(No Model.)

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J. F. PLACE.

GAS ENGINE.

No. 348,999. Patented Sept. 14, 1886.

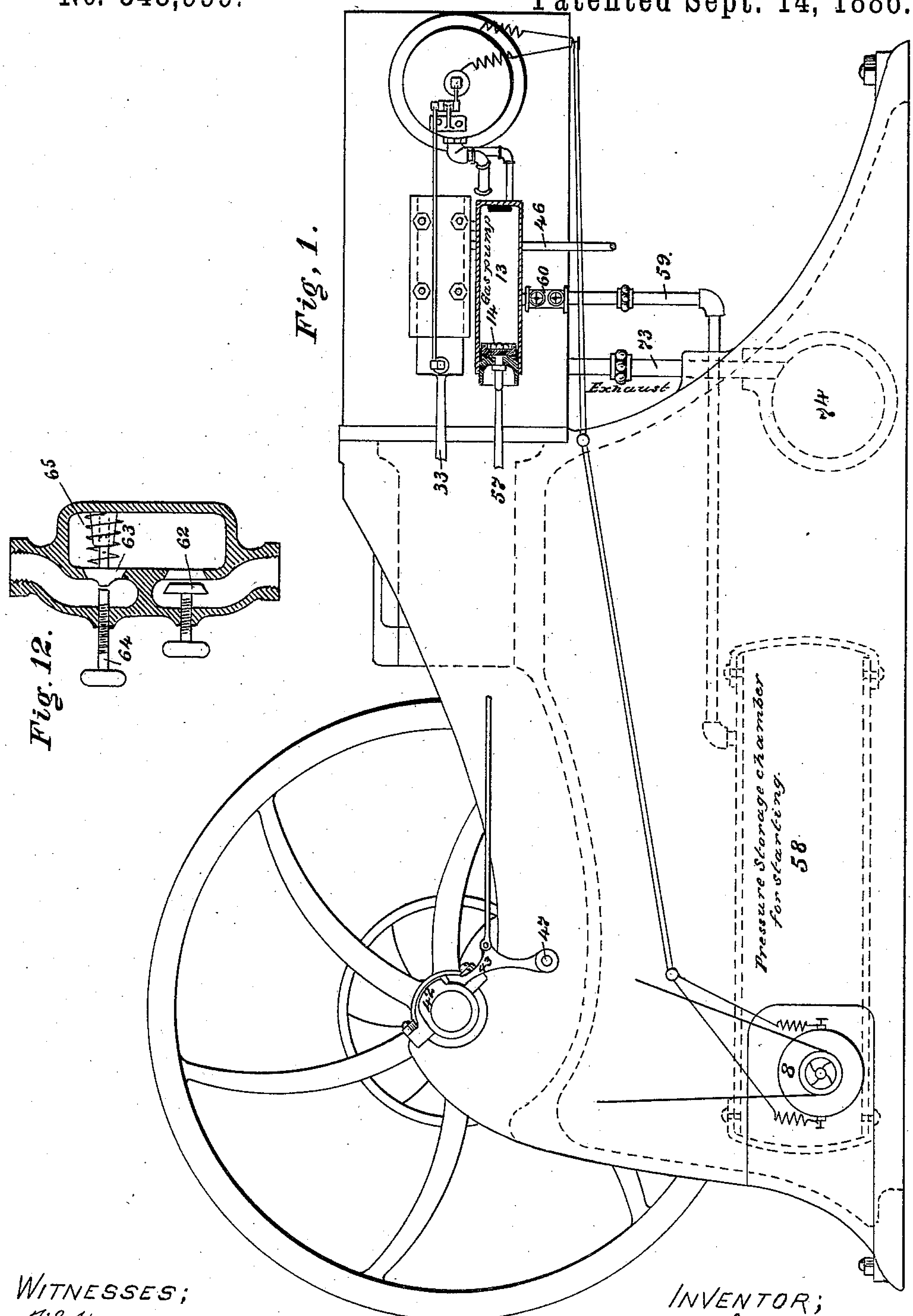

Fig. 1.

Fig. 12.

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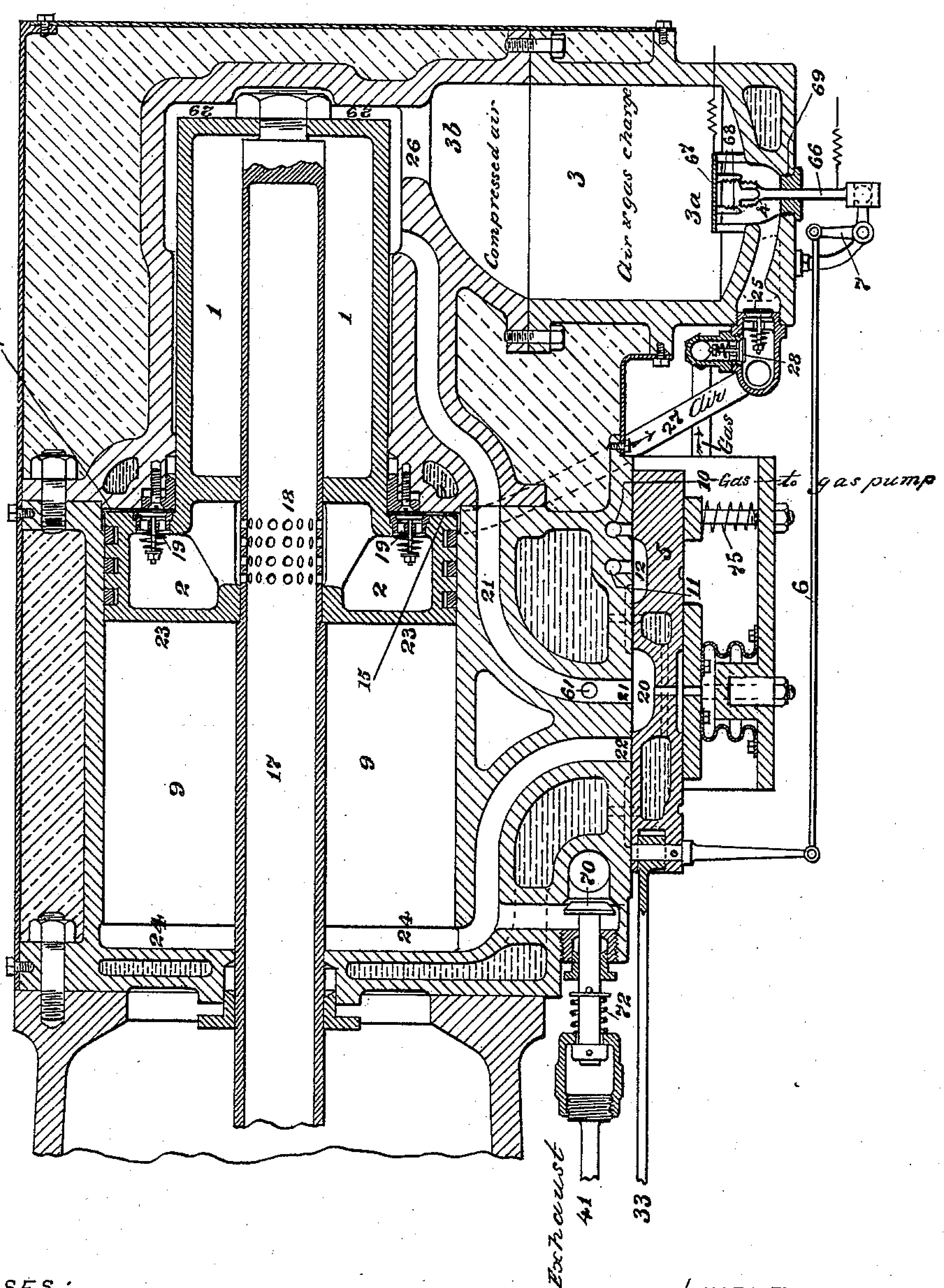
Fig. 2.



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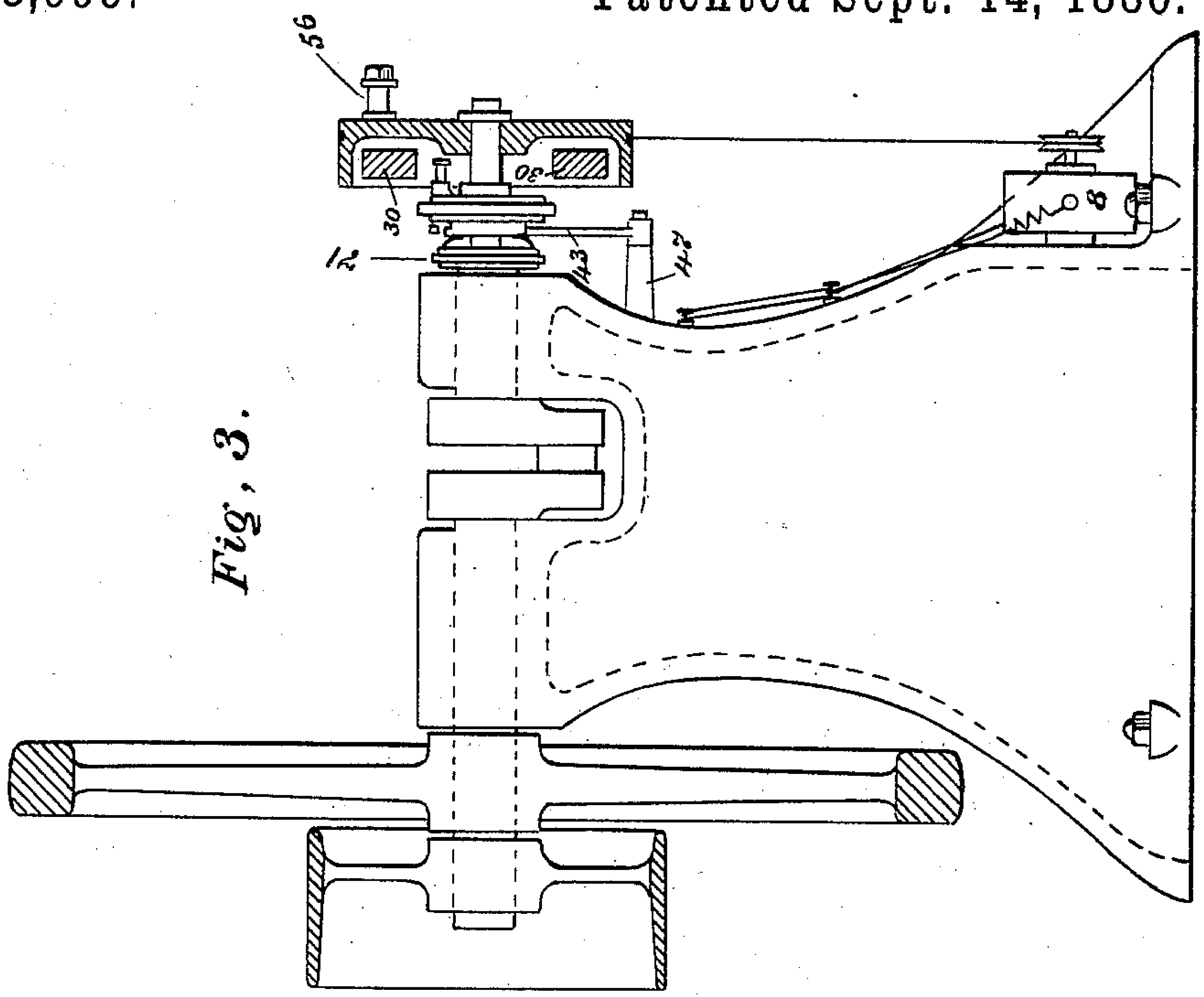
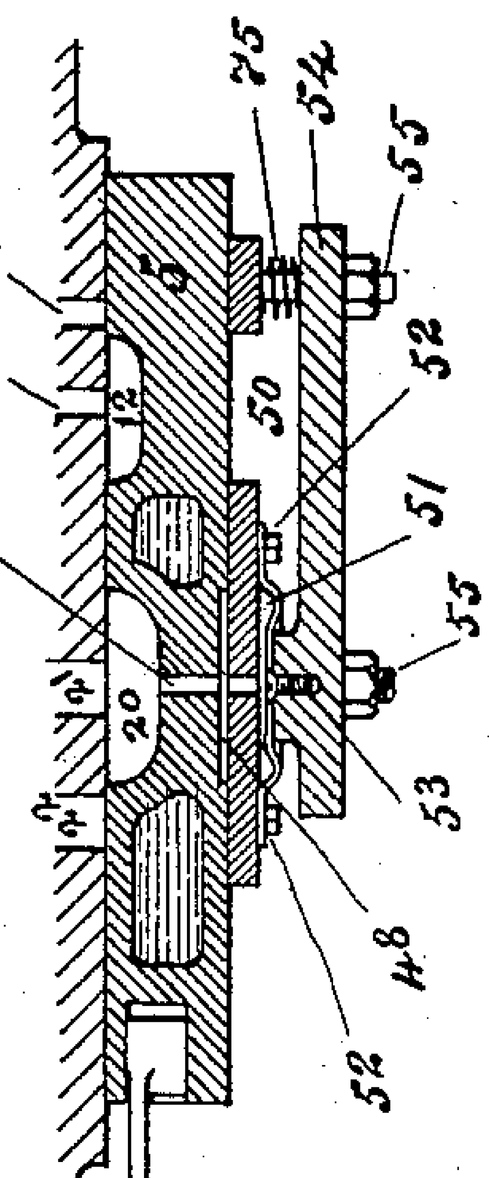
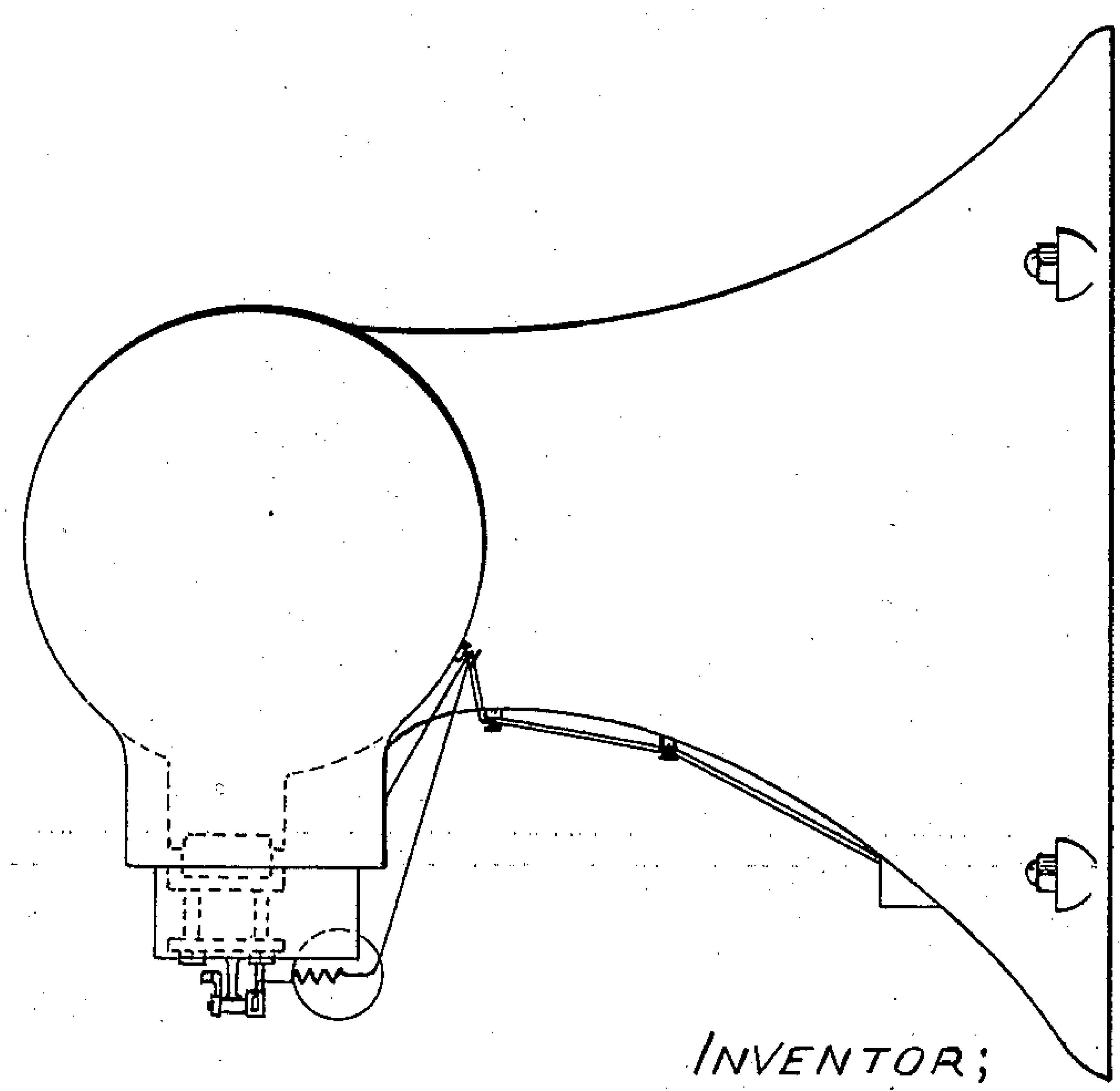


Fig, 3.



Fig, 11.



Fig, 4.

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No. 348,999.

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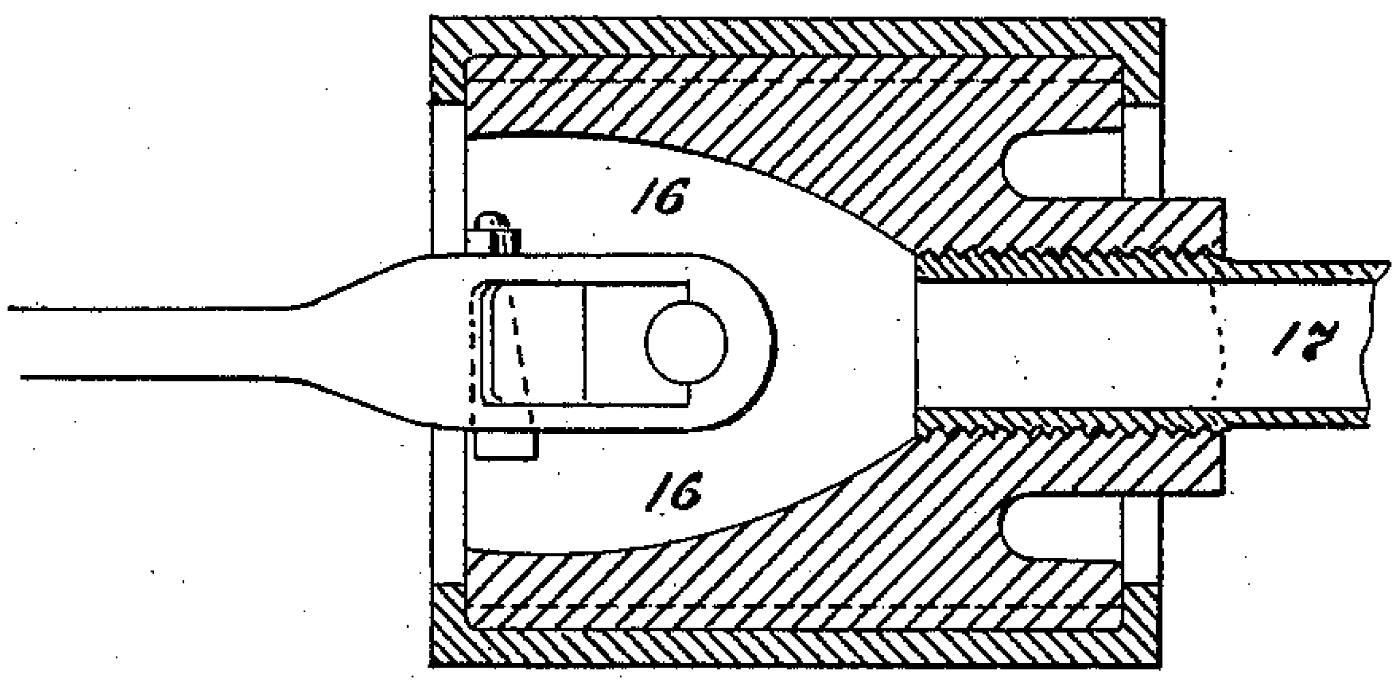
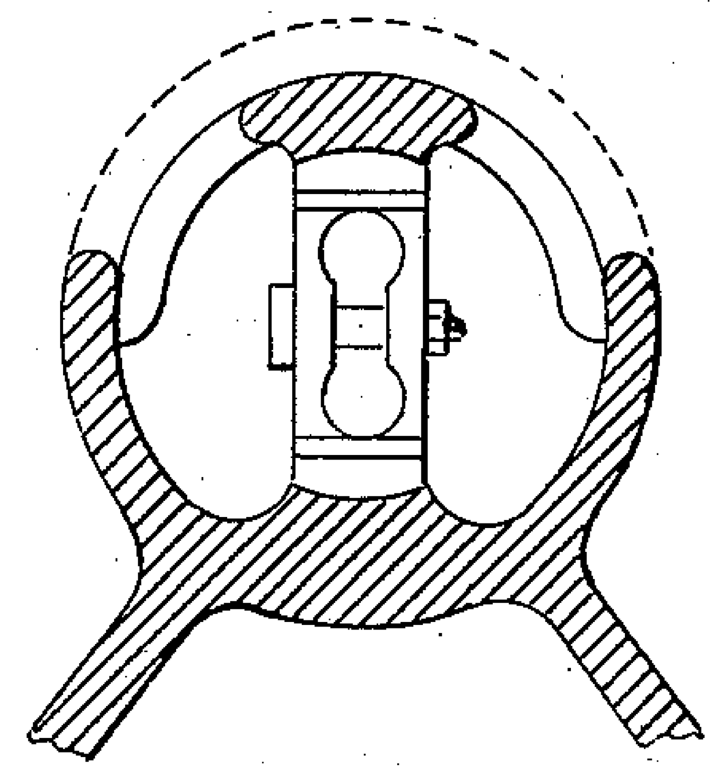
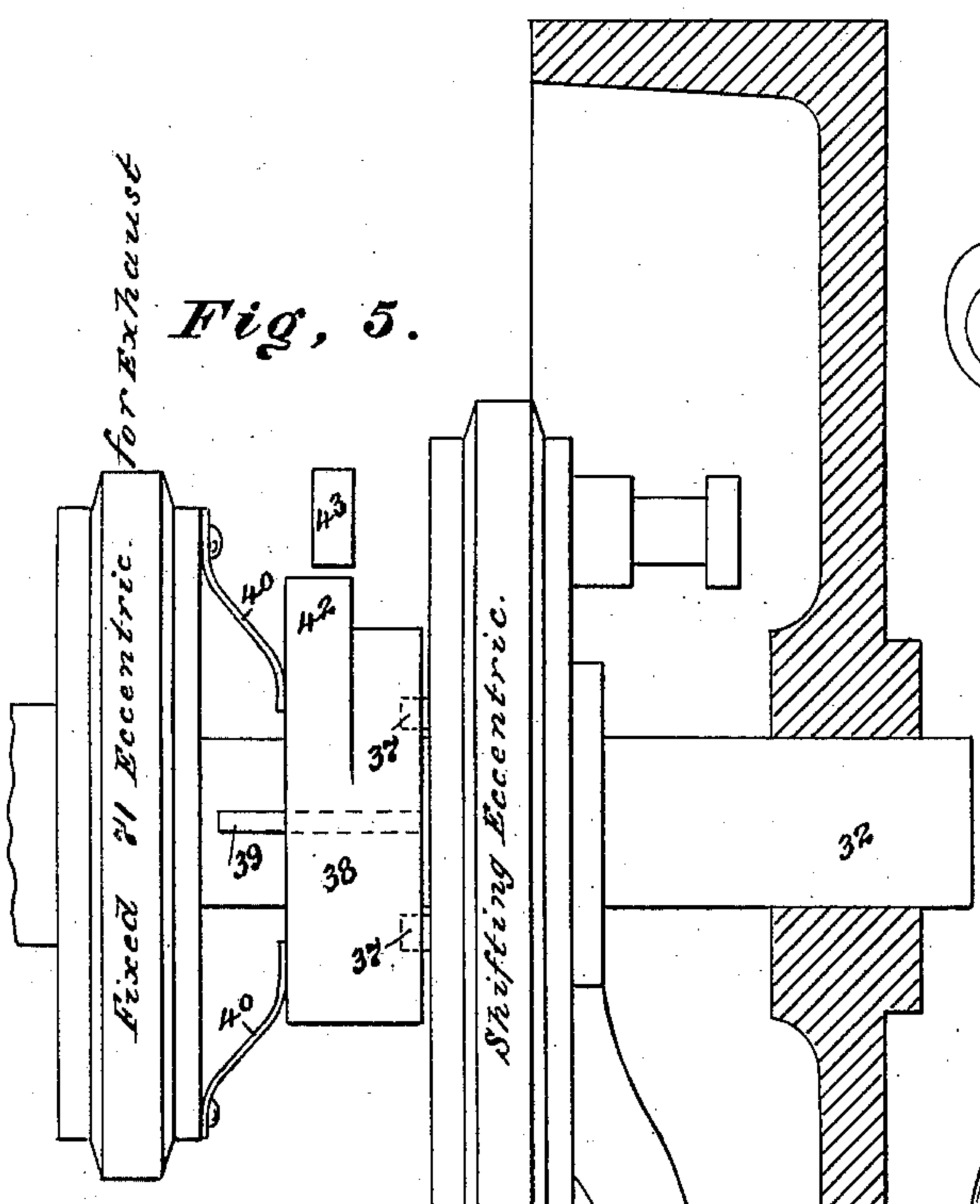
Fig, 9.



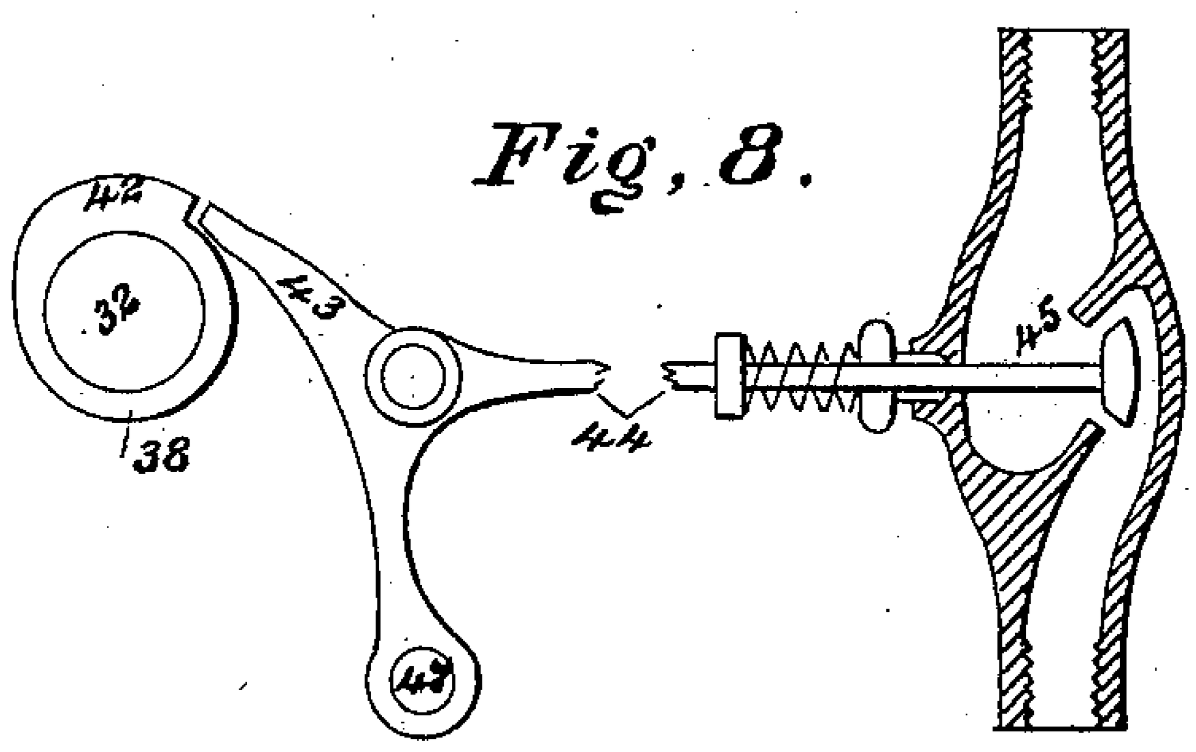
Fig, 10.



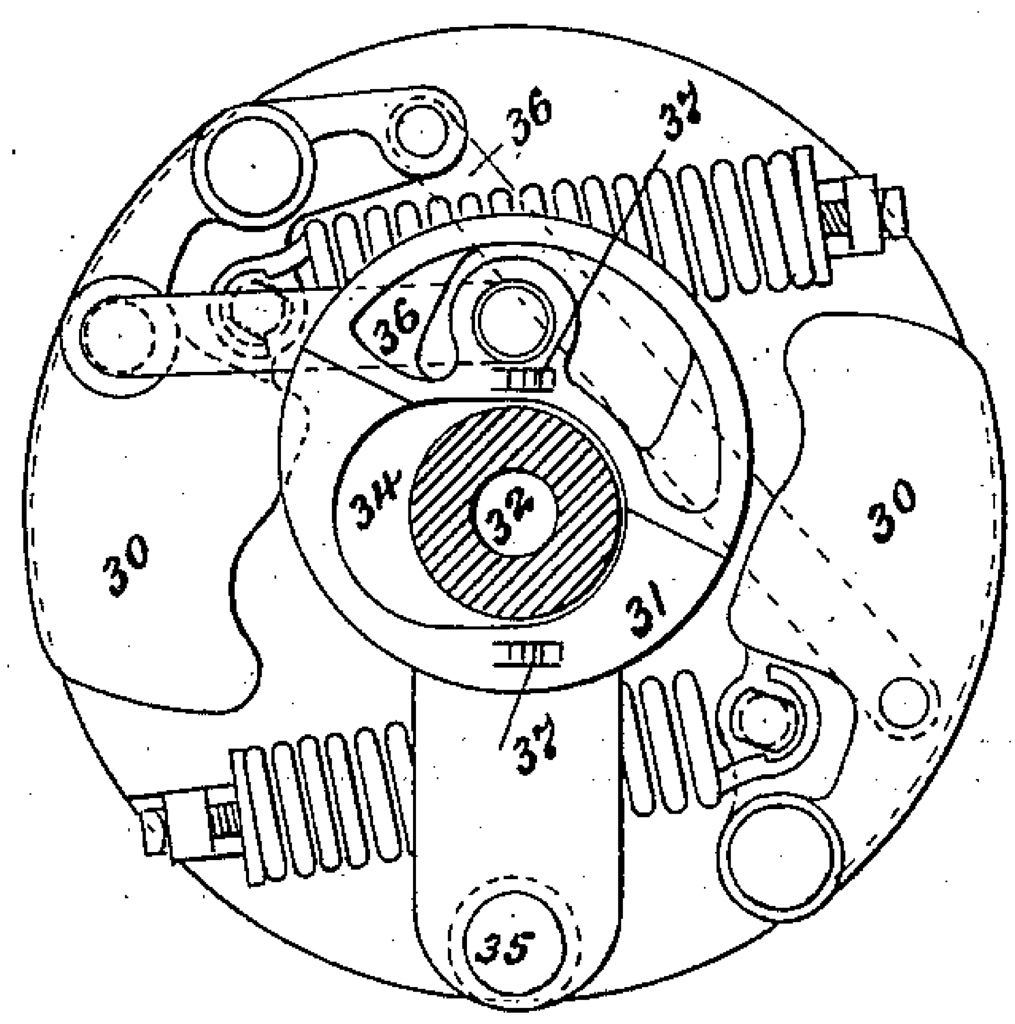
Fig, 5.



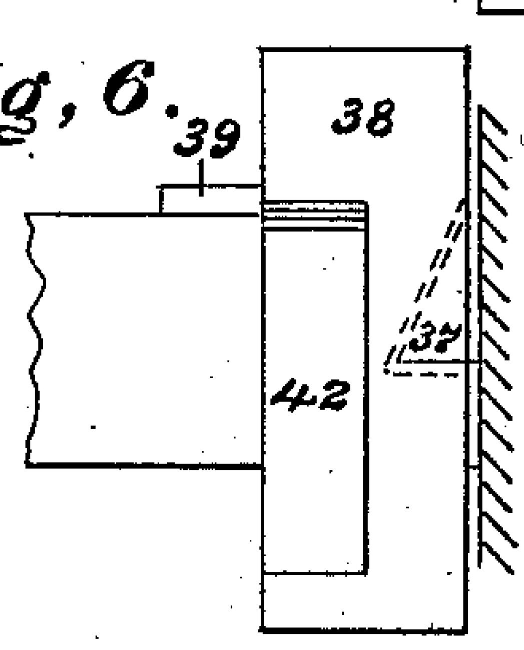
Fig, 8.



Fig, 7.



Fig, 6.



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UNITED STATES PATENT OFFICE.

JAMES FRANK PLACE, OF NEW YORK, N. Y.

GAS-ENGINE.

SPECIFICATION forming part of Letters Patent No. 348,999, dated September 14, 1886.

Application filed February 17, 1886. Serial No. 192,184. (No model.)

To all whom it may concern:

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

My invention relates to that class of motors or gas-engines in which the explosive charge is compressed before ignition. It is equally applicable to the use of ordinary coal or water gas or any other inflammable gas, or to the vapor of gasoline or other hydrocarbon liquids.

Wherever the word "gas" is used herein, it refers to inflammable gas, in contradistinction to atmospheric air.

My invention has for its object the securing of greater economy in the use of gas, a more uniform explosive mixture, greater regularity in speed, less annoyance from offensive odors, and greater simplicity in construction and ease in starting and running. To this end the engine is built so that the burned charge is "compounded" and allowed further expansion in a second cylinder, having a larger area of piston than the high-pressure or explosion cylinder. The amount of gas charged is varied, according to the speed and requirements of the engine, but is mixed with the air and is delivered to the explosion-chamber in such a manner as to retain a rich explosive mixture close to the igniter, the richness of the mixture being uniform, and the variation in amount of the explosive charge being regulated by the governor, so as to increase or diminish said amount without changing in any degree its richness or inflammability. In this case, when the speed "slacks up" or is diminished, the amount of the explosive charge is increased, and the amount of the "air-cushion" in the explosion-chamber and cylinder is correspondingly diminished as each explosive charge and air charge (or cushion) is delivered to the explosion-chamber, until the maximum explosive charge is reached, or until the speed ceases to slack up and recovers to that point for which the governor is fixed to run. If the speed increases beyond that point, then the amount of the explosive charge is diminished, and the amount of air charge (or cushion) in the cylinder and explosion-chamber is correspondingly increased until the speed ceases to increase, or falls to that point for which the governor is set to run. Should successive and constantly more and more diminished explosive charges not reduce the speed to that fixed point, then, when the minimum amount of the explosive charge is reached, the gas charge to the gas-measuring pump is, by the action of the governor or movement of the slide-eccentric, cut off entirely, and the engine will receive no explosive charge at all until the speed lowers, when it will receive the minimum explosive charge again, the action of the governor being to always maintain a uniform speed.

The regulation of speed is sought to be attained in all other gas-engines, so far as I know, by one of two methods—viz., first, by reducing or increasing the richness or inflammability of the explosive charge; or, second, by "skipping" charges or delivering the same at irregular intervals, and thus regulating the speed by the number or frequency of the explosions. In this latter case (which is at the present time the most popular method) the explosions are uniform in concussion, but very irregular in times, sometimes exploding at every other revolution, and at times not oftener than once in five or six revolutions, and unless the engine is heavily loaded the speed as a natural result is very irregular and "jerky." In the first method above named (where the engine speed is regulated by diluting the explosive charge) the regulation is of quite limited range. For instance, when the richness or inflammability of the explosive charge is reduced or diluted much below twelve of air to one of gas, the charge will not explode, and is thus wasted. The same result is reached generally when it is made richer than one of gas to six of air. Such a regulation, then, of the speed of a gas-engine, by reducing or increasing the amount of the gas alone, (which necessarily increases or diminishes the richness or degree of inflammability of the explosive,) is not only very irregular, imperfect, and of limited range, but is also very wasteful of gas. This important feature of regulating the speed by varying the amount of the explosive charge without varying its richness in gas or degree of inflammability is attained in my present engine by the slide-valve being driven by an automatic cut-off governor in combination with my gas-measuring pump. This gas-measuring pump is more fully described in my application for patent, Serial No. 190,692. As therein described, the gas-supply to the pump is regulated by a sliding rod or pawl acted upon by the governor-balls, which pawl or rod is acted upon in turn by a series of steps or incline face on the igniting-slide or pump-rod, which cuts off the gas-supply to the gas-pump at varying points in the stroke, the stroke of the pump-piston being synchronous with the power-piston. In my present invention the supply of gas to the gas-pump is cut off at varying points of the stroke by the main slide-valve, which has ports for regulating the supply of gas to the pump, as well as ports for connecting the high-pressure with the low-pressure cylinder. This slide-valve is operated by an eccentric, which is varied in its position on the main crank-shaft, so as to make the stroke of the eccentric (and consequently that of the slide also) longer or shorter, the inlet-port opening at very nearly the same point in the stroke at all times, while it cuts off at varying points in the stroke both the gas-inlet port to the gas-pump, and the port which connects the high-pressure and low-pressure cylinders. By this method the gas-supply to the gas-measuring pump is cut off earlier or later in the stroke, and the gas-charge thus varied in amount, and by the peculiar construction of this gas-pump (more fully described in application Serial No. 190,692, referred to above,) the gas-charge is invariably mixed with that portion of the air-charge which goes into the explosive-chamber last, or just before the piston reaches the limit of its outstroke (from the crank.) The areas or displacement of the low-pressure piston less the high-pressure piston, (which is the air-pump displacement,) and the gas-pump piston being in about the proportion of seven to one, the explosive charge is uniformly made in about those proportions, regardless of an earlier or later cut-off, thus securing invariably that explosive mixture for the charge which it most inflammable and which gives the best results. In this way also the explosive charge is always kept next to the igniter. The balance of the air charge, which was forced into the explosion-chamber before the gas charge in the gas-pump had reached that degree of compression equal to the air charge, is unmixed with gas, and it acts as a clearing-out or "scavenger" charge to clear the cylinder of carbon sparks, and it also acts as an "air-cushion" for the explosion. It receives the heat of the explosion, and while serving to reduce the initial pressure yet enables me to get a larger mass under pressure for a small engine and secure the benefit of increased expansion. This air-cushion (which goes into the explosion-chamber in advance of the explosive charge) also takes up the heat of the walls of the explosion chamber and cylinder, which augments its pressure, and to that extent it is in an economical point of view a clear gain. By varying the length of stroke of the slide-valve and changing the position of the eccentric on the shaft correspondingly under control of the governor, the compression of the remainder of the burned gases in the high-pressure cylinder after the connection between the ports of thetwo cylinders is closed by the slide-valve, is increased or diminished according to earlier or later cut-off by the slide-valve. Thus in this way, in my present improvement, as the gas charge is increased (and consequently the explosive charge is larger) the compression in the high-pressure cylinder (and explosion-chamber) is diminished, the cut-off to low-pressure cylinder being later, and as the gas charge is lessened (and explosive charge diminished in amount accordingly) the compression is increased, the cut-off to low-pressure cylinder being earlier in the stroke. This is an important and valuable feature in my present engine, and secures a uniform speed, and avoids the shocks and sudden strains which gas-engines hitherto have been liable to by reason of the great variation in the different explosive shocks. The expansion of the explosive charge after ignition in ordinary gas-engines as now built is about one volume into two or three volumes. Necessarily the terminal pressure is very high, in some cases as high as fifty pounds above the atmosphere, which involves a great loss in economy. By "compounding" or expanding in another cylinder the terminal pressure is reduced to almost nothing, which insures a very considerable gain, the same proportionally as in the steam-engine. In addition the pressure on the piston is divided between instroke and outstroke, making the engine practically double-acting, and thus rendering it less difficult for the governor to maintain a uniform speed.

The storage air-tank is not new, but with my system of valves, in combination with the slide-valve, it furnishes a very simple and very effective self-starter.

With my improvements the pressure of the compressed air from the tank acts upon both the high and low pressure pistons alternately, thus making it double-acting and as easily started as a steam-engine with steam.

A large portion of the friction of compression gas-engines as now built is due to the "slide." My device (a diaphragm-spring for balancing the slide-valve,) is simple, and reduces the friction to almost nothing.

With my gas-measuring pump the use of the ordinary gas-reservoir or rubber bag is avoided, which is always more or less "leaky" and offensive.

In the drawings annexed hereto the same numbers in different figures refer to similar parts.

Figure 1 is a side elevation of my engine, showing sectional view of gas-pump. Fig. 2 is a sectional plan of the two cylinders, pistons, slide with ports, &c. Fig. 3 is a view of the crank end, showing fly-wheel, automatic cut-off governor, &c., in section. Fig. 4 is a view of the cylinder end of the engine. Figs. 5, 6, and 7 are different views of the governor details. Fig. 8 is a view of the stop-off and gas-inlet check, which, when the engine runs too fast, cuts off entirely any gas-supply to the pump. Figs. 9 and 10 are sectional views of the cross-head and hollow piston-rod. Fig. 11 is a sectional view of the slide-valve, showing the manner of balancing with the diaphragm-spring. Fig. 12 is a sectional view of the check and screw valves to admit and retain a storage of burned gases and air to the air-tank, and for starting the engine with the same when under compression.

I will now proceed to describe the operation of my engine, supposing the position of the crank to be as shown in Fig. 2, the piston about to commence on the instroke (or move toward the crank.) 1 is the high-pressure and 2 and 23 the low-pressure piston. 3 is the explosion-chamber. The end 3^a, next to the igniter, we will suppose to have an explosive charge, ready for ignition, while the other part, 3^b, next to the cylinder, is filled with compressed air unmixed with gas. The slide 5 moves toward the explosion-chamber, and the rod 6, by means of the lever 7, raises the electric igniter and breaks the circuit at 4 of the electric current caused by the small dynamo 8, Fig. 3. An intense electric spark is the result at the points of the igniter 4, which ignites the charge. The fire fills the chamber 3, and instantly the pressure of the charge is augmented to from six to twelve atmospheres, according to the amount of the explosive charge in the end of the chamber at 3^a. This pressure fills the high-pressure cylinder 29, and acts on the piston 1 through the passage 26 and forces it out into the low-pressure cylinder 9. During this movement the slide 5 moves toward the explosion-chamber, and in its movement the slide-port 12 uncovers the port 10 and forms a connection between that and port 11, which allows the gas to enter the gas-pump 13, Fig. 1. Before the piston 14 of the pump reaches, say, half-stroke the slide 5 has returned and cut off the connection between the two gas-ports 10 and 11, so that for the balance of the stroke, or until the piston 14 reaches the point shown in Fig. 1, the supply of gas being cut off, the piston 14 pulls against a partial vacuum, and on its return commences to compress the gas charge at the point where the supply was cut off. When the main piston 1 2 commences to move under the pressure of the explosion, a vacuum is caused in the end of cylinder 9 at 15, which sucks air in through the cross-head 16, Fig. 9, the hollow piston-rod 17, Fig. 2, and the perforations 18, into the recess in the large piston 2, and thence through the valves 19, until when the piston has reached the limit of its instroke (toward the crank) the cylinder 9 (less the displacement of the high-pressure piston 1) is filled with air. At this point the slide 5 moves further toward the crank-shaft, and by means of the port 20 forms a connection between the ports 21 and 22. The burned gases and hot air, then under high tension, rushing in through the port 22, immediately act upon the low-pressure piston on the larger area 23 when it is in the crank end of the cylinder at 24 as the crank passes the center. The piston is thus forced back to the point shown in Fig. 2, and the hot air and burned gases are thus further expanded, down to almost atmospheric pressure. When the piston has reached about half-stroke in this last movement, the air in the air-compressor end 15 of the cylinder 9 will equal the pressure of the expanding burned gases, and the compressed-air outlet-valve 25 will be forced open, and the fresh-air charge follows the expanding burned gases through the pipe 27 into the explosion-chamber 3. This point (when the fresh air opens the valve 25 and begins to enter the explosion-chamber) varies, according to the amount of and pressure generated by the previous explosion, but as the burned charge is constantly being lowered in pressure, as the piston 2 moves on its outstroke, (from the crank,) the compressed air on the other side of the piston 2 at 15 is constantly increasing in pressure, so that when the pressures become equal one counterbalances the other—that is, the pressure on the area of the low-pressure piston at 23 just offsets the pressure on the high-pressure piston at 29 added to the pressure in the air-compressor at 15, and from that point it is simply a displacement, no power being absorbed, the compressed air entering through valve 25 as fast as the piston moves, and the burned gases (or old charge) receding from the explosion-chamber through the passage 26, and the ports 21 and 22 into the low-pressure cylinder, both the volumes and pressures remaining nearly the same. When about one-third of the compressed air has entered the explosion-chamber 3 from the compressor 15, the compression of the gas in the gas-pump 13 (depending, of course, upon the point of cut-off in the stroke when the gas entered the pump) will equal the air-pressure in the pipe 27, and will commence to enter and mix with the column of air through the check-valve 28. As the strokes of the main piston and the gas-pump piston are synchronous, and as the areas or displacement of the air-compressor and gas-pump are in proportion of about seven to one, the balance of the compressed-air charge is thoroughly mixed with gas from the pump through the valve 28, as it (the air) passes through the pipe 27 and the valve 25 into the explosion-chamber. It will be noticed that the explosive charge fills the explosion-chamber 3 in the igniter end at 3^a from one-fourth to two-thirds the capacity of the chamber, according to the amount of gas in the gas-pump, which amount varies according to the point of cut-off of the slide 5, and which point of cut-off depends entirely upon the governor which regulates the position of the eccentric on the shaft, (see Figs. 5, 6, and 7,) which I will now explain.

The automatic cut-off governor (shown in Fig. 7) is not new, but its adaptation to a gas-engine is entirely new. There are several forms of this kind of governor used on the steam-engine. Its operation is quite simple: As the speed increases, the weights 30 move outward and carry the eccentric 31 along on the shaft through the slot or opening 34, the eccentric being held or pivoted at the point 35, and connected to the governor-weights by the rods 36. In this movement of the eccentric (to the left in Fig. 7) the centers of the eccentric and shaft 32 come nearer together, and thus shorten the stroke of the eccentric and slide 5, which is driven by the rod 33, which rod is connected to the strap around the eccentric 31. On one side of the eccentric I have two lugs, wedge-shaped, 37, which fit into correspondingly-wedge shaped recesses in the sleeve or thimble 38 on the shaft. This thimble or sleeve is held in position on the shaft by the feathered key 39. It is also held up against the eccentric by the two springs 40, which are made fast to the small fixed eccentric 71, Figs. 3 and 5, which operates the exhaust-valve 70, Fig. 2. On the face of this thimble or sleeve I have a cam or raised part, 42, which corresponds to about two-thirds of a stroke, or, say, one hundred and twenty degrees; and I have a pawl or lever, 43, the end of which bears against the face of the thimble 38, and having a rod, 44, which is connected to a valve, 45, in the gas-supply pipe 10, Fig. 2, and 46, Fig. 1, just below where it enters the port. This pawl 43 is held in place by the stud 47, made fast to the frame. Now, when the speed increases beyond a predetermined point the governor-weights will carry the eccentric to the left, as shown in Fig. 7, and the stroke of the slide 5 being shortened the port 12, Fig. 2, cuts off the gas-supply at an earlier and earlier point in the stroke, and the gas charge admitted to the pump 13 becomes less and less. During this operation the thimble 38 is being gradually pushed by the lugs 37 to the left. (See Figs. 5 and 6.) Finally, when it is not economy to reduce the gas charge further, if the speed continues to increase at a predetermined point, the cam 42 on the thimble 38 is moved away from the pawl 43, Fig. 5, and the gas-supply check-valve 45, Fig. 8, is no longer raised at all, and as a consequence no gas at all enters the gas-pump 13 for the following stroke, or again until the speed lowers. The lugs 37 can be placed on the sleeve and the inclined recesses made in the eccentric, where the lugs are shown, (see Fig. 7,) or the recesses may be dispensed with and lugs placed on both the eccentric and sleeve. In either case the result sought is the same—namely, moving the sleeve and cam 42 out of contact with the lever 43 and leaving the gas-valve 45 closed until the speed is reduced. As soon as the speed slacks up any, then the eccentric will move to the right, (see Fig. 7,) and the lugs 37 will allow the springs 40 to push the thimble 38 to the right, as shown in Figs. 5 and 6, and the cam 42 comes in contact with the pawl 43 again, which causes the gas-check valve 45 to open at regular intervals again. The gas-charge in the pump will be light at first, owto the shortness of stroke and consequent early cut off; but if the speed continues to lower, the eccentric will continue to move to the right, (see Fig. 7,) which lengthens the stroke of the eccentric and slide 5, and the gas-supply will be cut off at a later and later point in the stroke by the port 12, Fig. 2, and the amount of gas-charge to the gas-pump will be correspondingly increased until the maximum charge is obtained. By the movement of the eccentric on the shaft under the action of the governor, the port 20, Fig. 2, cuts off the connection between the two ports 21 and 22 at different points in the stroke, which variation, however, is not as great as that of the gas cut off by port 12, owing to the less amount of "lap" in the port 20 in uncovering the port 22. The result of this is that the high-pressure piston 1 in the last portion of its outstroke (from the crank) compresses the air in the cylinder 29 and explosion-chamber, and the hot air and burned gases in the low-pressure cylinder 9 for the balance of the stroke (being cut off from the pressure in the high-pressure cylinder) are utilized by natural expansion, and are thus used more economically and the terminal pressure reduced to almost the pressure of the atmosphere. It will be observed that owing to the location of the cylinder-ports 21 and 22 with reference to the gas-ports 10 and 11 that the earlier the gas-supply is cut off (and consequently the smaller is the explosive charge) the earlier is the connection cut off between the ports 21 and 22, and as a consequence the higher is the compression in the high-pressure cylinder 29 and explosion-chamber 3, and vice versa—that is, the larger in amount is the gas-charge admitted to the pump, and consequently the larger is the explosive charge—the lower is the compression of the charge before ignition in the explosion-chamber. This is a valuable feature in my present engine, for by it the initial pressure after ignition of each explosion is anticipated, and the amount of compression best adapted for that explosion regulated in every instance by the same slide-valve which regulates the amount of the gas-charge, both under control of the same governor; and then, again, when the gas-charge under cumulatively high speed is cut off entirely by the pawl 43 dropping out of range of the cam 42, Fig. 5, the compression of the air-charge is kept up to the maximum, ready for a renewal of the gas charge, so that when renewed again (by the springs 40 forcing the cam 42 under the pawl 43) the best results of the explosion are attained. If this were not so constructed, then, if an explosion were missed, the next one following would not have the benefit of any compression at all, and would, consequently, be very weak, and several would have to take place before one of a fairly high initial pressure were obtained. The result would be less economy in gas, and not so quick a regulation of speed; but with my cut-off, as herein described, the compression varying with the gas charge inversely and the explosive charge being always delivered to the igniter end of the explosion-chamber, the governor can but be very sensitive, and the engine will respond quickly to its slightest changes of load.

The slide-valve is the principal cause of friction in most gas-engines. It is usually held to its face by stiff springs, which have to exert a pressure sufficient to overcome the highest initial pressure, which in some engines is two hundred and fifty pounds to the square inch. When the exhaust-valve opens, and there is no pressure at all in the cylinder, these springs are doing their full work just the same, holding the slide up to its face with a force of over two hundred and fifty pounds, all of which has to be overcome by the engine, as the slide must be kept moving.

I balance my slide 5, Fig. 11, by having a place on its back 48 recessed out about one thirty-second of an inch deep and of equal area to the port 20. A small hole, 49, connects the port 20 with the recess. Then I have a light independent back slide, 50, (see Fig. 11,) which is firmly held to a disk-diaphragm, 51, by the screws 52. This diaphragm is of thin sheet-steel, and acts as a spring to hold the independent back slide, 50, at all times with the pressure of a few pounds only against the main slide-valve 5. Between this diaphragm-spring 51 and the independent back slide, 50, there is a thin air-space, equal in area to the port 20. This diaphragm is held firmly by the screw 53 to the fixed guide 54, which guide is fastened to the outside of the cylinder or frame by the bolts 55. It will be observed that no matter what the pressure may be against the slide in the port 20 it is reacted against the fixed guide 54, and that the only pressure on the slide at any time is the amount due to the spring of the diaphragm 51, which can be adjusted to just sufficient in amount to prevent any leakage. The diaphragm under the edges (at the screws 52) can be packed with ordinary sheet-rubber packing.

The amount of extra clearance due to balancing the slide-valve in this manner is almost nothing. Another form of this diaphragm-balance is shown in Fig. 2. I prefer, however, the one shown in Fig. 11. The other end of the slide 5, which covers the gas-ports 10 and 11, (see Fig. 2 or 11,) is held to its face by a very light spring, 75, as there is no pressure in the gas-ports to amount to anything.

The piston of my gas-measuring pump I drive from a crank fixed to the face of the governor case or guard 56, Fig. 3. The connecting-rod which connects to this crank-pin 56 is shown at 57 in Fig. 1. This gas-measuring pump and its manner of operation are fully described in my application for patent on February 3, Serial No. 190,692.

In Fig. 1 is shown a boiler-iron air-tank, 58, located under the engine inside the frame, and which is connected to the side of the cylinder by the pipe 59 and the valves 60. (Shown in detail in Fig. 12.) The pipe 59 continues above the valves 60 and opens into the port 21 (see Fig. 2) at the point 61.

In Fig. 12 the valve 62 is the storage-valve. 63 is a check-valve, with a hand-screw, 64, by which it can be kept open against the spring 65. When the engine is running, the valve 62 may be opened, and valve 63 is left as a check-valve to be operated by the spring. The air and burned gases under high pressure are forced through the check-valve 63 until the pressure in the air-tank 58 equals the pressure of the explosion. Then valve 62 may be tightly closed, and the contents of the air-tank are ready for use whenever the engine is to be started at some future time. In starting, all that is required is to open valve 62 and also check-valve 63 by screwing in the thumb-screw 64 and forcing the valve off its seat. The compressed air enters the port 21 (see Fig. 2) at 61; and no matter what position the crank may be in (if slightly off the center) the engine will start at once, the pressure of the air acting on both pistons 1 and 23, the engine being for the time the same exactly as an ordinary double-acting steam-engine.

For ignition I use a small dynamo of about one-tenth horse power, and drive the same with a small round belt from the governor case or guard. (See Fig. 3.)

I am aware that the use of a small dynamo to generate the ignition electric spark is not new; but my devices connected with the poles of the wires forming the igniter are new, and are made so as to avoid the trouble hitherto experienced of the gathering of soot on the insulated poles. The current is carried to the insulated rod 66, Fig. 2, which is raised by the lever 7. The other end of the wire connects with insulated disk 67, which has the points or projections 68. The ends of the igniter 4 are in form of two springs, which are forced in between the points 68, which points are rough or corrugated on the inside edges, so the rubbing of the sides of the spring ends 4 on the same will always preserve both ends and points clean and free from carbon or soot. As the piston reaches the limit of its outstroke, (from the crank,) the rod 66 is raised through the metallic insulated stuffing-box 69, and the electric current is broken, and an intense electric spark is generated between the spring ends 4 and the projections 68. The exhaust-valve 70, Fig. 2, I drive with a small eccentric, 71, Fig. 3, connecting to the rod 41, Fig. 2. The stem of the valve has a relief-spring, 72, which the eccentric works against on half its stroke, and lifts and closes the valve during the other half, corresponding in time to one full instroke (toward the crank) of the main piston. The exhaust products are carried off by the pipe 73 into the cast-iron exhaust-pot 74 inside the frame, from which they are carried off in the usual manner.

Having thus fully described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. In a gas-engine, in combination with a gas-supply pump, a slide-valve operated from a movable eccentric, which is controlled by a governor so as to cut off the gas-supply to said pump at varying points in the stroke, substantially as described.

2. In a gas-engine, in combination with a gas-supply pump, a slide-valve regulating the supply to said pump and operated by an eccentric on the main shaft, the centers of said eccentric and said shaft relatively to each other being dependent upon the position of the weights of a centrifugal governor relatively to their axial center, substantially for the purpose and as herein described.

3. In a gas-engine, in combination with a gas-supply pump, a slide-valve regulating the supply to said pump and operated by a revolving eccentric, which eccentric is movable radially and spirally on its shaft in a plane at right angles to the axis of said shaft, its position in that respect relatively to the center of the shaft depending upon the speed of a centrifugal governor, substantially as and for the purpose herein described.

4. In a compound gas-engine having on one valve-seat ports for connecting the high and low pressure cylinders and for the supply of gas to a gas-supply pump, the combination, with the high and low pressure cylinders and the gas-supply pump, of a slide-valve actuating the above-named ports and operated by an eccentric on a revolving shaft, the positions of centers of said eccentric and said shaft relatively to each other being dependent upon the speed of a centrifugal governor, so as to shut off the connection between the two cylinders and the gas-supply at varying points of the stroke according to the fluctuations of the speed of the engine, substantially as set forth.

5. In a compound gas-engine, in combination with ports to the high and low pressure cylinders and to a gas-supply pump, all opening on the same seat, a slide-valve actuating all said ports, substantially as described.

6. In a gas-engine, a sleeve or thimble having a cam for opening a gas-supply valve arranged to be moved by an eccentric on a revolving shaft (the movement of said eccentric on said shaft being in a plane at a right angle to the axis of the shaft) out of contact with the gas-valve pawl or lever when the engine runs beyond a predetermined speed, thereby closing said valve until the speed lowers, substantially as and for the purpose herein described.

7. In a gas-engine, a sleeve or thimble having a cam for opening a gas-valve, arranged to be moved by an eccentric on a revolving shaft, so the cam will be entirely to one side of the pawl or lever against a spring when the engine runs too fast, said spring so fixed as to move the cam in contact with the pawl again when the speed is reduced, substantially as and for the purpose herein described.

8. In a gas-engine having a movable sleeve or thimble with cam thereon for opening the gas-inlet valve, lugs or projections on said sleeve for forcing said cam out of contact with the gas-valve pawl or lever when the engine runs too fast, substantially as and for the purpose herein described.

9. In a gas-engine having a sliding sleeve or thimble with cam thereon for opening the gas-inlet valve, lugs or projections on a movable eccentric for forcing said cam out of contact with the gas-valve pawl or lever when the engine runs too fast, substantially as and for the purpose herein described.

10. In a gas-engine, a valve and an automatic cut-off governor arranged so as to cut off the gas-supply and cut off the outlet of the explosion-cylinder, both at varying points in the stroke, so that the smaller the gas charge admitted the greater is the compression of the explosive charge before ignition, substantially as and for the purpose herein described.

11. In a compound gas-engine, the automatic cut-off governor with the movable eccentric, the length of the stroke of which is dependent upon the speed of said governor, in combination with a slide-valve operated by said eccentric, which controls admission of the gas charge and the connection between the two cylinders, and the air-compressor in one end of the low-pressure cylinder, all substantially as and for the purposes herein described.

12. In a gas-engine, the centrifugal governor with the guard or shield, in combination with the crank-pin and the gas-measuring pump, substantially as and for the purpose herein described.

13. In a gas-engine, an electric igniter consisting of the spring-forked end, and the lugs provided with grooved edges, arranged so that the spring end rubs the said edges when in contact and preserves the points of contact free from soot and carbon, substantially as and for the purpose herein described.

14. In a gas-engine, in combination with a small dynamo, the rod and lever 7, and the spring-pointed igniter, with the lugs to come in contact therewith, substantially as and for the purpose herein described.

15. In a gas-engine, a centrifugal governor and movable eccentric under control of same, in combination with the sliding sleeve and cam, and the gas-inlet valve and a lever operating said valve by said cam, substantially as and for the purpose herein described.

16. In a gas-engine, the movable eccentric on a revolving shaft, controlled in the length of its stroke by a centrifugal governor, in combination with the sliding sleeve, the double-ported slide-valve, and the air-compressor and gas-measuring pump, substantially as and for the purpose herein described.

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Witnesses:

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