the cylinder, and the chamber 35 is provided at its ends with ports 14, which also open outward in close proximity to the ports 13. The side of the cylinder through which the ports 13 14 open is provided with a projecting portion, 86, which forms a chest or seat for a reciprocating charging and firing valve, 41, which is held to its seat by a covering-plate, 42, and is operated through a rod, 109, from an eccentric, 110, on the main shaft 102. The valve 41 is provided upon its inner face with two cavities or recesses, 15, (see Figs. 2 and 20,) which are of such extent, and are located in such position, that as the valve is reciprocated they establish communication between the ports 13 14 at the opposite ends of the cylinder alternately, thereby establishing communication between the chamber 35 and the cylinder, and permitting the charge forced out of the pump to pass into one end or the other of the cylinder, depending upon the position of the valve. As hereinbefore stated, the movements of the pump and power pistons and the charging and firing valve are so timed with relation to each other that communication is established between the ports 13 14, or, in other words, between the chamber 35 and either end of the power-cylinder, just before the power-piston has completed its stroke toward the opposite end of the cylinder, and after it has partly uncovered the exhaust-opening, and that communication will be again cut off between the ports 13 14 just after the power-piston has commenced its return-stroke and covered the exhaust-opening, and that the pump-piston will complete its stroke simultaneously with the cutting off of communication between the ports 13 14 by the valve. From this it results that before the ports 13 14 are brought into communication the pump has already made a large part of its stroke and has compressed a considerable part of the charge into the tank 91 and the passage 56 and chamber 35, or the passage and chamber alone, so that as soon as the ports 13 14 are brought into communication the charge thus compressed at once expands and rushes into the cylinder, thereby quickly expelling the products remaining from the explosion of the last charge through the exhaust-opening. After this the pump completes its stroke and forces the remainder of the charge into the cylinder, and simultaneously with the completion of the stroke of the pump the power-piston covers the exhaust-opening, and the valve cuts off communication between the ports 13 14, thereby confining the charge in the cylinder, where it will be compressed by the power-piston during the remainder of its return-stroke, after which, as the piston arrives at the end of its return-stroke and is about to commence its next forward stroke, the charge is exploded.

The firing of the charges thus compressed in the power-cylinder is effected as follows: The charging and firing valve 41 is provided upon its outer face and near its opposite ends with two recesses or cavities, 16, (see Figs. 2 and 23,) in which are located igniting-burners which consist of layers of wire-gauze or similar foraminous material, 17, (see Figs. 23 and 24,) inserted in the ends of short flaring tubes 18. The ends of the tubes 18 project slightly beyond the gauze 17, as will be observed. The purpose of this will appear when the operation of the engine is described. The tubes 18, which constitute the stems or shanks of the burners, extend through the valve and open inward through its inner face (see Figs. 21 and 22) in such position that as the valve reciprocates they will respectively be brought into communication with the ports 13 at the opposite ends of the cylinder.

The igniting-burners are fed from the charges in the power-cylinder as follows: The valve 41 is provided with small ducts 2, (see Figs. 22 and 23,) which communicate with the tubes 18 of the burners, and extend upward and inward and open into channels 3, formed in the inner face of the valve. The channels 3 communicate with ducts 4, (see Figs. 19, 21, and 22,) which open outward through the valve-seat and upward through the top of the projection 86 of the cylinder in which the valve-seat is formed, and in close proximity to vertical ducts 5, which open downward into the passages leading from the ports 13 to the interior of the cylinder. Communication between the ducts 4 5 at the opposite ends of the cylinder is controlled by means of a swinging plate 22, (see Figs. 3, 18, 21, and 22,) which is pivoted at the middle of its length and rests upon the top of the projection of the cylinder in which the valve-seat is formed, and in such position as to cover the ducts 4 5. This plate is provided upon its under side and directly over the ducts 4 5 with recesses or cavities 6, which form, in effect, a pair of D-valves, and are located in such position that when the plate is swung in one direction the valve at one end of the plate will be brought into position to establish communication between the ducts 4 5 at that end of the cylinder, while the valve at the other end of the plate will be brought into such position as to cut off communication between the ducts 4 5 at the other end of the cylinder, and vice versa. The plate 22 is swung or vibrated so as to alternately establish and cut off communication between the ducts 4 5 at the opposite ends of the cylinder by means of a stud, 43, which is secured to the upper side of the valve 41 and projects through a slot, 44, in the top of the valve-chest. As the stud 43 is moved back

and forth by the movement of the valve 41, it runs in contact with a curved lever, 45, which is pivoted at its middle in such position that its outward-curved ends overlap the slot 44. By reason of this arrangement a swinging movement is imparted to the lever 45 by the movement of the stud 43. The lever 45 is so arranged with relation to the plate 22 that as it is swung by the stud 43 it engages with the plate 22, and thereby swings the plate, as already stated. The plate 22 is provided at its ends with curved slots 19, through which pass bolts which prevent the plate from being raised from its seat. The igniting-burners 17 are relighted after each explosion by means of permanent master-lights 57, (see Fig. 22,) which are located in chimneys 58, formed upon the outside of the covering-plates 42 of the valve-chest, and with which the igniting-burners are brought into communication at the proper time through ports 23, formed in the plate 42. The movements of the plate 22 are so timed with relation to the movements of the valve 41 that communication will be cut off between the ducts 4 5 at either end of the cylinder just as or slightly before the igniting-burner for that end of the cylinder arrives in position to fire the charge, and will remain so cut off after the charge has been fired until the power-piston has proceeded far enough upon its stroke to partly or wholly uncover the exhaust-opening. The valve 41, in addition to the ports and ducts already specified, is provided with small ports 7, (see Figs. 21, 22, and 23,) which are located directly beneath the igniting-burners and in such position that when the burners are in position to fire the charges they establish direct communication between the ports 13 and the recesses 16. The valve is also provided with small ducts 8, which extend downward and outward from the ports 7 and open into the recesses 16 at a point near the outer ends of the tubes 18. The purpose of these various features will more fully appear when the operation of the engine is explained.

The operation of the organization thus far described is as follows: For the purpose of this description it will be assumed that the engine is in operation and that a charge has just been exploded in the outer or left-hand end of the power-cylinder, so as to start the power-piston upon its inward stroke. At the time this takes place the charging and firing valve will be at the limit of its stroke inward or toward the right, the igniting-burner at the outer or left-hand end of the valve will be in communication with the induction-port 13 at that end of the cylinder, the recess 15 at the inner or right-hand end of the valve will be in position to establish communication between the ports 13 14 at that end of the cylinder, the plate 22 will be in position to establish communication between the ducts 4 5 at the inner end of the cylinder and to cut off communication between the ducts 4 5 at the outer end of the cylinder, and the piston of the pump will be nearing the end of its stroke inward or toward the right. As the power-piston commences its stroke inward, the charging and firing valve will commence its stroke in the opposite direction, so that by the time the power-piston has covered the exhaust-opening 29 the valve will have arrived in such position as to cut off communication between the ports 13 14, so as to confine the charge in the cylinder, and simultaneously with the cutting off of communication between these ports the pump-piston will complete its inward stroke. After this the power-piston will proceed upon and complete its inward stroke, thereby compressing the charge in front of it in the cylinder, and the pump will commence its outward stroke, thereby compressing a fresh charge into the tank 91, passage 56, and chamber 35, or into the passage and chamber alone, depending upon the position of the valve 36. As the power-piston is making its inward stroke, the valve will proceed upon its outward stroke, and the ducts 4 5 being in communication a portion of the charge which is undergoing compression in the cylinder will be forced through the ducts 5 4, groove 3, and duct 2 into the tube 18, and thence through the meshes of the gauze forming the igniting-burner 17 at that end of the cylinder, so that said burner will be lighted from the master-light 57. The igniting-burner thus lighted will continue to be fed from the charge in the cylinder, and will continue to burn as the valve proceeds upon its outward stroke. Just as or slightly before the valve arrives at the limit of its outward stroke, and after the power-piston has uncovered the exhaust-opening, the stud 43 will rock the lever 45, and through said lever swing the plate 22 so as to cut off communication between the ports 4 5 at the inner end of the power-cylinder and establish communication between the corresponding ports at the outer end of the cylinder, and simultaneously with or immediately after this the power-piston will arrive at the limit of its inward stroke and the valve at the limit of its outward stroke, thereby bringing the igniting-burner at the inner end of the valve into communication with the port 13 at that end of the cylinder. As soon as this takes place, a portion of the charge compressed in the cylinder will pass through the port 7 and duct 8, so as to establish an equilibrium upon both sides of the burner 17 and permit the flame of the burner to be communicated to and explode the charge in that end of the cylinder. At the time when the port 7 and tube 18 are thus brought into communication with the port 13, the pressure in the power-cylinder is of course at its maximum, and as a consequence the mixture will rush into the recess 16 with considerable force, and if means were not provided for preventing it might extinguish the flame of the burner. By providing the duct 8 the mixture is caused to enter the recess upon both sides of the flame, so as to prevent a strong current from being formed in any direction.

It might sometimes happen, however, that the jet from the duct 8 being projected across the flame of the burner would be sufficient to extinguish it, were not the flame protected from this by having the gauze forming the burner 17 placed a short distance within the tube 18, as before explained. Just before the power-piston arrives at the limit of its inward stroke and the valve at the limit of its outward stroke, as just stated, the piston will uncover the exhaust-opening 29, and as this takes place the recess 15, at the outer end of the valve, will commence to open communication between the ports 13 14 at that end of the cylinder, thereby allowing the portion of the charge which has been compressed by the pump into the tank 91, passage 56, and chamber 35, or into the passage and chamber alone, depending upon the position of the valve 36, to expand into the cylinder and aid in quickly expelling the products remaining from the explosion of the last charge through the exhaust-opening. As the power-piston makes its outward stroke, the operation just described will be repeated, but at the opposite ends of the power-cylinder.

In operating the engine thus organized, it sometimes happens that a charge fails to be exploded when the igniting-burner is brought into communication with the port 13. Whenever this occurs, the power-piston proceeds upon and makes its stroke, impelled by the momentum of the fly-wheel; but since a part of the charge which entered the cylinder has passed out through the ducts 5, 4, &c., to feed the igniting-burner, it results that as the piston nears the end of its stroke and before it uncovers the exhaust-opening, a partial vacuum is formed in the cylinder, which tends to cause a current of air to pass inward through the igniting-burner, and the ducts through which it is fed to the cylinder. The recess 16, in which the igniting-burner is located, is at this time in communication with the master-light, and therefore, unless means are provided for preventing it, this inward current is liable to carry the flame from the master-light inward through the igniting-burner and the ducts through which it is fed to the cylinder, and thus cause a tardy explosion of the charge. The difficulty does not, however, end here. When a charge is thus tardily exploded, there is not sufficient time for the flame to die out in the cylinder before the valve will arrive in position to admit the next charge, and this is liable to cause a premature explosion which may result in serious damage to the engine. In order to avoid this difficulty and danger the plate 22 and its auxiliaries are provided, by which, as explained, the ducts through which the igniting-burners are fed are closed just before the explosion takes place or should take place, and remain closed until after the exhaust is opened, thereby preventing the flame of the master-light from being carried into the cylinder, even though a partial vacuum should be formed therein. In order to stop the engine it is only necessary to close the cocks or valves which control the air and gas openings 30 31, or even the cock or valve that controls the gas-opening. To start the engine it is only necessary to open the air and gas openings, light the master-lights, and turn the fly-wheel 111 until two or three charges have been forced into and exploded in the cylinder. If it is desired that the pump shall compress the charge to a considerable extent before the charging and firing valve establishes communication between the ports 13 14, so that as soon as communication is established between these ports the charge will expand into the cylinder with considerable force, and thus expel the products remaining from the explosion of the last charge very quickly, the valve 36 will be moved so as to cut off communication between the tank 91 and the passage 56, and thus cause the pump to compress the charge into the passage 56 and the chamber 35 alone. If, on the other hand, such a degree of compression is not desired or found necessary in any particular case, the valve 36 will be moved so as to open communication between the tank and the passage 56 and thus allow the pump to compress the charge into the tank as well as the passage 56 and chamber 35. This will remove a part of the labor from the pump, but it will cause the cylinder to be exhausted more slowly.

From what has been said it will be seen that in closing and opening the exhaust-opening the power-piston performs the function of a piston-valve. It is therefore to be understood that the exhaust opening or openings may be controlled by an independent valve without wholly departing from the invention.

In operating those gas-engines in which a charge is introduced into and fired in the cylinder at each stroke of the piston, and particularly when the engine is run at high speed, it has been found that even when the charge is fired at the proper time it will sometimes burn so slowly that the flame caused by the exploding of one charge will not have time to entirely die out before the next charge is admitted, and thus the incoming charge will be prematurely exploded. In order to avoid this and to hasten the complete combustion of the charges after they are fired, I cause a quantity of air to be introduced into the power-cylinder behind the piston after the piston has made a part of its stroke, which air, mingling with the burning charge, will hasten its complete combustion, and thus cause the flame in the cylinder to die out more quickly. To effect this, each end of the power-cylinder is provided with an air port or passage, 24, (see Figs. 4 and 5,) which opens into the cylinder in such position as to be uncovered by the power-piston after it has made a part of its stroke and somewhat before the exhaust-opening is uncovered. These air-ports 24 communicate with small air-chambers, 46, having ports 9, which open to the air and are controlled by inwardly-opening check-valves 25. The operation of this air-introducing apparatus is as follows: As soon as the power-piston

making its stroke in either direction uncovers the exhaust-opening, the products resulting from the last explosion will rush out through the exhaust-opening, and this will cause a partial vacuum to be formed in the chamber 46, whereupon the air upon the outside will raise the valve 25 and flow into and fill the chamber. As the power-piston makes its return-stroke, the air which has passed into the chamber 46, together with a small quantity of the explosive mixture which will be compressed into the chamber, and the port 24, will be entrapped therein by the piston when the latter covers the port 24, and will remain therein until after the next charge has been fired and the piston has proceeded far enough upon its stroke to uncover the port 24. As soon, however, as the port 24 is uncovered, the air in the chamber 46 will mingle with the burning charge, and thereby hasten its complete and perfect combustion, and as soon as the piston uncovers the exhaust-opening, the outrush of the products through the exhaust-opening will cause the chamber 46 to be again filled with air, as already explained, and so the operation will continue to be repeated.

I do not limit my claim to the precise apparatus herein shown for effecting the introduction of the air into the power-cylinder, as it is manifest that the apparatus for this purpose may be varied greatly without departing from the principle of the invention. The air, instead of being drawn into the chambers 46 by the outrush of the products through the exhaust-opening, may be supplied to the chambers by a pump, or in any other suitable manner, and the ports 24, instead of being controlled by the power-piston, may be controlled by an independent valve or valves. The power-piston, so far as its function of controlling the ports 24 is concerned, is in effect and is the equivalent of a piston-valve. It is also to be remarked that instead of using two of the air-chambers 46, a single air-chamber may in some cases be used and made to communicate with both of the ports 24.

The oil for properly lubricating the power-piston and the charging and firing valve is supplied from an oil-chamber, 47, which, as shown, is located between the chambers 46. (See Figs. 4 and 5.) This chamber is supplied in any suitable manner, as from an oil-cup which communicates with the opening 1, and is provided with a duct, 26, which opens into the power-cylinder in such position as to be covered by the power-piston, except for a short time at the end of each stroke, and also with two small pipes, 27, (see Figs. 1, 3, and 18,) which communicate with ducts formed in the projection 86, which open downward on top of the charging and firing valve near its opposite ends. The chamber 47 is provided with an oscillating valve, 28, the stem of which is connected through a slotted arm, 48, with the stud 43. By means of this connection the valve 28 is rocked or oscillated at each reciprocation of the charging and firing valve, thereby uncovering the duct 26 and the openings to the pipes 27 for a short time, and thus allowing a small amount of oil to enter the duct and pipes and flow to the power-piston and the charging and firing valve at each stroke of the engine. The parts are so timed that the duct 26 will be covered by the valve 28 at those times when it is not covered by the power-piston.

As hereinbefore stated, the engine is provided with a governor apparatus by which, when its speed is accelerated beyond the proper point, the charges forced into the power-cylinder are reduced in volume, thereby reducing the power of the engine and bringing it back to its normal speed. This governor apparatus is arranged to act upon the same general plan as that described in my former Letters Patent, before referred to, and consists of means by which, when the speed of the engine becomes unduly accelerated, a portion of the charge drawn into the pump at one stroke, instead of being forced into the power-cylinder at the next stroke, is simply transferred to the opposite side of the pump-piston. To effect this the pump-cylinder is provided with two ducts, 83 84, (see Figs. 9, 10, 14, and 15,) which lead from the opposite ends of the cylinder and open into a chamber, 85, upon opposite sides of a nearly-balanced valve, 49, having a spring, 73, which acts to hold the valve closed when not acted on by the governor, as will be hereinafter explained. The stem 50 of the valve 49 extends out of the chamber 85, and is connected to an arm, 59, secured to a rod, 60, (see Figs. 14, 1, and 2,) which extends to a point at the side of the driving-pulley 112, where it is provided with an arm, 61, (see Figs. 25 to 32,) having a bowl which rests against or lies in close proximity to the inclined shoulder 62 of a disk, 63, which is mounted loosely upon the hub 64 of the pulley 112. The disk 63 is provided with coarse screw-threads, which engage with corresponding threads which are formed on the hub 64, so that when the disk is revolved around the hub it will be moved inward and press against the bowl of the arm 61, thereby rocking the rod 60 and arm 59, so as to open the valve 49 and establish communication through the ducts 83 84 between the opposite ends of the pump. As soon as this is done, a part of the explosive mixture drawn into the pump at one stroke will upon the next stroke be transferred from one end of the pump-cylinder to the other, thereby reducing the volume of the charge forced into the power-cylinder. The disk 63 is provided with two radial recesses, 65, which receive studs 66, projecting from a pair of weighted levers, 67, which are pivoted at 68 to the web of the pulley 112. The levers 67 are acted on by springs 69, which are located upon the opposite side of the pulley from the levers, and are connected to the levers by means of rods 70 and studs 71, which pass through curved slots 72 in the web of the pulley. The springs 69 are of such tension that so long as the engine is running

at its proper speed, they will hold the weighted ends of the levers 67 inward away from the rim of the pulley. As soon, however, as the engine attains an undue speed, the weighted ends of the levers will, by reason of their centrifugal force, overcome the tension of the springs 69 and be thrown outward, so that their opposite ends will, through the studs 66, turn the disk 63 around the hub 64 and force it inward, so as to open the valve 49, as before explained. As soon as the engine resumes its normal speed, the springs 69 will rock the levers 67 back to their normal position, and thereby allow the valve 49 to close.

Although the engine herein shown is arranged horizontally and is double acting, it will be readily seen that many or all parts of the invention may be applied to vertical as well as horizontal engines, and to single as well as double acting engines. It will also be seen that parts of the invention may be used without the whole.

What I claim is—

1. The combination, with the power cylinder and piston, of a pump for charging the cylinder, having its piston arranged to complete its stroke in advance of the power-piston, and a positively-actuated charging-valve arranged to open the induction-port at the same time or after the exhaust-opening is opened, and to close the induction-port at the same time that the pump completes its stroke, substantially as described.

2. The combination, with the power cylinder and piston, of the exhaust-opening arranged to be uncovered by the power-piston as it arrives at the end of its stroke, a pump for charging the cylinder, having its piston arranged to complete its stroke in advance of the power-piston, and a positively-actuated charging-valve arranged to open the induction-port at the same time or after the exhaust-opening is opened, and to close the induction-port at the same time that the pump completes its stroke, substantially as described.

3. The combination, with the power cylinder and piston, of a positively-actuated charging and firing valve carrying an igniting-burner and arranged to open the induction-port to admit the charge, close the port to confine the charge in the cylinder, and then bring the igniting-burner into communication with the charge to fire it, substantially as described.

4. The combination, with the power cylinder and piston, of the exhaust-opening arranged to be uncovered by the power-piston as it arrives at the end of its stroke, and a charging and firing valve carrying an igniting-burner and arranged to open the induction-port to admit the charge at the same time or after the exhaust-opening is uncovered, close the port so that the charge will be confined in the cylinder and compressed by the power-piston upon its return-stroke, and then bring the igniting-burner into communication with the charge to fire it, substantially as described.

5. The combination, with the power cylinder and piston, of the exhaust-opening arranged to be uncovered by the power-piston as it arrives at the end of its stroke, and a charging and firing valve carrying an igniting-burner and having suitable ducts through which it is fed from the charge in the power-cylinder, and arranged to open the induction-port to admit the charge at the same time or after the exhaust-opening is uncovered, close the port so that the charge will be confined in the cylinder and compressed by the power-piston upon its return-stroke, and then bring the igniting-burner into communication with the charge to fire it, substantially as described.

6. The combination, with the power cylinder and piston, of a pump for charging the cylinder, having its piston arranged to complete its stroke in advance of the power-piston, and a positively-actuated charging and firing valve carrying an igniting-burner and arranged to open the induction-port at the same time or after the exhaust-opening is opened, close the port at the same time that the pump-piston completes its stroke, and then bring the igniting-burner into communication with the charge to fire it, substantially as described.

7. The combination, with the power cylinder and piston, of the exhaust-opening arranged to be uncovered by the power-piston as it arrives at the end of its stroke, a pump for charging the cylinder, having its piston arranged to complete its stroke in advance of the power-piston, and a positively-actuated charging and firing valve carrying an igniting-burner and arranged to open the induction-port at the same time or after the exhaust-opening is opened, close the port at the same time that the pump-piston completes its stroke, and to then bring the igniting-burner into communication with the charge to fire it, substantially as described.

8. The combination, with an igniting-burner fed through suitable ducts from the charge in the power-cylinder and a firing-valve for establishing communication between said burner and the charge to fire it, of a positively-actuated valve arranged to close the ducts through which the burner is fed at or about the time communication is established between the burner and the charge to fire it and to open said ducts after the exhaust is opened, substantially as described.

9. The combination, with a firing-valve carrying an igniting-burner which is fed through suitable ducts from the charge in the power-cylinder, and is arranged to be brought into communication with the charge in the cylinder to fire it, of a positively-actuated valve arranged to close the ducts through which the burner is fed at or about the time communication is established between the burner and the charge to fire it, and to open said ducts after the exhaust is opened, substantially as described.

10. The combination, with a stationary master-light and a firing-valve carrying an ignit-

ing-burner which is fed through suitable ducts from the charge in the cylinder, and is arranged to be brought into communication with the master-light to be lighted and into communication with the charge in the cylinder to fire it, of a positively-actuated valve arranged to close the ducts through which the burner is fed at or about the time communication is established between the burner and the charge to fire it, and to open said ducts after the exhaust is opened, substantially as described.

11. The combination, with an igniting-burner fed through suitable ducts from the charge in the power-cylinder and a charging and firing valve arranged to open the induction-port to admit the charge, close the port to confine the charge in the cylinder and allow it to be compressed by the piston and then establish communication between the burner and the charge to fire it, of a positively-actuated valve arranged to close the ducts through which the burner is fed at or about the time communication is established between the burner and the charge to fire it, and to open said ducts after the exhaust is opened, substantially as described.

12. The combination, with a stationary master-light and a charging and firing valve carrying an igniting-burner, which is fed through suitable ducts from the charge in the cylinder, said charging and firing valve being arranged to open the induction-port to admit the charge, close the port to confine the charge in the cylinder and allow it to be compressed by the piston and then bring the burner into communication with the charge to fire it, of a positively-actuated valve arranged to close the ducts through which the burner is fed at or about the time communication is established between the burner and the charge to fire it, and to open said ducts after the exhaust is opened, substantially as described.

13. In a gas-engine, an igniting-burner consisting of the tubular stem 18, through which the mixture for the burner passes, and the foraminous material 17, which is located within the tubular stem and a distance back from its end, whereby the flame of the burner is inclosed within and protected by the end of the tubular stem of the burner, substantially as described.

14. In a gas-engine, the combination, with an igniting-burner consisting of the tubular stem 18, through which the mixture for the burner passes, and the foraminous material 17, which is located within the tubular stem and a distance back from its end, whereby the flame of the burner is inclosed within and protected by the end of the tubular stem of the burner, of the port 7 and duct 8, arranged to be brought into communication with the charge in the power-cylinder and to direct the jet of the mixture issuing from the cylinder across the end of the tubular stem in which the flame of the burner is inclosed, substantially as described.

15. The method or process of hastening the combustion of the charges in a gas-engine, which consists in admitting or introducing a quantity of air into the cylinder of the engine after the charge has been fired and before the exhaust is opened, substantially as described.

16. The combination, with the power-cylinder and piston, of an air opening or port through which a quantity of air is admitted or introduced into the cylinder after the charge has been fired and before the exhaust is opened, substantially as described.

17. The combination, with the power cylinder and piston, of an air opening or port through which a quantity of air is admitted or introduced into the cylinder after the charge has been fired and before the exhaust is opened, and a valve for controlling said opening or port, substantially as described.

18. The combination, with the power cylinder and piston, of an air-chamber communicating with the cylinder and with the atmosphere, a valve for preventing the escape of the air from the chamber, and a valve arranged to open communication between the chamber and the cylinder after the charge is fired and before the exhaust is opened, substantially as described.

19. The combination, with the power cylinder and piston, of an air opening or port arranged to be uncovered by the piston after the charge has been fired and before the exhaust is opened, and a valve for controlling said opening or port, substantially as described.

20. The combination, with the power cylinder and piston, of an air-chamber communicating with the atmosphere and also with the cylinder by an opening or port which is arranged to be uncovered by the power-piston after the charge has been fired and before the exhaust is opened, and a valve for preventing the escape of the air from the chamber, substantially as described.

21. The combination, with the chamber 89, containing a body of water and provided with connections by which a flow of water is maintained through the chamber, of the exhaust-pipe 90, opening downward so as to deliver the exhaust products directly onto the surface of the body of water in the chamber, substantially as described.

22. In a gas-engine, the combination, with the oil-chamber 47, having the duct 26 communicating with the interior of the power-cylinder in position to be covered by the power-piston during a part of the stroke and to be opened to the cylinder during a part of the stroke, of the positively-actuated valve 26, for controlling said duct, said valve being arranged to close the duct when it is open to the cylinder and to open the duct when it is covered by the piston, substantially as described.

23. In a gas-engine, the combination, with the oil-chamber 47, having the duct 26 communicating with the interior of the power-cyl-

inder in position to be covered by the power-piston during a part of the stroke and to be open to the cylinder during a part of the stroke, and the pipes 27, leading to the charging and firing valve, of the positively-actuated valve 28, for controlling said duct and pipes, said valve being arranged to close the duct when it is open to the cylinder and to open the duct when it is covered by the piston, substantially as described.

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

PETER MURRAY, JR.

Witnesses:
LUTHER C. CROWELL,
JAS. J. KENNEDY.