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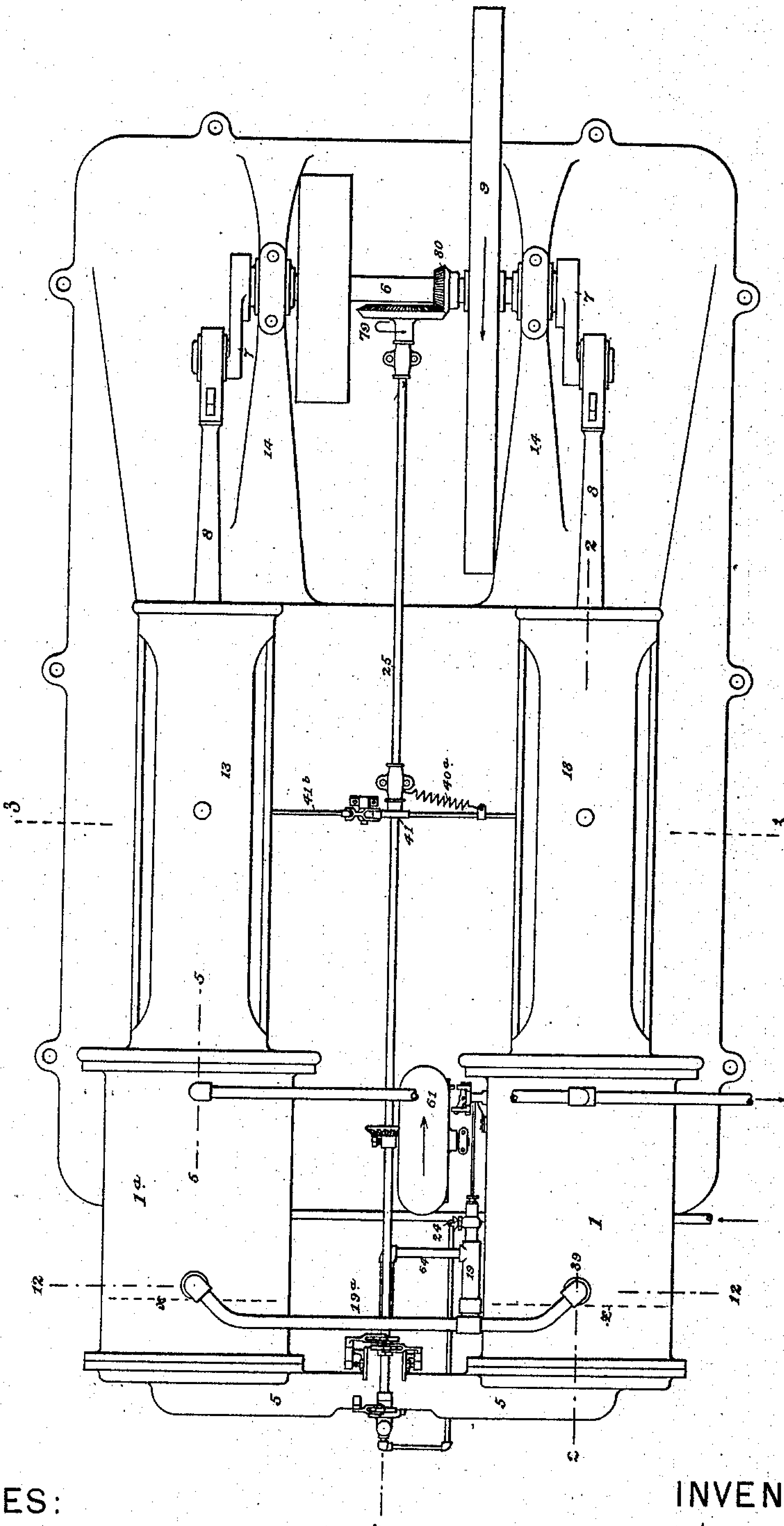
J. F. PLACE.

GAS ENGINE.

No. 322,477.

Patented July 21, 1885.

Fig. 1.



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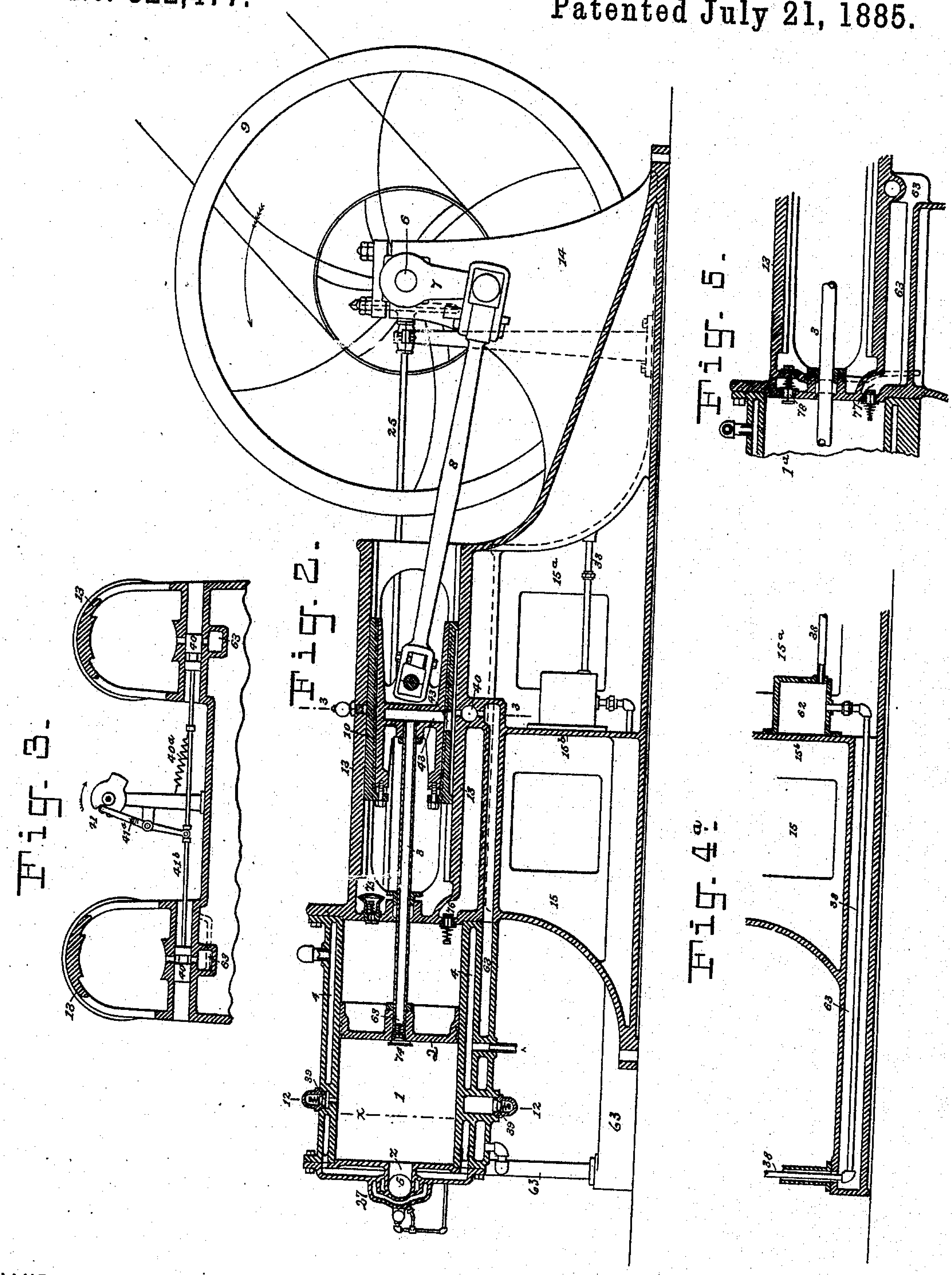

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Fig. 4.

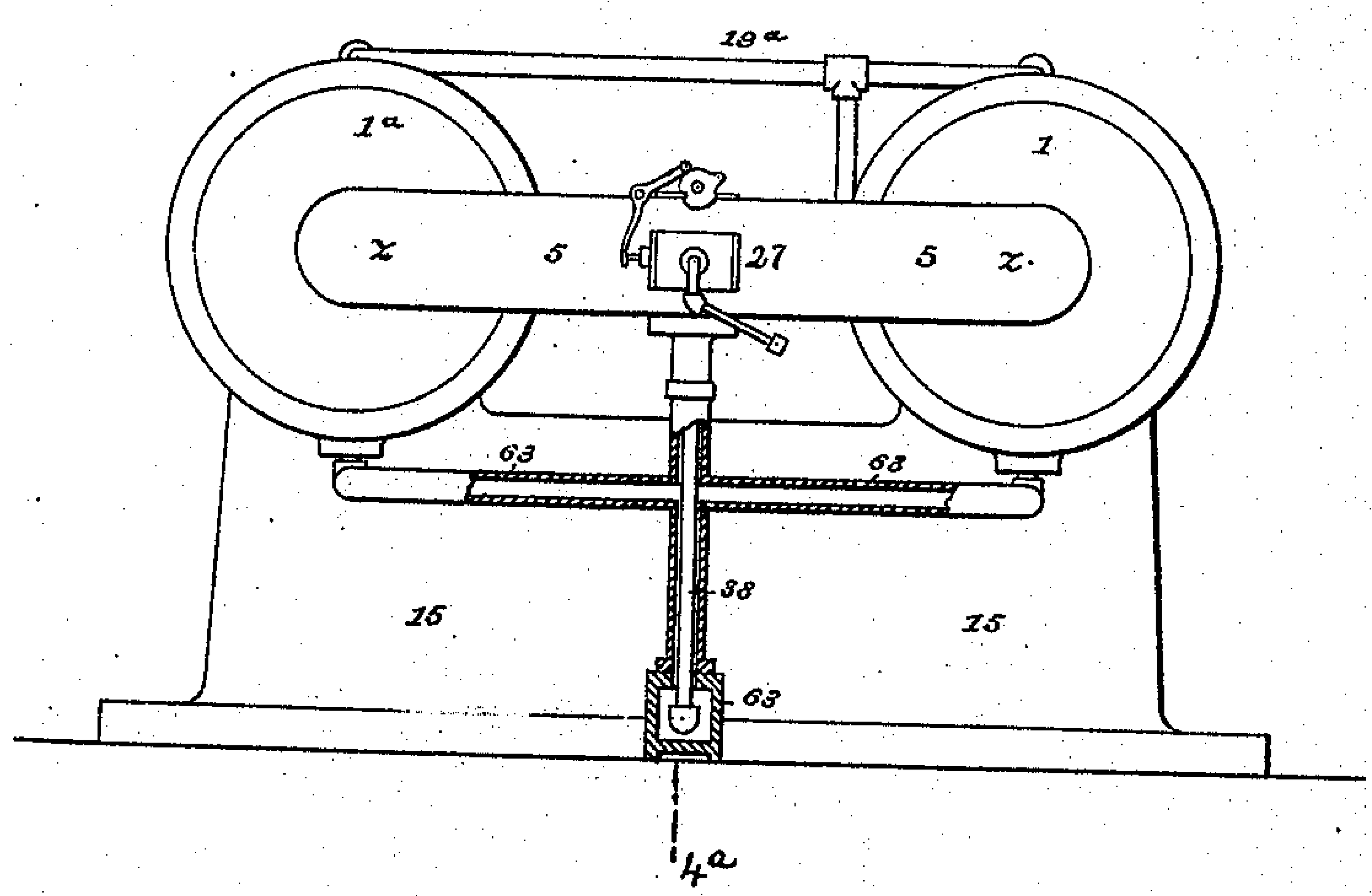


Fig. 13.

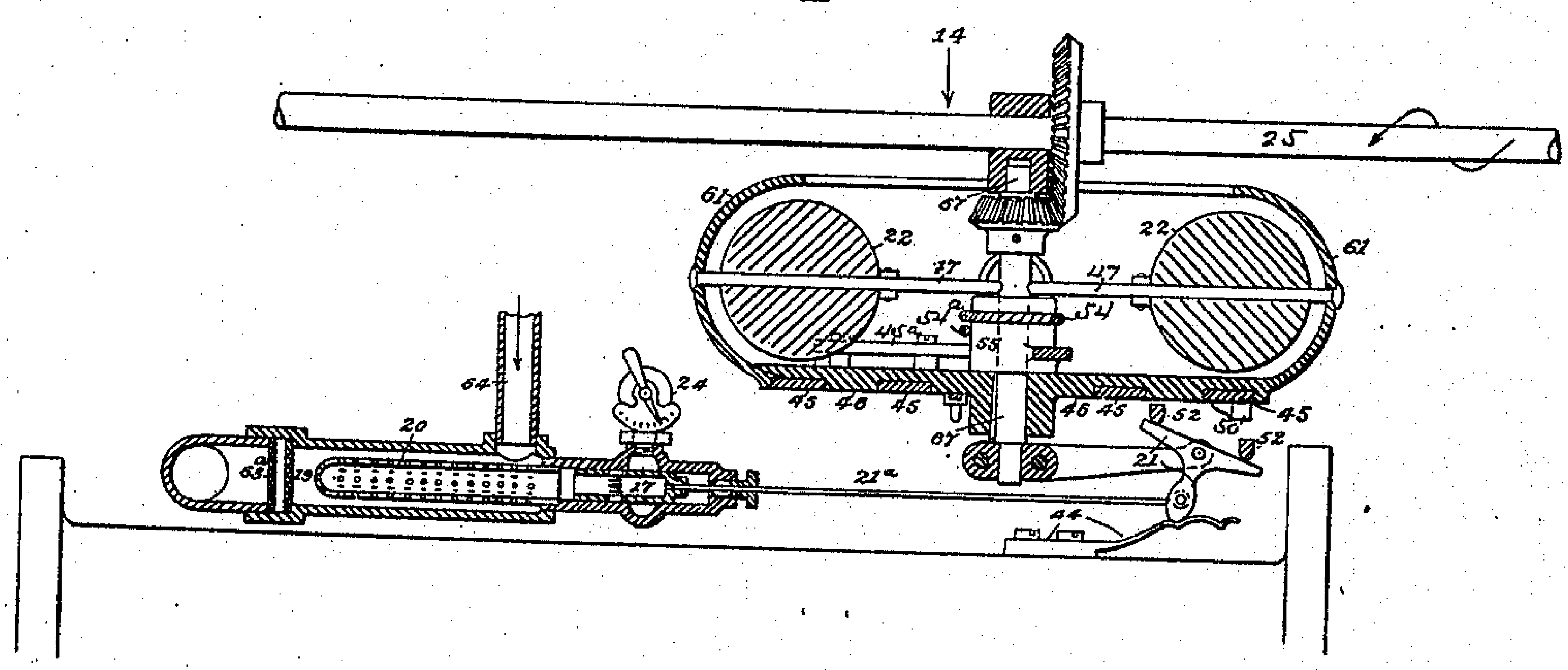


Fig. 16.

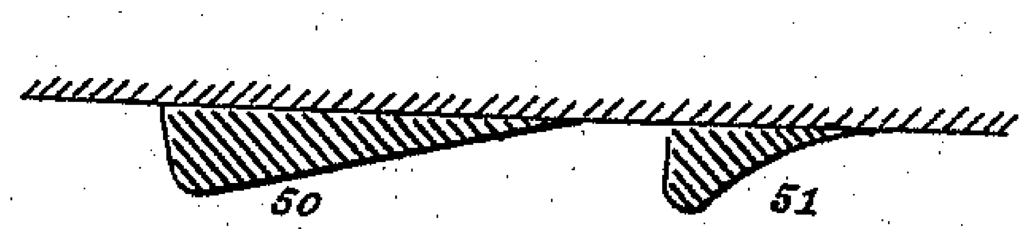
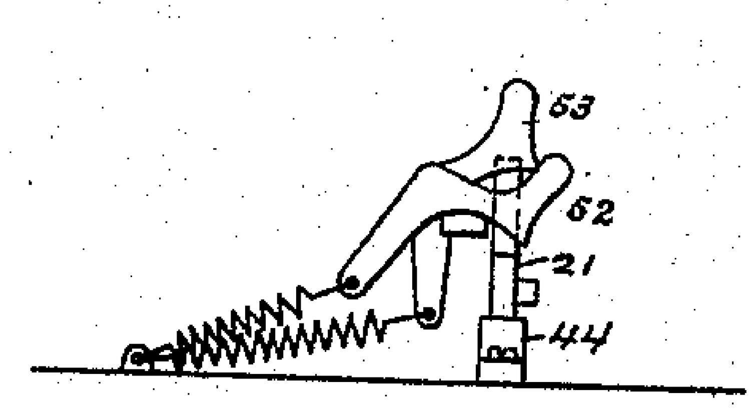


Fig. 17.



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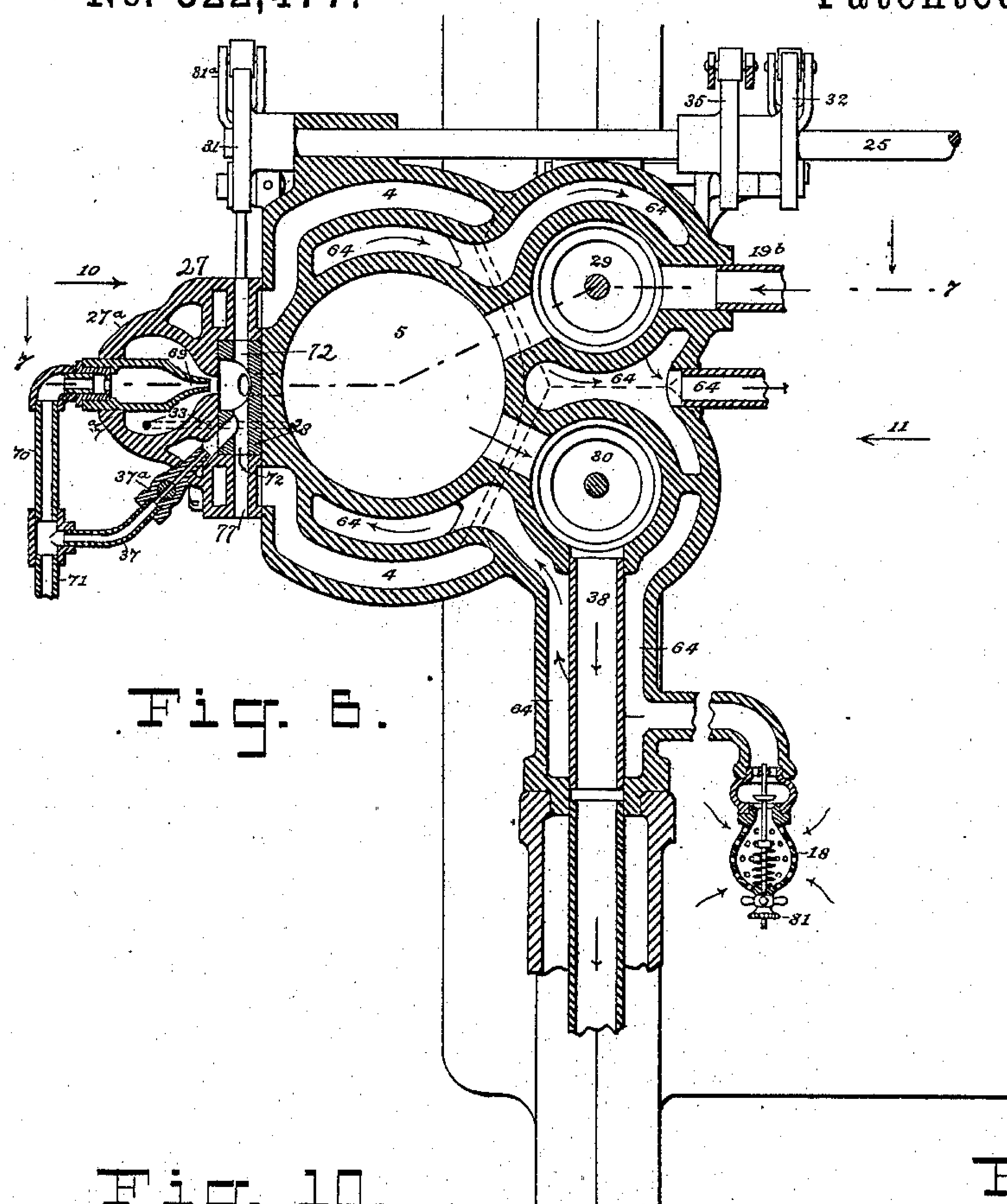


Fig. 6.

Fig. 10.

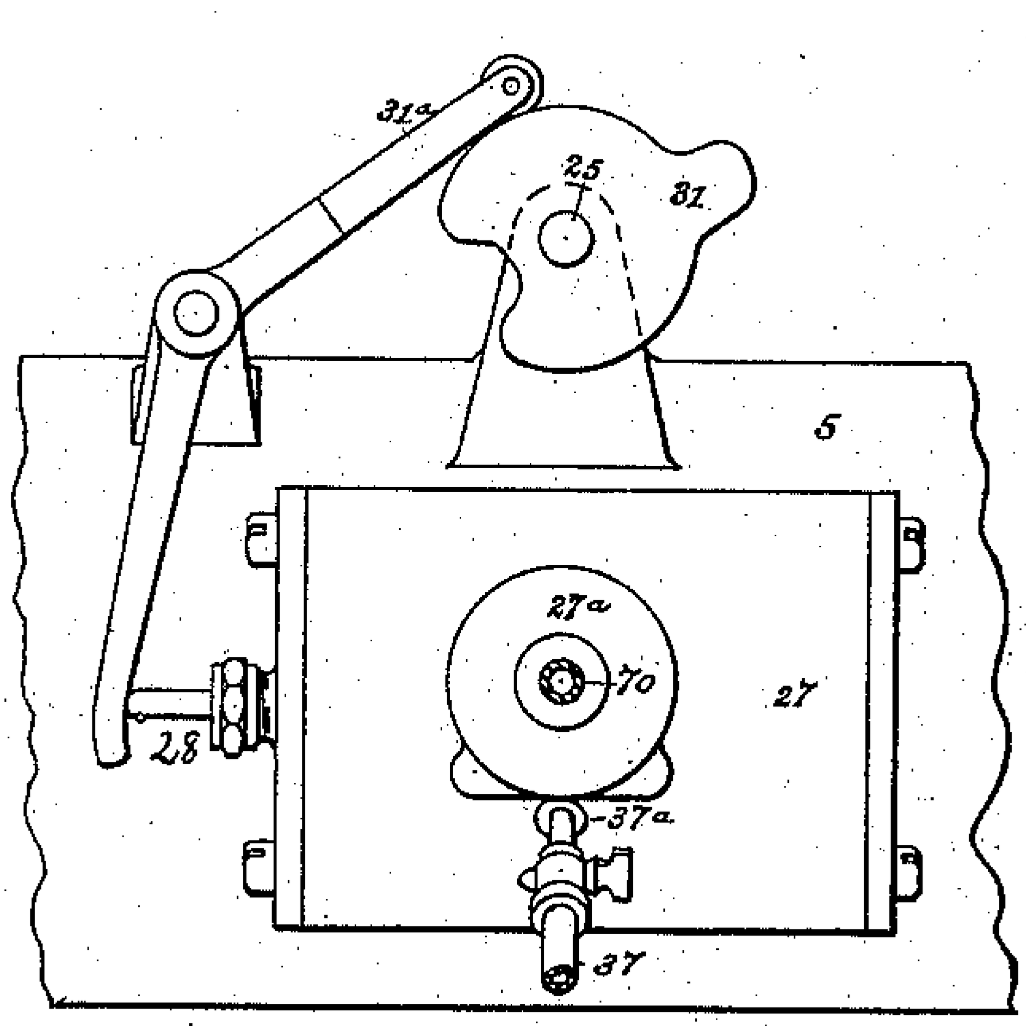
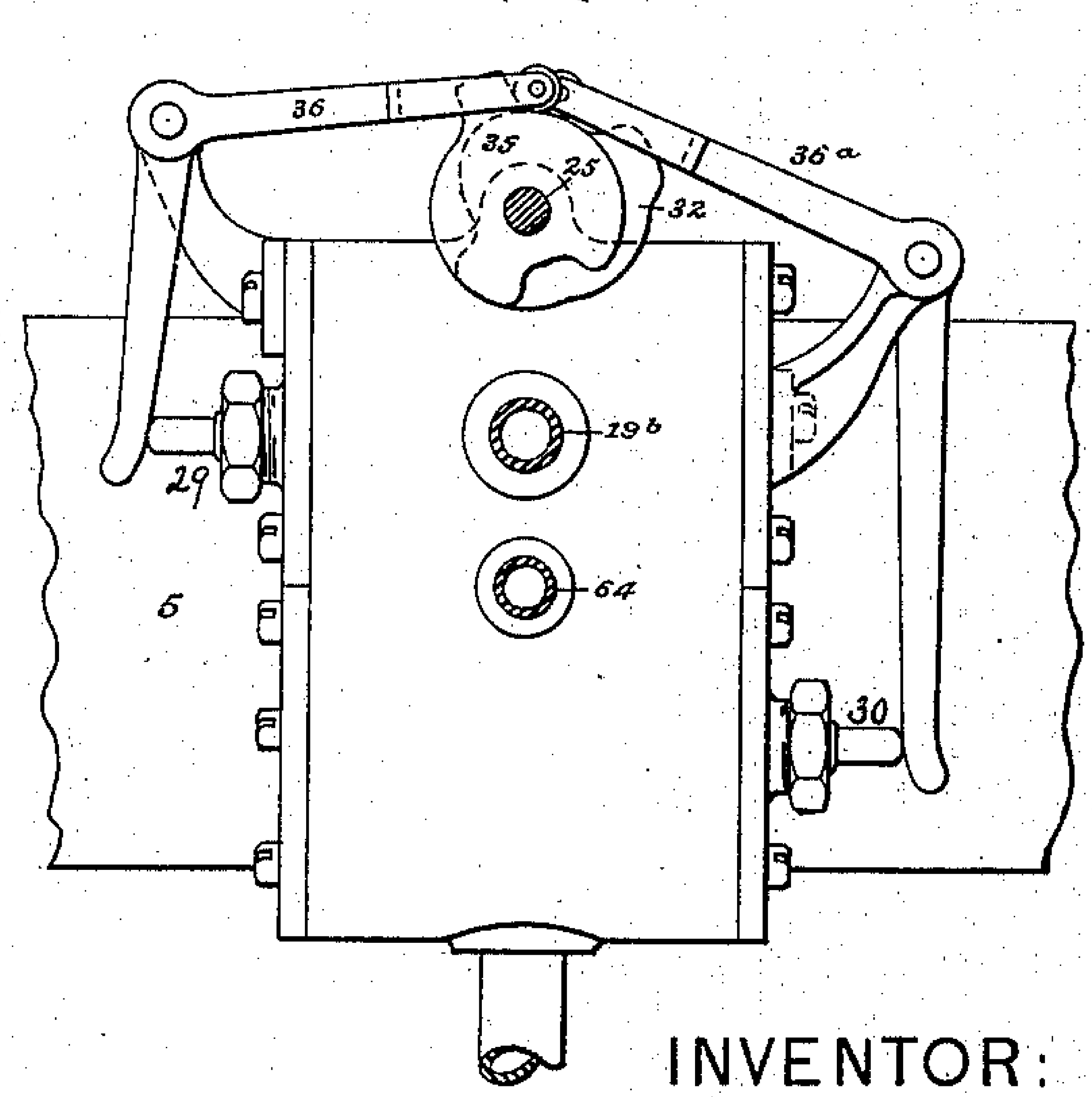


Fig. 11.



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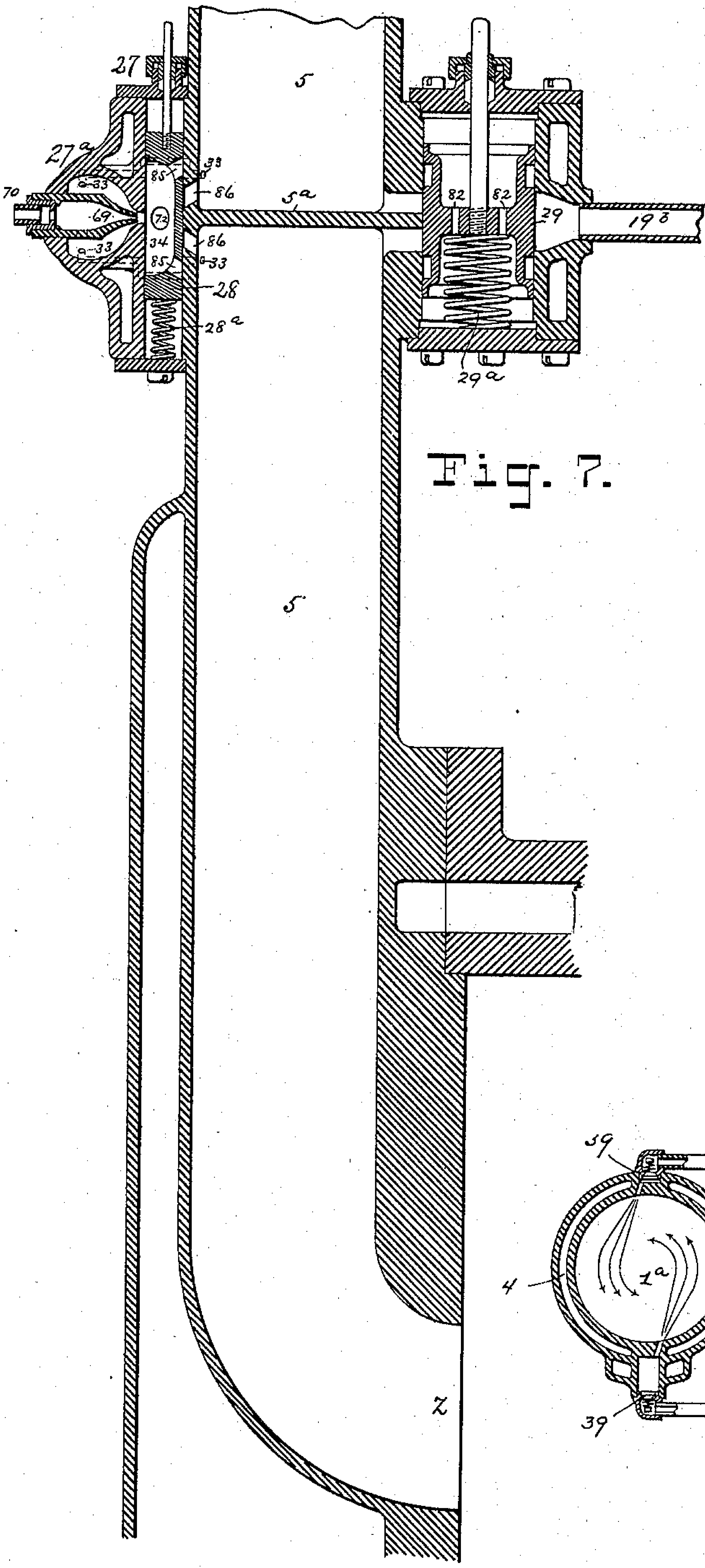


Fig. 7.

Fig. 8.

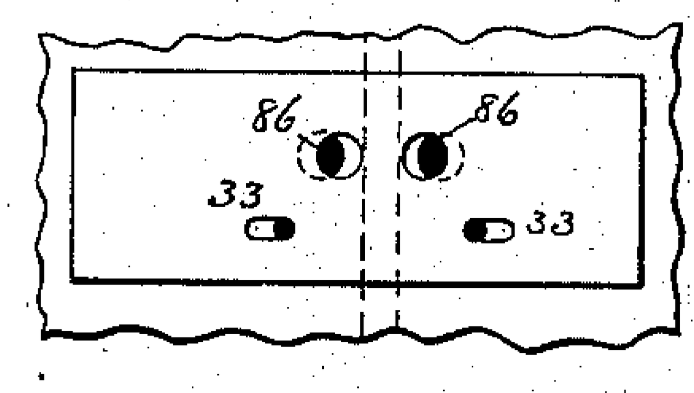


Fig. 9.

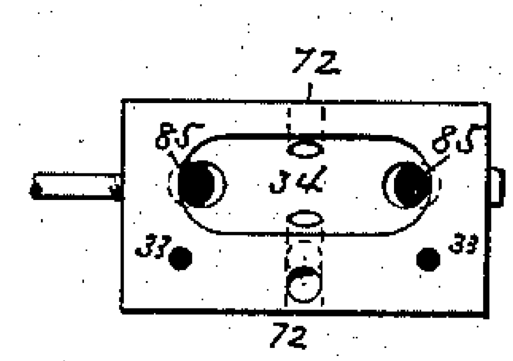
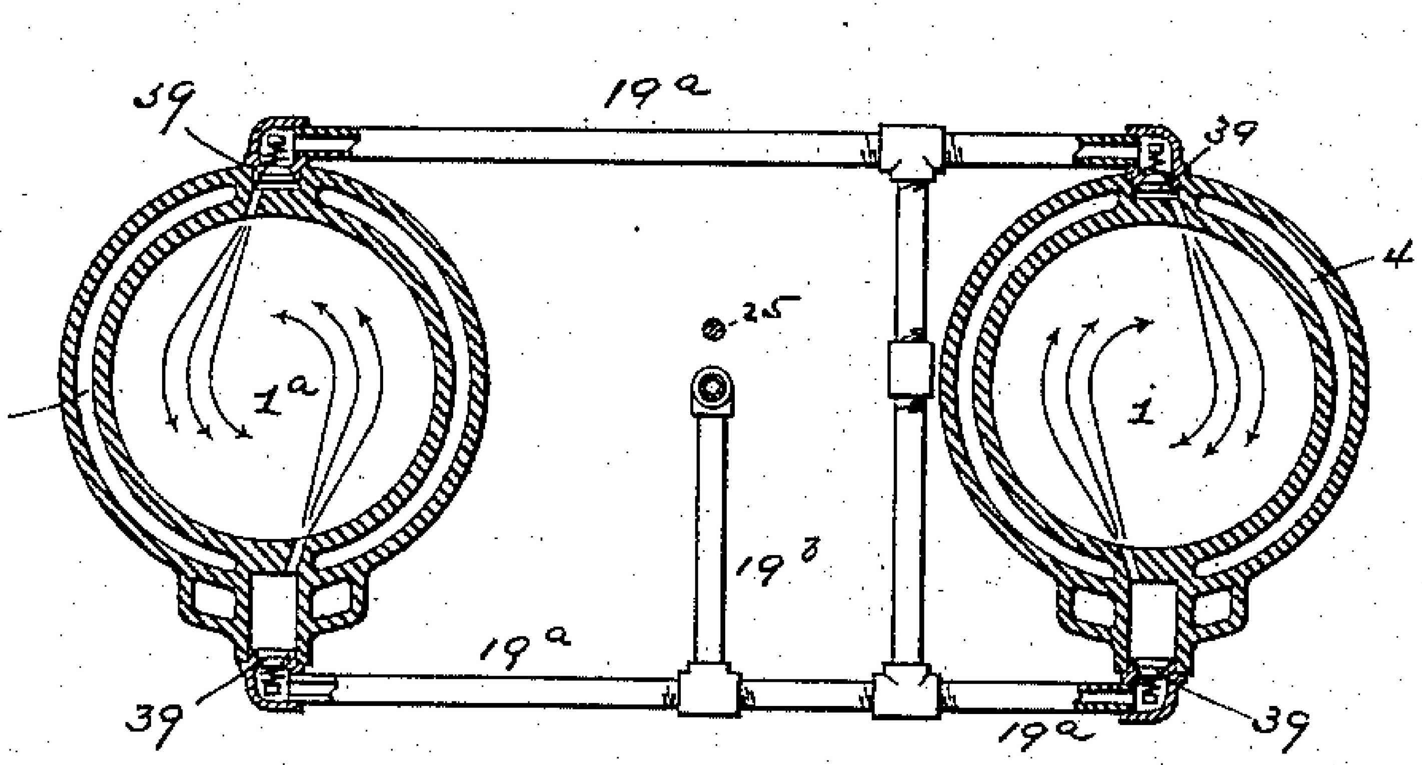


Fig. 12.



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GAS ENGINE.

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Fig. 14.

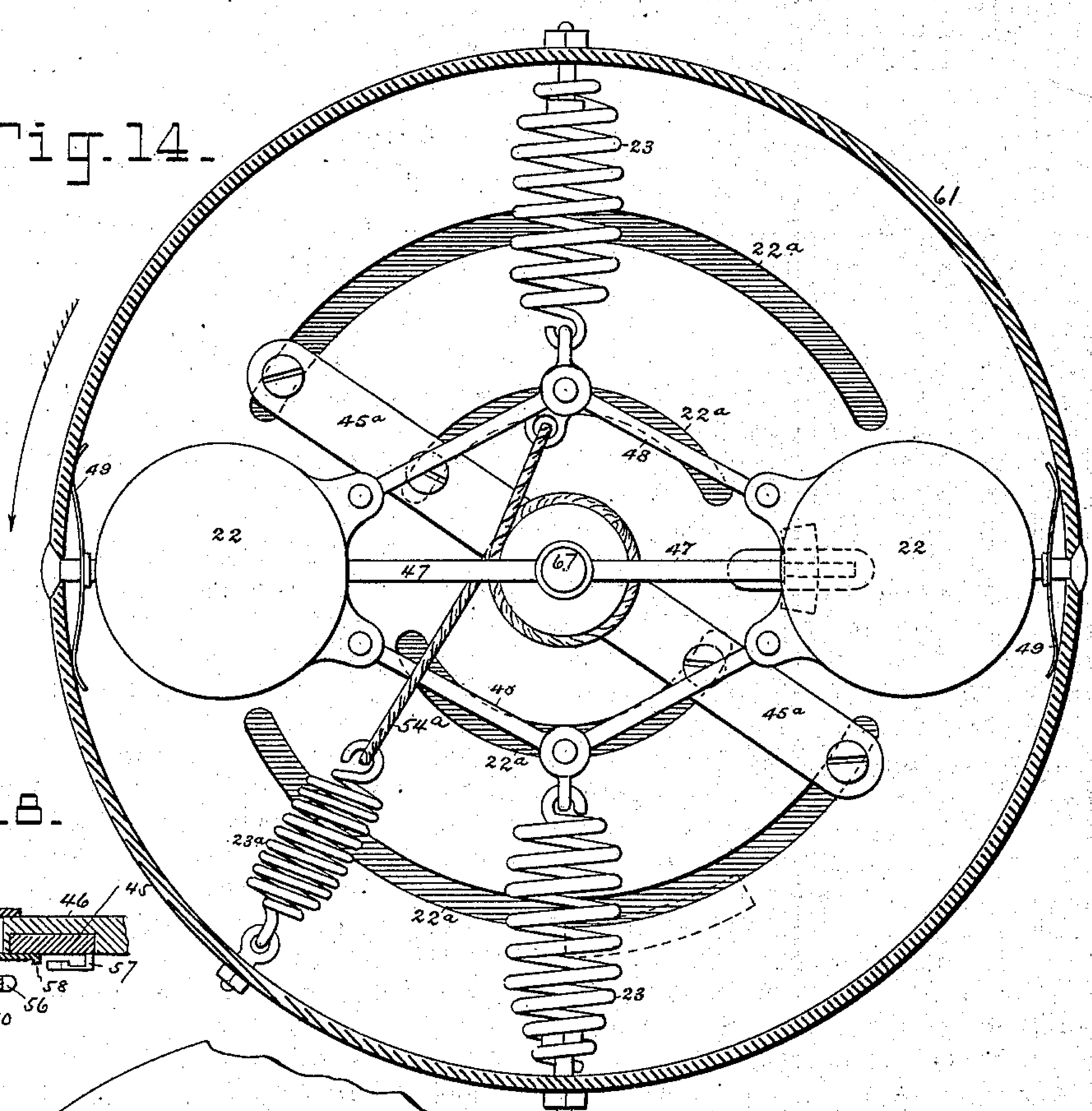


Fig. 18.

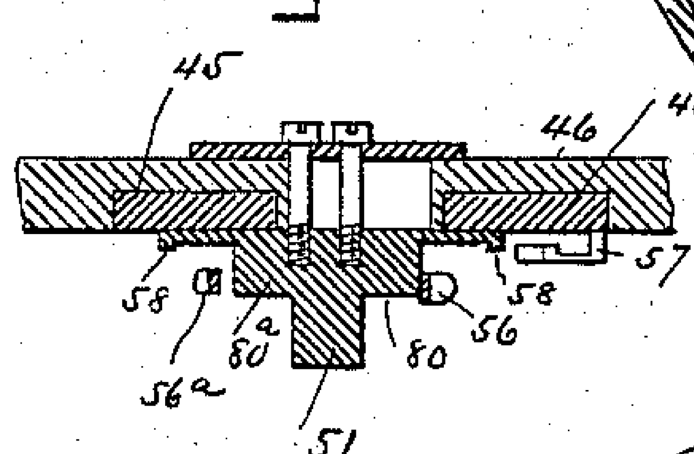
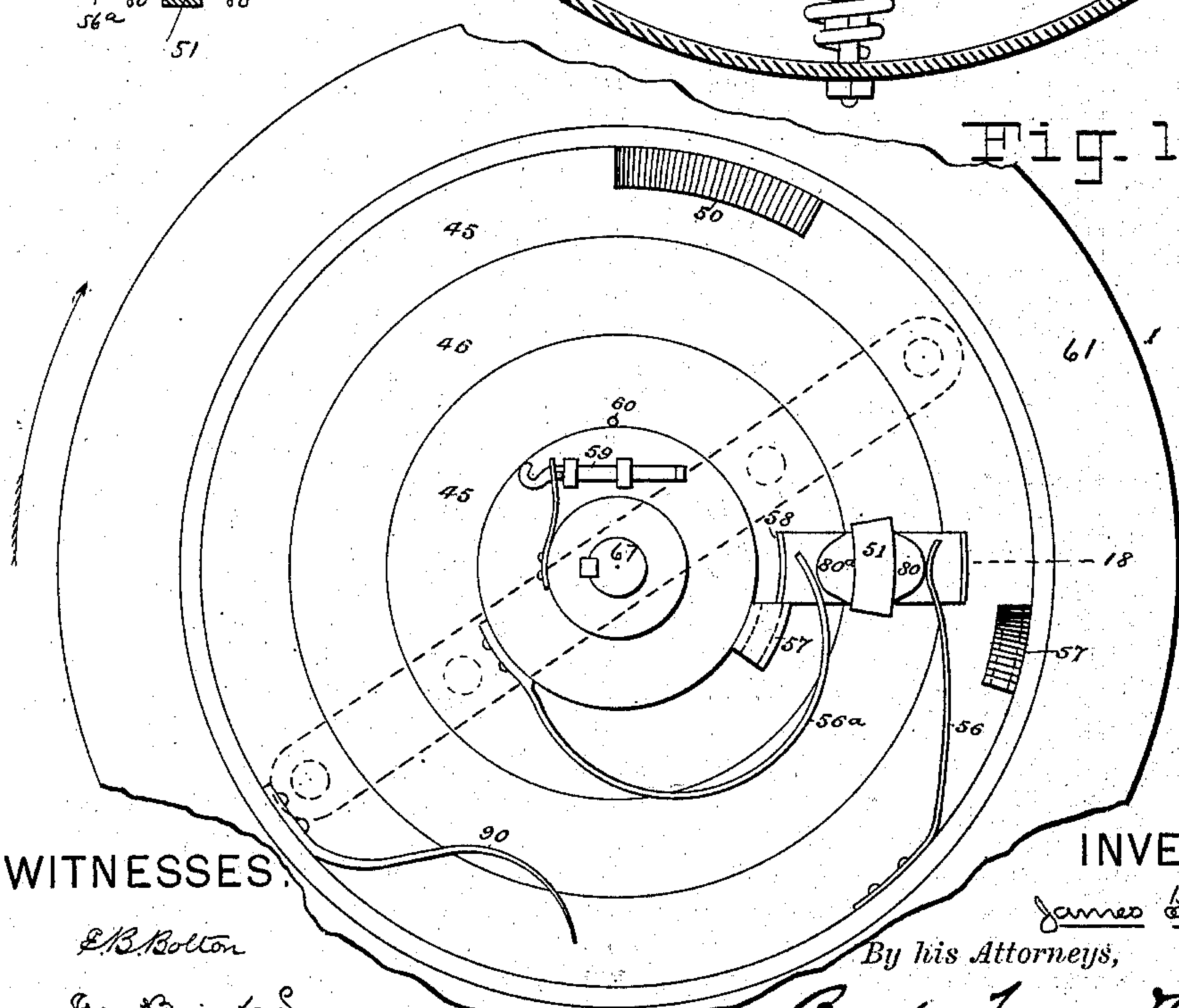


Fig. 15.



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UNITED STATES PATENT OFFICE.

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GAS-ENGINE.

SPECIFICATION forming part of Letters Patent No. 322,477, dated July 21, 1885.

Application filed July 25, 1884. (No model.)

To all whom it may concern

Be it known that I, JAMES FRANK PLACE, a citizen of the United States, and a resident of the city, county, and State of New York, have invented certain Improvements in Gas-Engines, of which the following is the specification.

My invention has for its object the production, in a gas-engine, of the following advantageous results over such engines now in use: a more uniform speed under varying loads, and consequently less vibration, shock, and waste heat in the engine; greater economy in the use of gas, or, in other words, the maximum of available power and the minimum of gas consumption; a more thorough mixture of the gas and air; a more thorough combustion of the explosive gases in the explosion-chamber, and an avoidance of any admixture with the explosive gases of the burnt gases or products of combustion; the better avoidance of leakage of products of combustion and other gases into the engine-room; the use of less water for cooling the engine; a simpler, more positive, and less expensive means and mechanism for igniting the explosive charge and the better utilization of the waste heat from the engine and products of combustion to heat, first, the air employed in the explosive mixture of gas and air, and, second, the air employed to drive out the products of combustion; also, other minor advantageous features, which will be hereinafter set forth.

The principles underlying my invention by which I seek to attain the objects named above are: an explosion of the charge of inflammable gas and air at every revolution of the crank, instead of at every other revolution; and a charge of inflammable gas and air which varies in richness according to the work to be done. As a consequence of this a greater or less amount of pressure is exerted on the piston, as may be required, by the varying load on the engine. A distribution in the explosion-chamber of a charge of air and gas which varies in richness according to its location—that is to say, richest nearest the piston and uniformly more diluted toward the igniting end of the cylinder—whereby when the rich strong charge at the igniter is fired the flame is thrown into the cylinder and ignites the weaker portion of the charge first, the richer portion being fired after the piston is in motion. Thus the greatest pressure is exerted on the piston when at half-stroke, and when the crank is acting at its greatest leverage. The power exerted on the crank is thus made cumulative, the culmination being reached when the leverage is greatest. An adaptation to the engine of an automatic cut-off governor to regulate the admission of gas, whereby the gas-supply may be cut off at different points of the stroke, and the explosive charge is made rich in gas at first and gradually diluted with air afterward. This governor is also adapted to entirely cut off the gas-supply when the charge is too much diluted to explode first at one cylinder, then at the other, as the load is lessened, and to immediately and automatically resume the supply first to one cylinder and then to the other, first diluted and then uniformly richer as increased power is required; the admission of cold air to the crank end of one cylinder, then to the crank end of the other cylinder, then forcing it from the latter into a chamber surrounding the exhaust, and then into the explosion-chamber of the cylinder through the piston-rod and piston. This drives all the burnt gases out from the cylinder before the admission of each explosive charge, and the waste heat of the cylinders, and the escaping products of combustion are absorbed to a great extent by the air which forms a part of the explosive mixture, and is utilized by conversion into power.

Having thus stated the objects I seek to obtain by my invention, and the principles underlying the same, and through which said objects are to be attained, I will now describe my invention with reference to the accompanying drawings, wherein—

Figure 1 is a plan of the engine. Fig. 2 is a sectional elevation, the line of the section being taken through one of the engine-cylinders on line 2 2 in Fig. 1. Fig. 3 is a transverse section through the cross-head guides on line 3 3 in Figs. 1 and 2, showing certain air-valves. Fig. 4 is a front elevation, partly broken away, to show the air-passage around the exhaust-pipe. Fig. 4[a] is a vertical section of the air-passage and a part of the air-chamber, substantially in the vertical plane indicated by line $4^a 4^a$ in Fig. 4. Fig. 5 is a vertical mid-section of the end of the second cylinder, 1^a, of the engine and a part of the cross-head guide of same on line 5 5 of Fig. 1. Figs. 6 to 11 are on a much larger scale than the preceding. Fig. 6 is a vertical transverse section of the igniting mechanism and the induction and eduction valves. The position of this section is indicated by the line 6 6 in Fig. 1. Fig. 7 is a section on line 7 7 in Fig. 6, showing, also, part of one cylinder. Fig. 8 is a plan of the seat of the igniting slide-valve. Fig. 9 is a plan of the igniting slide-valve. Fig. 10 is an elevation of the igniting valve chamber and the operating mechanism of the valve, seen from arrow 10 in Fig. 6. Fig. 11 is an elevation of the induction and eduction valve chambers and the mechanism for operating said valves seen from arrow 11 in Fig. 6. Fig. 2 is a cross-section of the engine-cylinders, taken on line 12 12 in Figs. 1 and 2, and on the same scale as these figures. Fig. 13 is a horizontal mid-section of the automatic cut-off governor and the gas-inlet valve and mixer on a large scale. Fig. 14 is an elevation of the governor as seen from arrow 14 in Fig. 13, but on a larger scale; and Fig. 15 is a similar elevation of the opposite side or face of the same. Fig. 16 is a view showing the tappets which actuate the gas-inlet valve on a large scale, and Fig. 17 is a side view of the intermediate levers acted on by these tappets. Fig. 18 is a detail in section on line 18 in Fig. 15.

I will preface the description of my engine by saying that I employ, as in other engines of this character, an explosive mixture of inflammable gas and air, which is compressed by the piston before ignition. My engine comprises two cylinders, the pistons of which move together or in unison, being coupled to cranks which are set alike on the power-shaft. The explosions take place alternately in these two cylinders, whereby I obtain one explosion for each revolution of the shaft—that is to say, one piston is compressing its explosive charge while the other is expelling the burned gases, and on the instroke one is moving under the impulse of the explosion while the other is receiving its charge of the explosive mixture of gas and air. The inner or crank ends of the cylinders of my engines are closed, and the piston-rods play through stuffing-boxes, and I supply these cylinder-heads with induction and eduction air-valves, whereby I employ one end of each cylinder as an air-pump to compress a charge of air which is employed to wash out or expel the burned gases from the explosion-chamber at each revolution. This charge of air enters the explosion-chamber (or outer end of the cylinder) through the tubular piston-rod and a valved aperture in the piston.

I may also state here that I am aware gas-engines have been proposed having two cylinders, in which the charges are exploded alternately, and having the cranks, pistons, and piston-rods arranged to move in unison; and I am also aware that gas-engines have been proposed having the crank ends of the cylinders closed and provided with induction and eduction valves. These features I do not therefore claim, broadly.

Referring now particularly to Figs. 1 and 2, 1 and 1^a are the cylinders; 2 the pistons, which are shown at mid-stroke in Fig. 2 and at outstroke in Fig. 1.

The dotted lines x in Figs. 1 and 2 indicate the limit of the outward travel of the pistons. That portion of the cylinders between this line and the outer heads of the cylinders is reserved to form the explosion-chambers, and these explosion-chambers occupy about one-third of the cylinders.

3 are the hollow or tubular piston-rods, attached to cross-heads 10, which play in cross-head guides 13.

4 represents the water-jackets around the cylinders, which may be supplied with running water in the usual way.

6 is the main shaft, mounted in suitable bearings, and provided with two cranks, 7 7, set alike or in the same plane. These cranks are coupled to the cross-heads by connecting-rods 8 8.

14 is a bed-plate, which is cast hollow to form two air-chambers, 15 and 15^a, which are separated by a partition, 15^b. On the bed-plate thus formed are mounted the cross-head guides 13 and the bearings for the power-shaft 6.

9 is the fly-wheel.

Referring now to Figs. 6, 7, 11, 12, and 13, as well as Figs. 1 and 2, I will explain how the air and gas are mixed and admitted to the explosion-chamber.

5 is the igniting chamber or chambers, which extends across the ends of the cylinders and opens into them at z, as shown. This chamber is divided at its center by a cross-partition, 5^a.

18, Fig. 6, is the air inlet or supply pipe, which is controlled by a thumb-screw, 81. The air entering at this valve passes around the igniting-chambers and valve-chambers through passage 64 to the mixing-chamber 19, Fig. 13. Here it is mixed with the proper proportion of gas through the medium of the devices I will now describe.

To the end of the mixing-chamber 19 is connected a cylindrical valve-chamber in which plays a parted gas-valve, 17, and to which gas is admitted at an inlet, 24, controlled by a cock. The gas-valve 17 is controlled by an automatic cut-off governor, which will be hereinafter described. The gas does not enter the mixing-chamber directly, but passes into a perforated tube, 20, arranged in the mixing-chamber, and through the perforations into the mixing-chamber in jets, whereby it is thoroughly mixed with the air entering said chamber through the air-passages 64. I may also arrange in the mixing-chamber a foraminous partition or partitions, 63^a, through which the air and gas must pass, and which will serve to insure a more thorough commingling of the two; but these I do not consider essential.

Mixers for gas-engines having a perforated gas tube or pipe arranged within an air-pipe having been heretofore proposed, I do not claim this construction.

The mixed charge of gas and air is led to the cylinders through pipes 19^a and 19^b, the former admitting it at the sides of the cylinders, as will be hereinafter explained, and the latter admitting it through the medium of the igniting-chambers 5 and the induction-valve 29. This valve and its operative mechanism are best shown in Figs. 1, 6, 7, and 11. A shaft, 25, is rotatively mounted on the bed-plate, and is driven through the medium of a bevel-wheel, 79, on said shaft, and a bevel-wheel, 80, of half the diameter of 79, on the power-shaft. Thus the shaft 25 makes one revolution to two of the main shaft.

On shaft 25 is fixed a cam, 35, Fig. 11, which acts on a roller in the forked end of the bell-crank lever 36, the other end of which lever acts on the stem of valve 29 to move it in one direction. The valve is moved in the other direction by a spring, 29^a, Fig. 7. This valve 29 is cylindrical, and plays longitudinally in a cylindrical chamber. It has two circumferential grooves forming ports or channels, which grooves, when the valve is moved back and forth, form, alternately, channels of communication between the inlet 19^b and ports on either side of the partition 5^a, leading from the valve-chamber into the igniting-chamber 5.

The cam 35 is of such a form (shown in Fig. 11) that, in connection with the spring 29^a, it admits a portion of the explosive mixture first to one cylinder through its igniting-chamber, and then to the other, but the ports are opened only for a moment and then closed.

I will now explain the mechanism for admitting the explosive charge at the sides of the cylinders, referring particularly to Figs. 1, 2, and 12. The pipes 19^a lead the explosive mixture from the mixing-chamber 19 to ports in the sides of the cylinders, which ports are controlled by spring-valves 39, which open inward. The apertures which admit the charge to the cylinders are oblique, so that the charge is given a gyratory motion as it enters, as shown in Fig. 12. Now, when the piston stands at the end of its outstroke (see dotted line x) it covers these side inlets; but as it moves in toward the crank these side inlets are opened, and the suction of the piston causes the charge to enter at these ports, as described, the port controlled by the valve 29 being now closed. Thus I get a rich charge in the igniting-chamber 5, and a rich charge next the piston, this latter charge being uniformly more and more diluted in proportion to the distance from the piston.

The exhaust or induction valve 30 is constructed and operated precisely in the same way as the induction-valve 29. Therefore the sectional view of valve 29, Fig. 7, will serve for both. This valve is operated by a cam, 32, on shaft 25, and a bell-crank lever, 36^a. The products of combustion pass off through a pipe, 38.

I will now describe the means employed for driving out the burned gases or products of combustion from the explosion-chamber, and the means adopted for utilizing the waste-heat of the products of combustion, and the cylinders for heating the charge of air that is employed to drive off said burned gases and to replace them.

Referring particularly to Figs. 1, 2, 3, 4, 4^a, and 5, in the inner end of the cylinder 1 is a valve, 75, which opens inward, and which, when the piston moves outward from the crank, admits cold or normal air to said cylinder. On the return-stroke of the piston this air is forced out of the cylinder through a valve, 76, which opens into air-chamber 15. The air from this chamber 15 is drawn into cylinder 1^a (see Fig. 5) through a valve, 78, in same, and on the return-stroke forced out said cylinder into chamber 15^a. Thus by passing through both cylinders the air is caused to absorb heat from the same, and the cylinders and pistons are made to serve as air-pumps to compress one charge of air at each revolution.

In the chamber 15^a is a chamber, 62, arranged in the exhaust-pipe 38, and this serves also to raise the temperature of the air in chamber 15^a; and to further utilize the heat of the burned gases, I arrange the exhaust-pipe 38 within a passage, 63, which leads from chamber 15^a to valve-chambers (see Fig. 3) arranged under the cross-heads and having cylindrical valves 40. The under side of the cross-head is recessed, and this recess connects with a passage, 43, in the cross-head, which in turn connects with the tubular passage through the piston-rod 3. The valve 40 controls the admission of the heated air from 63 to the passage through the piston-rod and piston, and the passage through the piston is controlled by a spring-valve, 68, which opens outward or into the explosion-chamber.

The mechanism for operating the valve 40 comprises a cam, 41, on shaft 25, arranged to act on one end of the lever 41^a, the other end of which engages a valve-rod, 41^b, common to both valves 40. The cam 41 is constructed very similar to the cams that actuate the induction and eduction valves before described, and it moves the valve in one direction, the movement in the opposite direction being effected by a spring, 40^a. Each of the valves 40 controls the admission of air to its respective cylinder, and the cam 41 opens and closes each valve at alternate revolutions, as will be understood.

I will now describe the igniting mechanism with especial reference to Figs. 6, 7, 8, 9, and 10.

Mounted on the side of the igniting-chamber 5, and at its middle, is the chamber 27, containing the igniting slide-valve 28. On the back of chamber 27 is a globular chamber, 27^a, which opens into the valve-chamber, and in this chamber is arranged the igniting-jet 69, which connects by a branch pipe, 70, with a gas-supply pipe, 71, from any source of gas.

37 is a pipe, which branches from 71 and supplies gas to a master-light, 37^a, which enters the valve-chamber obliquely from below. The slide-valve 28 is provided with a recess, 34, in its upper side, which is always open to the igniting-jet 69. Through or across the valve, vertically, is arranged a passage, 72, which is at the proper time brought into coincidence with an air-passage, 77, in the valve-chamber, whereby air is admitted to the jets. The valve also has two ports, 85, which at the proper time are brought to coincide with respective ports 86, opening through the valve-seat into the chambers 5 on opposite sides of partition 5^a.

In Fig. 10 the mechanism for operating the valve is illustrated. It consists of a cam, 31, on shaft 25, arranged to act on one arm of a bell-crank lever, 31^a, the other end of which acts upon the end of the stem of the valve. A spring, 28^a, Fig. 7, serves to move the valve in the opposite direction. In the walls of the valve-chamber are two passages, 33, which lead from the igniting-chambers 5, from opposite sides of partitions 5^a, to the globular chamber 27^a. These passages extend through the valve-chamber, and are controlled by the valve, the latter having ports which, as the valve moves, are put into and out of coincidence with said passages, thus opening and closing them at the proper time. The purpose of this is to admit a portion of the explosive mixture from the chamber 5 to the chamber 27^a, in order to drive out any burnt gases that may be incarcerated therein and to so render the mixture of gas in the recess or hollow of the valve more explosive. As the explosive mixture in chamber 5 is compressed at the moment communication is established with chamber 27^a, it will be readily seen that a strong jet will be forced through passage 33 at the proper moment.

In order to prevent compression of the air in the closed chambers of the valves 29 and 30, holes are made in the partitions across them, to which the valve-stems are attached. These are shown at 82 in Fig. 7. The slide-valve 28, which also plays in a closed chamber, should be similarly provided.

So far as described, the operation of my improved engine is as follows: The pistons being at the ends of their outstrokes, (line x,) as they start to return the inlet-port of one cylinder is opened, and the explosive compound from the mixing-chamber is drawn into that cylinder through the igniting-chamber 5. The piston, now moving inward, passes the inlet-opening in the sides of the cylinder controlled by valve 39, and the inlet-valve 29 is instantly closed. The explosive compound is now drawn directly into the cylinder at these lateral ports. When the piston has reached the inner end of its stroke, it will be found that, owing to the action of the governor, which will be hereinafter described, the charge of explosive gases next the piston will be rich, and that it will be more and more diluted as we approach the outer end of the cylinder, and that the explosive charge in the igniting-chamber 5 will be rich. The piston now starts to return on its outstroke, the valves 39 instantly close, and the charge is compressed in the explosion-chamber. At the instant the piston reaches the end of its out stroke the slide-valve 28 brings the ports 85 and 86 appertaining to that cylinder into coincidence, and the flame from the igniting-jet 69, which has been burning, ignites the explosive compound in the igniting-chamber 5 belonging to this cylinder, which immediately communicates it to that in the explosion-chamber of the cylinder. As the charge in the chamber 5 is rich and strong, the combustion is rapid, and the explosion is communicated with much mechanical disturbance to the charge in the cylinder. Although apparently simultaneous, owing to the rapid movement of the piston, the combustion is really cumulative, owing to the varied richness of the charge, the greatest explosive force or impact on the piston being exerted when the crank reaches a position at or about at right angles with the connecting-rod. Thus I am enabled to avoid the expenditure of the force of the explosion on the crank as it is passing the center. When the piston has reached the end of its instroke, the igniting-valve closes, and the exhaust or eduction valve opens its port, to allow the burned gases to pass out through pipe 38 and chamber 62. While the above operations have been going on, the inner end of the cylinder, acting in its capacity as a pump, has taken in air and compressed it in chamber 15^a. The valve 40 is at this moment opened and a charge of heated air rushes through the tubular piston-rod and into the outer end of the cylinder as the piston starts on its outstroke, thus driving out the burned gases by the combined action of the charge of air and the outward displacement of the piston.

In order to guard against the incarceration of the burned gases next to the piston I provide a deflecting-plate, 74, Fig. 2, mounted on the outer face of the piston, so as to screen the air-inlet controlled by valve 68. This plate deflects the incoming air laterally in a sheet close to the piston and drives the burned gases forward. The operation of compressing and heating this charge of air has been sufficiently explained hereinbefore. While the above-described operations are going on in one cylinder, they are being repeated in the other cylinder; but, as before stated, one cylinder is receiving its charge while the piston in the other is being acted upon by the expansion of the exploded charge, and one is compressing its charge while the other is expelling its burned gases. In this manner the pistons, while moving in and out in unison, are really being acted upon by the successive explosions alternately, whereby I get one explosion for each revolution of the main shaft.

I have shown two side inlets for the admission of the explosive charge to the cylinder, but I may employ one or more. I arrange these inlets obliquely in order to give the gases a gyratory motion, so that when they enter they may follow the curved wall of the cylinder, and thus fill the space next the piston, displacing the air already there.

I may apply my improvements to a single-cylinder engine, and contemplate doing so; but in that case there will be an explosion only at alternate revolutions. As I only require one charge of compressed air to remove the products of combustion at each alternate revolution, I compress the air from one cylinder in chamber 15, and take air with the other cylinder from this chamber and force it into chamber 15^a. By this means I better utilize the heat in heating the air. I do not limit myself to this specific arrangement, however. Each cylinder might take in cold or normal air and compress it in a chamber common to both or in separate chambers.

Heretofore gas-engines have been, and they are at present, provided with governors similar to those on steam-engines, and adapted to lessen the amount of gas used in proportion to the decrease of the load on the engine. These, however, do not cut off the gas at different points in the stroke, and they are limited in their movement by the fact that in such engines the reduction of the gas-supply below a certain proportion to the air employed will prevent an explosion.

Now, as my construction insures a rich explosive charge in the igniting-chamber and a rich partial charge next the piston, the explosion of my charge is assured, no matter if the charge intervening be all or nearly all air. Therefore I am enabled to employ an automatic cut-off governor that will cut off the supply of gas completely at different points of the stroke, varying with the load; and in addition to this, by employing a cut-off tappet of peculiar shape, I am enabled to cut off the gas gradually, so as to obtain a gradually-diluted charge; but the governor always opens the gas-inlet valve fully, and then closes it entirely. Thus it is possible for me to employ, taking the entire volume of gases in the cylinder and igniting-chamber, a proportion of gas that is much below the proportion that will form, when intimately mixed, an explosive compound.

In Figs. 13, 14, 15, 16, 17, and 18 I have shown my improved automatic governor, which I will now describe. 67 is a horizontal shaft driven from the shaft 25 by bevel gear-wheels. This shaft 67 makes two revolutions to one of the shaft 25. Secured to shaft 67 is a disk, 46, provided with a curved inturned outer rim, 61. On arms 47, which branch from shaft 67, are mounted to slide governor-balls 22. The balls 22 are provided with links 48, to which are attached springs 23, which tend to draw the balls in toward shaft 67. The centrifugal force tends to throw the balls out and distend the springs. On the rear face, Fig. 15, of the disk 46 is mounted a tappet, 51, which, as the disk rotates, acts on the end or arm of an intermediate spring-lever, 53, Fig. 17, and this lever acts on one arm of a three-armed lever, 21, Fig. 13, to depress said arm. The lower or pendent arm of lever 21 is coupled to the rod 21^a of the gas-valve 17, and when the tappet 51 acts as above described this valve 17 is thrown full open and gas is admitted to the mixer. (Shown in section in Fig. 13.) A spring, 44, which acts against the pendent arm of lever 21, holds it in position whichever way it may be thrown. Another tappet, 50, (shown enlarged in side elevation in Fig. 16,) acts on another intermediate lever, 52, Fig. 17, and through it on the other lateral arm of lever 21, and by swinging the pendent arm of said lever over (to the position seen in Fig. 13) serves to fully close the gas-inlet controlled by valve 17. Now, in the construction shown the tappets 50 and 51 are so arranged that normally the limit of cut-off is at one-third of the stroke; but this limit may be varied.

I will now describe the means whereby the movement of the governor-balls is caused to vary the position of the cut-off tappet 50 with reference to the opening tappet 51, so as to vary the point of cut-off. In concentric grooves in the outer face, Fig. 15, of the disk 46 are arranged to play rings 45, which are secured to arms 45^a by pins or studs, which pass through slots 22^a in disk 46. These arms 45^a are attached to a boss or hub, 55, which turns freely on shaft 67. To this hub is secured one end of a cord, 54, which is wrapped around the hub, and has its other end attached to one of the springs 23. This construction is such that when the speed slackens and the springs 23 draw the balls 22 in toward the axis the cord 54 will also rotate the hub 55, which will move the rings 45 around in their grooves. When the balls are thrown out by the increase in speed, and the springs 23 are distended, then the rings 45 will be rotated in the opposite direction by means of another cord, 54^a, wound oppositely on the hub 55, and connected to a spring, 23^a, as shown. Now, one of these rings 45 bears the cut-off tappet 50, and it will be obvious that as the speed increases and the balls are thrown out the tappet 50 will be carried ahead or toward the radial plane in which the opening-tappet 51 stands, and that in consequence the higher the rate of speed the sooner will the gas be cut off after the valve has been thrown open, and, also, the slower the speed, the later will the gas be cut off, as the cut-off tappet will be carried backward as the speed slackens. Figs. 14 and 15 show the balls thrown out and the governor cutting off at one-third of the stroke. I may provide spring 49, arranged, Fig. 14, so that when the balls near their extreme outer limit they will impinge on said springs, and thus require an increased velocity to move them farther. These, however, I do not consider as essential.

Referring now particularly to Figs. 15 and 18, it will be seen that the tappet 51 is mounted to slide radially in order that it may be moved out of the path of the intermediate lever, 53, when the speed has reached its maximum, and thus the gas remains cut off. When the speed reaches its maximum, as when the load is thrown off the engine and the balls of the governor are thrown out, a shoulder, 80, on the sliding tappet 51, will engage a spring, 56, and be thrown inward out of the way of lever 53, and the engine will receive no explosive charge. This will slacken the speed, the governor-balls will be drawn in, the rings 45 will move back, and spring 56^a will contact with the opposite shoulder, 80^a, on tappet 51, and move it back again into the way of lever 53.

In order that the movement of the tappet 51 by the springs 56 and 56^a may be sudden instead of gradual, I provide keepers 57, arranged to engage projections 58 on the base of the tappet at the time the springs engage it, and to free it when the spring has flexed sufficiently to move the tappet fully over. These devices may be arranged in various ways, so long as the sudden and not gradual movement of the tappet is effected.

In order to throw the tappet 51 out of the way of the lever 53 when the engine is stopping, and thus insure the cutting off the gas, I employ the spring 90.

In starting the engine the spring-bolt 59 is hooked on to the pin 60, which brings the tappet out of range of spring 90 and in range of pawl 53. As soon as the engine begins to run at ordinary speed, the pin 60 is forced away from bolt 59, which is then drawn by its spring out of the path of said pin.

I am aware that it has been proposed in a hydrocarbon-vapor engine to inject the mixture of air and vapor into the cylinder obliquely, and I do not broadly claim this oblique injection; but in such engines the entire explosive charge has been introduced to the explosion-chamber in this way, and the air-valve controlling the injection has been operated mechanically, opening and closing at regular intervals. My construction is different. I introduce a compressed charge of gas and air, and employ automatic valves which are closed by the explosion. The inlet is normally closed against the injection of the charge by the piston, and when the explosion takes place is closed by the self-closing valves. I am also aware that it is not new with me to heat the air used to mix with the gas in making the charge, and that the heat of products of combustion have been to some extent utilized for this purpose.

I do not wish to limit myself to the specific construction of the mechanism herein shown, as said mechanism may be varied to a considerable extent without departing from my invention. For example, I might employ other forms of governors for cutting off the gas completely at different points in the stroke, and also other forms of igniting mechanism.

Having thus described my invention, I claim—

1. A gas-engine provided with a tubular piston-rod constructed to admit air through said piston-rod for the purpose of expelling the burned gases from the explosion-chamber.

2. In a double-cylinder gas-engine, the means, substantially as described, whereby the piston of one engine compresses a charge of fresh air in an air-chamber, and the piston of the other cylinder compresses air from this chamber into a second chamber, whence said air is taken to expel the burned gases from the explosion-chambers of the cylinder, as set forth.

3. In a gas-engine, the herein-described method of heating the air to be mixed with the gas to form the explosive charge, which consists in passing the said air, on its way from the air-inlet to the mixer, through a jacket around the valves and igniting-chambers, substantially as and for the purposes set forth.

4. A gas-engine provided with an air jacket or passage around the valve-chambers, and igniting chambers, and a mixer, substantially as set forth, and with an air-inlet connected at one end with said passage or jacket, and the other end of said passage or jacket connected with the mixer, whereby the air employed in forming the explosive charge is heated by waste heat, as set forth.

5. In a gas-engine, the means, substantially as herein described, for admitting a portion of the explosive charge through the igniting-chamber and the remainder of the charge through lateral openings in the cylinder, for the purposes set forth.

6. In a gas-engine, the combination of a mixer for the explosive charge, an igniting-chamber, a pipe or passage connecting said mixing and igniting-chambers, a valve and its operative mechanism for controlling the passage, a cylinder provided with one or more lateral valve-controlled passages arranged substantially as shown and connected with the mixer, a piston and piston-rod, a connecting-rod, a crank, and a power-shaft, substantially as and for the purposes set forth.

7. The herein-described method of supplying an explosive mixture of gas and air to the cylinder and igniting-chamber of a gas-engine, which consists in first supplying a rich charge to the igniting-chamber, and then supplying a charge to the cylinder which is richest next the piston and more diluted toward the outer end of the cylinder, for the purposes set forth.

8. The combination, with a gas-engine, of an automatic cut-off governor adapted to open

the gas-inlet valve fully at the commencement of the instroke of the piston, and to completely close the gas-inlet valve at varying points in the stroke of the piston, as required by the varying load on the engine, substantially as and for the purposes set forth.

9. The combination, with a gas-engine, of an automatic cut-off governor arranged to control the admission of gas to form the explosive charge, said governor being provided with means, substantially as described, for gradually cutting off the gas supply, whereby the explosive charge is richest at the first moment of admission and more diluted, uniformly, during the time of admission, for the purpose set forth.

10. In a gas-engine, means, substantially as described, for supplying to the cylinder of the engine an explosive charge that varies in richness, whereby the said charge is made richest next the piston and more diluted toward the outer end of the cylinder, for the purposes set forth.

11. The herein-described method of introducing an explosive charge composed of inflammable gas and air to the cylinder of a gas-engine, which consists in first introducing a rich portion of the charge to the igniting-chamber, then a rich portion of the charge next to the piston, and then a more diluted portion of the charge intermediate between these richer portions, whereby an explosion is assured when the proportion of gas in the charge, as a whole, is less than the proportion to form an explosive charge, as set forth.

12. The herein-described method of introducing the gas to the mixing-chamber of a gas-engine for making the explosive charge, which consists in first admitting the gas in larger quantity in order that the first portion of the charge may be rich, and then gradually reducing the quantity of the gas admitted in order to dilute the charge more and more, for the purposes set forth.

13. The combination, in a gas-engine, of the cylinder provided with induction and eduction air-valves in their closed inner or crank ends, the air-chambers 15 and 15ª, the air-passages 63, leading from chamber 15ª to the cross-head guides, the recessed cross-heads 10, provided with air passages or ports, which connect with the tubular piston-rods, the said rods, the pistons provided with valves 68, to admit air from the tubular rods to the explosion chamber, and valves and their operative mechanism, substantially as described, for controlling the admission of air from chamber 15ª to the tubular piston-rods, substantially as and for the purposes set forth.

14. The combination, with the tubular piston-rod, the piston, and the valve in the piston for admitting air to the explosion-chamber, of the deflecting-plate 74, mounted on the piston over the said valve to deflect the air laterally, substantially as and for the purposes set forth.

15. In a gas-engine, the combination, with the cylinders, their pistons, and tubular piston-rods, of the chambers 15 and 15ª, the air-passage leading from 15ª to the cross-heads, and the exhaust-pipe for the products of combustion, arranged within said air-passage, whereby the heat of said products is utilized to heat the air employed for expelling the products of combustion from the cylinder, substantially as set forth.

16. In a gas-engine, the combination of the cylinder, the piston, the tubular piston-rod, the valve 68 in the piston, the cross-head provided with ports 43, the air-chamber 15ª and air-passages 63, and the valve 40 and its operative mechanism, all constructed and arranged to operate substantially as set forth.

17. In a double-cylinder gas-engine, the combination, with the cylinders, pistons, tubular piston-rods, ported cross-heads and their guides, connecting-rods, cranks, and power-shafts, of the valves 75 and 76 in cylinder 1, and valves 77 78 in cylinder 1ª, the air-chambers 15 and 15ª, the air-passage 63, and the valves 40 and their operative mechanism, all arranged to operate substantially as set forth.

18. In a double-cylinder gas-engine, the combination of the two cylinders, the igniting-chambers 5, the induction-valve, constructed substantially as shown, and its operative mechanism, the eduction-valve and its operative mechanism, and the igniting-valve and its operative mechanism, all arranged to operate substantially as shown, whereby the explosive charge is admitted to the cylinders and ignited, and the burned gases removed in alternate order, as described.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

JAS. F. PLACE.

Witnesses:
HENRY CONNETT,
GEO. BAINTON.