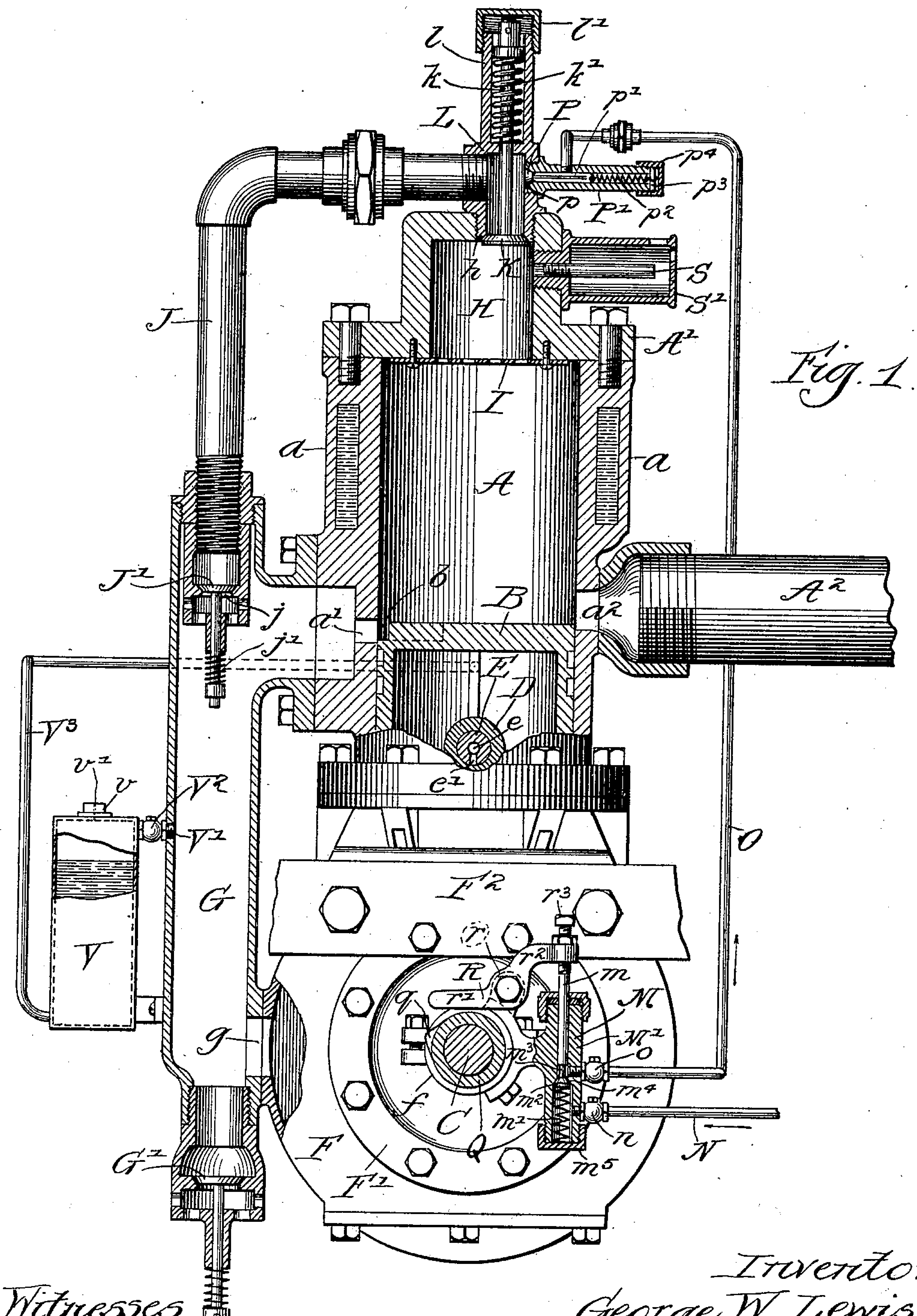
No. 620,941. Patented Mar. 14, 1899.

G. W. LEWIS.
EXPLOSIVE ENGINE.

(Application filed Dec. 14, 1895.)

(No Model.) 2 Sheets—Sheet 1.



Witnesses
Wm. J. Henning
L. Clinton Hamlink

Inventor
George W. Lewis
by Dayton, Poole & Brown
his Attys.

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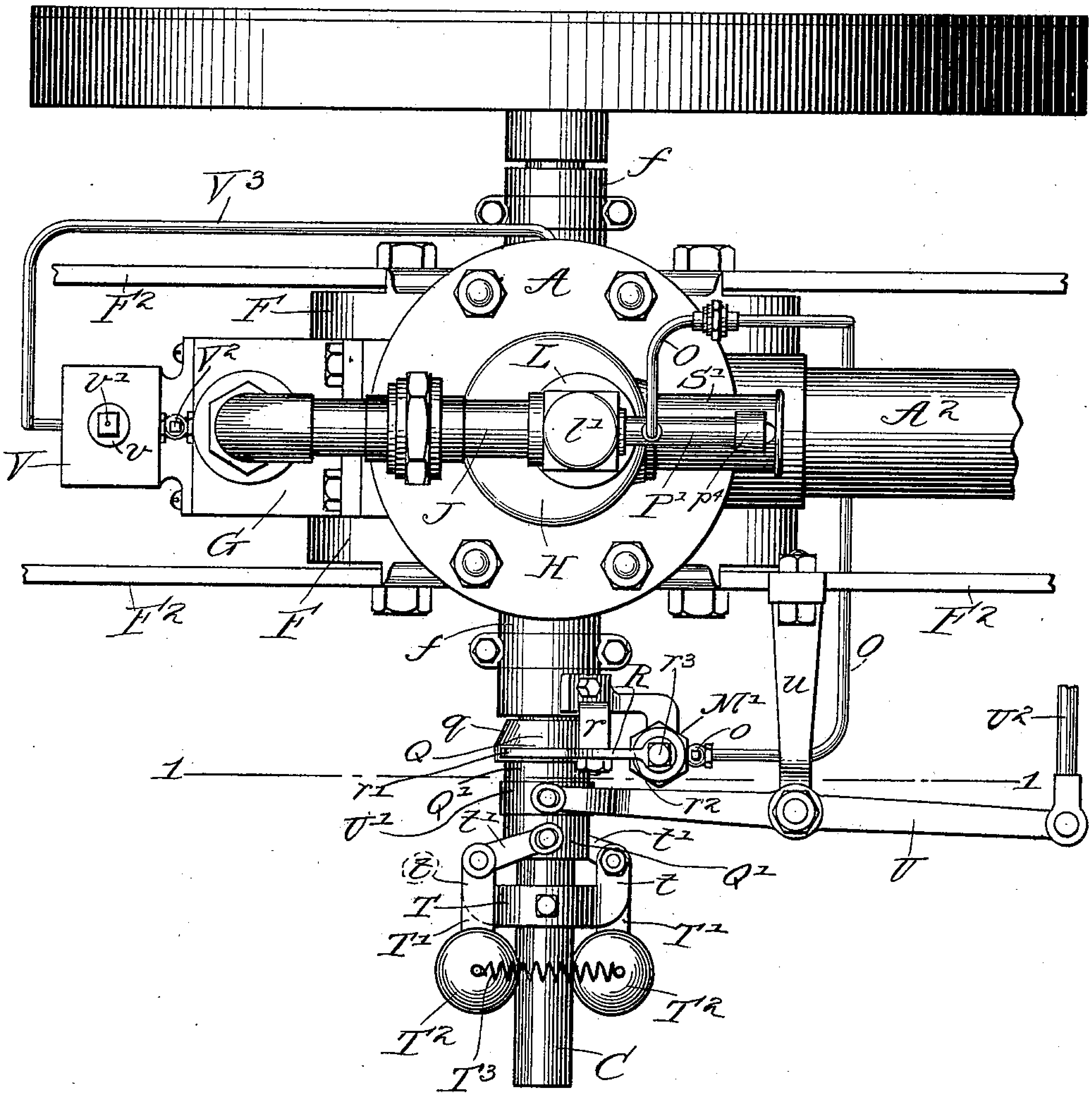
Fig. 2.



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UNITED STATES PATENT OFFICE.

GEORGE W. LEWIS, OF CHICAGO, ILLINOIS, ASSIGNOR TO THE J. THOMPSON & SONS MANUFACTURING COMPANY, OF BELOIT, WISCONSIN.

EXPLOSIVE-ENGINE.

SPECIFICATION forming part of Letters Patent No. 620,941, dated March 14, 1899.

Application filed December 14, 1895. Serial No. 572,123. (No model.)

To all whom it may concern:

Be it known that I, GEORGE W. LEWIS, of Chicago, in the county of Cook and State of Illinois, have invented certain new and useful Improvements in Explosive-Engines; and I do hereby declare that the following is a full, clear, and exact description thereof, reference being had to the accompanying drawings, and to the letters of reference marked thereon, which form a part of this specification.

This invention relates to improvements in explosive gas or vapor engines of that class in which an explosion or impulse takes place at every forward or power stroke of the piston in the power-cylinder of the engine and which embrace an air-compression chamber from which air is admitted to the cylinder behind the piston at the termination of each power-stroke of the latter.

The invention consists in the matters hereinafter described, and pointed out in the appended claims.

In engines of the character above referred to as heretofore commonly constructed the explosive mixture has been introduced into the cylinder at the time the piston is at the forward or power end of its stroke and the entrance of the fresh charge of air at the time the piston reaches the limit of its forward stroke has been employed to force from the exhaust-port the spent gases resulting from the previous explosion. This construction has been found to possess the disadvantage that the incoming mixture of gas or vapor and air is likely to become mixed to some extent with the dead gases as the latter are forced from the cylinder with the result that the strength of the charge is reduced by the presence of a quantity of the spent gases or a part of the charge is lost by escape from the exhaust-port with such gases, thus involving both a loss of fuel and an objectionable smell of gas or vapor in the atmosphere.

I propose to remedy the defects above referred to by introducing the compressed air into the cylinder separately from the charge of vapor or gas and by providing a mixing space or chamber in open communication with the cylinder, into which the charge of gas or vapor is introduced and in connection with which the igniting devices are arranged, the parts being so arranged that the gas or vapor shall remain in such chamber without the admixture therewith of a sufficient quantity of air to make an explosive mixture until the air introduced into the cylinder at the end of the power stroke is compressed by the inward movement of the piston and driven by such inward movement into the said chamber, and thus mixed with the gas or vapor therein to produce an explosive admixture.

In addition to the general features above referred to the invention also embraces other improved features of construction in gas-engines, as will be hereinafter more fully set forth.

The invention may be more readily understood by reference to the accompanying drawings, in which—

Figure 1 is a view, partially in side elevation and partially in vertical section, taken through the central axis of the power-cylinder and the air-supply pipe leading thereto, of an engine embodying my invention. Fig. 2 is a plan view of the engine shown in Fig. 1.

As illustrated in said drawings, A indicates the power-cylinder of the engine, which is provided with the usual water-jacket *a* and has within it a piston B, which is connected with the crank-shaft C through the medium of a pitman D, having direct pivotal connection with the piston B by means of a transverse pivot-pin E. Said cylinder is open at its end adjacent to the crank-shaft and is closed at its opposite or explosion end by means of a head A′. The piston B is of the form known as a "trunk-piston," the same consisting of a hollow cylinder open at one end for the insertion of the pitman D, as common in similar engines.

F indicates an air-compression chamber which in this instance is connected directly with the open end of the cylinder A and forms a casing which supports the bearings *f f* for the crank-shaft C and surrounds or incloses the crank-shaft and connecting-rod. In the particular construction illustrated said chamber F is made in the form of a hollow casing having apertures in its sides which are covered or closed by separate plates F′, on which are cast the bearings *f f* for the crank-shaft.

Said chamber, moreover, in the instance illustrated forms the main support or frame for the engine, the same being shown as attached to horizontal frame-bars F^2, which may constitute part of the framework of the vehicle in case the engine is employed as a vehicle-motor. Air is compressed in said chamber by the action of the piston at each power stroke of the same in a manner heretofore proposed. As far as the operation of said chamber F as an air-compression chamber is concerned its attachment to the open end of the cylinder in a manner to form a casing or housing for the crank is not essential, and the same general results may be produced by a location of said chamber elsewhere than in the position shown and by compression of the air therein otherwise than by the direct action of the power-piston. The said cylinder A is provided at one side with a plurality of admission-ports a', which are covered by the piston except when the latter is at the outward limit of its stroke. Said ports are in communication with the upper end of an air pipe or passage G, which is connected at its lower end with the compression-chamber F by means of a lateral passage *g*. Said pipe G is provided at its lower end with air-admission openings and with an inwardly-opening check-valve G', which is for the purpose of admitting air to the compression-chamber F during the upward or back stroke of the piston, the inlet-port a' of the cylinder being covered by the piston during such upward or back stroke thereof, so that air can enter the compression-chamber at such time only by the opening of the check-valve. In the power or outward stroke of the piston such check-valve G' is closed to prevent escape of air from the compression-chamber, and the air is compressed within the latter until the piston approaches the outer limit of its stroke and uncovers the ports a', and at such time the air theretofore compressed within the chamber passes into the power-cylinder.

At the opposite side of the power-cylinder is located an exhaust-port a^2, communicating with an exhaust-pipe A^2. Said exhaust-port is located in position to be uncovered by the piston when it reaches the outward limit of its stroke, and the spent or dead gases resulting from the explosion are forced from the said exhaust-port at the time the same is opened by the entrance of air at the same time through the ports a' from the compression-chamber. A segmental recess or rabbet formed in the piston opposite the air-inlet port affords a deflecting surface or shoulder against which the current of entering air strike and by which it is directed toward the closed end of the cylinder, so that the cylinder is filled with the incoming air from its inner toward its outer end, and the spent gases are thereby forced from the exhaust-port before any considerable part of the incoming air reaches the same.

As far as above described the engine illustrated is substantially like that shown in my prior application, Serial No. 555,973, filed July 15, 1895, wherein provision is made for the driving out of waste gases from the cylinder by the entrance of compressed air through the inlet-port.

To now refer to the novel features of construction to which the invention more particularly relates, these are in the particular embodiment of the invention illustrated constructed as follows: Connected with the power-cylinder and in communication with the power end thereof is a charge holding or mixing chamber H, which is in open communication with the power end of the cylinder. Said chamber H is shown as formed by means of a cylindric extension or cylinder cast integral with the cylinder-head A' and as separated from the main part of the cylinder by means of a perforated plate I, which is secured to the cylinder-head in the manner illustrated. In this construction entrance of the incoming charge of compressed air into said mixing-chamber H is prevented both by the location of the chamber and the presence of the perforated plate I, whereby the incoming current of air entering at the outer end of the cylinder is prevented from sweeping around or through said chamber H, it being obvious that the air-current thrown toward the head of the cylinder from the inlet-port will move along the side wall of the same and by reason of the central location of the chamber H will strike the cylinder-head outside of said chamber and will be deflected thereby transversely across the cylinder-head, so that it would have little or no tendency to enter the chamber H even if the plate I were absent. Said chamber H is for the purpose of retaining or holding a charge of gas or vapor without the admixture of any considerable air therewith during the entrance of the compressed air by which the spent gases are driven out, so that any admixture of the said charge of gas or vapor with the entering air will be prevented and no loss of gas or vapor will take place in case a part of the air escapes with the spent gases as the latter are expelled.

To now refer to the devices used for supplying a charge of gas or vapor to the chamber H, it may first be stated that while the special devices illustrated are intended for the use of liquid fuel yet the same general features of construction may be employed where gas is used to make the explosive mixture.

Referring now to the features of construction illustrated, J indicates a pipe leading from the air-pipe G to the chamber H, and L a short tube by which the said pipe is connected with the mixing-chamber, said pipe J and tube L together constituting a chamber which will be hereinafter called the "charge-measuring" chamber. The tube L communicates with the chamber H through the medium of a port *h*, provided with a check-valve

K. Said pipe J is not in open communication with the pipe G, but is provided with an air-inlet port or opening j, provided with a check-valve J', which is held normally closed by means of a spring j', placed around the stem of the valve between a shoulder thereon and the guide or bearing of the valve-stem, so that air can only enter the charge-measuring chamber when the pressure in the latter is less than that in the air-pipe G. In the particular construction illustrated the valve K is mounted in the tube L, which is secured to the wall of the chamber H and extends through the same, so as to form a seat for the valve. The valve K is shown as attached to a stem k and is held closed by means of a coiled spring k', properly applied to the stem in such manner as to hold the valve against its seat. The valve K is arranged to open inwardly toward the cylinder, so that the pressure produced by the explosion within the cylinder will tend to close the valve and prevent the backward escape of gases into the charge-measuring chamber J. The spring k' is shown as located within a tubular extension l of the tube L, which tubular extension is closed at its outer end by means of a cap l'.

The liquid hydrocarbon for producing the vapor is introduced into the charge-measuring chamber formed by the pipe J and tube L, preferably at a point in the tube L just above the said valve K. The means illustrated for supplying the liquid to the said passage L are constructed as follows: M indicates a supply-pump, and N a pipe leading to the same from a tank or other source of supply. O indicates a pipe leading from the pump to the tube L or charge-measuring chamber, with which it communicates by means of an inwardly-opening check-valve P. Said check-valve is herein shown as formed by means of a tube P', secured in the side wall of the tube L and having a valve-seat p formed at its inner end for the said check-valve. The valve has attached to it a stem p', which extends outwardly through the tube P' and has attached to its outer end one end of a contractile coiled spring p^2, the opposite end of which is attached to a cross-bar p^3 at the outer end of said tube P'. A cap p^4 upon the outer end of the tube P' serves to close the same and prevent leakage of the liquid therefrom. The pipe O is shown as connected with the tube P' by connection with one side of the same at a point outside of the valve in a manner illustrated.

The pump M is adapted to be actuated by suitable connections with the crank-shaft of the engine, so that at each stroke of the piston a quantity of liquid will be forced through the pipe O and past the valve P to the tube.

The feed-pump M, as herein shown, is constructed as follows: M' is a pump-barrel that is secured to one of the bearing-sleeves f of the crank-shaft. The pump-barrel contains a piston or plunger m, which is held at the outward limit of its stroke by means of a coiled spring m', located in the lower part of the pump-barrel and acting on a valve-disk m^2, which is connected with the plunger m by a stem m^3, which is smaller in diameter than the plunger. Said disk is arranged to bear against a seat m^4 when the plunger is at the outward limit of its movement. Said spring m' abuts at its lower end against a cup m^5, by which the barrel is closed. The supply-pipe N is connected with the pump-barrel below the disk m^2 and delivery-pipe O and is connected with the barrel below the lower end of the plunger, but above the disk. Said pipes are provided with check-valves n o, of which the valve n opens inwardly toward the pump, while the valve o opens outwardly or toward the delivery-pipe. This pump operates in the manner of an ordinary force-pump, drawing the oil inwardly at each outstroke of the piston and forcing it out through the pipe O at each instroke of the piston, while acting as a valve to positively prevent passage of liquid from the supply and the delivery pipe when the pump is not in action.

For actuating the pump a cam Q is mounted on the crank-shaft C, said cam being provided with a cam projection q, which operates through suitable connections with the pump-plunger to give one stroke to the same at each revolution of the shaft. The actuating connection between the cam and pump-plunger, as shown in the accompanying drawings, consists of a lever R, pivoted between its ends to a bracket r on the adjacent crank-shaft bearing and provided with an arm r', which engages the cam, and with another arm r^2, which bears against the end of the plunger m to force the same inwardly against the action of its actuating-spring. To afford adjustment of the stroke of the pump-plunger, a set-screw r^3 is inserted through the lever-arm r^2, so as to act against the plunger. The outward movement of said plunger is limited by contact of the valve-disk m^2 with its seat m^4; but the possible movement of the lever is greater than the stroke of the plunger, so that the extent of movement of the latter may be varied by adjustment of the set-screw r^3, so that the plunger will be moved either the full stroke of the actuating-lever or a portion only thereof. It follows from the above that at each revolution of the crank-shaft the actuating-lever will be moved by contact of the cam projection q therewith so as to thrust inwardly the pump-plunger a desired distance, and thereby force a quantity of liquid through the pipe O into the chamber L, which quantity will be determined by the length of the stroke of the pump-piston.

As hereinbefore stated, the ignition device is connected with or located in the chamber H. Said ignition device may be of any preferred or desired form; but the same as herein shown consists of an ignition-tube S, which is closed at its outer end and in open communication with the chamber H at its inner end and is kept constantly heated by an externally-applied flame to such a high temperature that the explosive mixture entering the same will be ignited, as common in such devices. The tube S is herein shown as surrounded by casing S′, with which will be connected the burner (not shown) for heating the tube. The casing S′ is shown as being provided with an integral screw-threaded plug which enters an aperture in the wall of the chamber H and which is provided with a central passage, in which the tube S is secured.

The operation of the engine illustrated is as follows: As hereinbefore stated, the engine is of that class in which an explosion occurs at each revolution of the crank-shaft, so that every outstroke of the piston is a power-stroke. In the outward movement of the piston after the explosion has taken place within the cylinder the expanding gases follow the piston until the same reaches the outward limit of its stroke and uncovers the exhaust-port a^2 and the air-inlet port a'. As the piston moves outwardly it compresses the air within the chamber F, so that at the time it reaches the outward limit of its stroke and before the inlet-port a' is uncovered the air is under considerable pressure within the compression-chamber and pipe G, so that as soon as the inlet-port is uncovered air rushes therethrough and, being directed upwardly or toward the inner end of the cylinder by contact with the opposing surface of the piston, the current of air is thrown against the cylinder-head and filling first the inner end of the cylinder forces the spent gases therefrom through the exhaust-port. The action of the feed-pump is so timed as to force the desired quantity of liquid into the passage L during the inward or back stroke of the piston, so that when the piston reaches the limit of its outward stroke the liquid will be contained within the tube L. During the outward stroke of the piston air within the charge-measuring chamber formed by the pipe J and tube L will be compressed to nearly the same degree as that within the air-chamber F and pipe G, because as soon as the pressure in said pipe G exceeds that within the pipe J to an extent sufficient to overcome the slight tension of the spring j' and open the valve J′ the air under pressure will pass into said pipe J. As soon, however, as the piston reaches the outward limit of its stroke and the exhaust-port is uncovered, the cylinder A and pipe G will be relieved of pressure, while the air held under compression in the charge-measuring chamber will immediately expand through the check-valve K into the chamber H. No air can at this time escape backwardly from the pipe J to the pipe G and no air can flow from the pipe G into the pipe J, because the pressure in the pipe G will be relieved as soon as the ports a' are open, and the valve J′ will therefore remain closed. The size of the space or chamber afforded by the pipe J and tube L will be such that the expansion of the air or gas contained therein will not more than fill the chamber H, so that none of the vapor or gas coming from said pipe will pass out of said chamber into the cylinder. In other words, the combined areas of the charge-measuring chamber and the mixing-chamber is such that the gas or vapor held under compression in the measuring-chamber will not more than fill that area when allowed to expand by the removal of pressure in the cylinder. It follows that the size of the space formed by the pipe J and the tube L will largely determine the quantity of gas or vapor delivered to the mixing-chamber, the other factor, which also controls in this matter, being the pressure at which the gas or vapor-ladened air is compressed in the said space. A principal function, therefore, of the said space is to limit the charge of vapor or gas to the size of the mixing-chamber, and for this reason the term "charge-measuring chamber" is herein applied to such space. The liquid entering the tube L may be vaporized in whole or in part by contact with the heated walls thereof, so that the compressed air in the tube J may be largely ladened with vapor before it enters the chamber H. If, however, some or all of the liquid should remain unvaporized in the said tube L at the time the pressure is removed from the main cylinder, the air passing from the pipe J to the mixing-chamber will take up or vaporize all of the liquid in said tube L and the air entering the mixing-chamber will be fully charged with vapor. Inasmuch as the air will enter the inlet-ports of the cylinder at the same time that the exhaust-port is opened and the main cylinder relieved from pressure, it follows that the charge of vapor will enter the chamber H at or about the same time the air under pressure enters the cylinder for the purpose of driving out the spent gases. By reason of the location of the mouth or opening of the chamber H and of the presence of the perforated plate I between the chamber and the cylinder no mixing of the incoming air with the vapor will occur, because the entering air-current will flow across the opening and the plate will make a partial separation between the mixing-chamber and cylinder, calculated to prevent or retard the mixing of the charge with the incoming air. Moreover, as before stated, the vapor-ladened air which expands into the chamber H will not more than fill the same, so that there is no liability of its entering the body of the cylinder by its expansive action. The vapor-ladened air so entering the mixing-chamber will not be ignited by the ignition-tube when the latter is employed as an igniting device, because the proportion of vapor will be so great that the mixture will be unexplosive. The compressed air entering the cylinder, as described, will therefore drive out all of the spent gases, leaving the body of the cylinder full of compressed air, while the charge of vapor will remain in the chamber H unexploded. As soon, however, as the piston begins its backward movement or stroke the air contained in the cylinder will be compressed in the inner end thereof, and as the space for the air decreases on the approach of the piston toward the cylinder-head the air will be forced into the mixing-chamber H, with the result of becoming mixed or commingled with the vapor therein contained. The complete admixture of the air with the vapor will take place at the completion of the inward stroke of the piston, and at this time the proportions of air and vapor being suitable for explosion ignition will then take place at the proper time. In case an electric ignition device be employed the time of explosion will be determined by the action of the working parts of the engine; but if a heated tube be employed, as herein shown, the time of explosion will be that when the mixture is brought to an explosive state. The use of the perforated plate described affords a means of controlling the time of explosion, so that it shall not occur too soon or too late for effective action of the engine, because by making the holes in the plate larger the mixing of the air with the gas or vapor in the mixing-chamber is hastened, while by making the holes smaller such mixing is retarded. By proper proportioning of the size of the holes, therefore, the time of ignition may be controlled with all the accuracy required for practical purposes.

As a separate and further improvement, I have provided a governing device for the engine of the character described, the same embracing means by which the stroke of the feed-pump may be varied to force a greater or less quantity of the liquid into the passage L. The device illustrated for giving such variable stroke to the feed-pump consists in mounting the cam Q on a sleeve Q′, which is adapted to slide endwise on the shaft C, and of making the projections *q* of said cam of tapered or oblique form approaching nearer to the central axis of the shaft at one end than at the other, as clearly seen in Fig. 2, so that the lever R will be moved to a greater or less extent, according to the position on the shaft to which the cam is moved. For giving motion to the said cam I have provided a governing device consisting of a collar T, which is secured to the shaft C outside of the cam and provided with two arms *t t*, on which are pivoted bell-crank levers T′ T′, having at their outer ends centrifugally-acting governor-weights T^2 T^2 and transverse arms *t′ t′*, which engage with the sleeve Q′ by suitable slot-and-pin connections. The governor-weights T^2 are held at their inward position by means of a coiled spring T^3, connecting the same, so that normally the cam Q will be held with its most elevated part in position to act on the pump-actuating lever, and thus give a maximum feed or supply of fuel to the engine. If the desired speed be exceeded, however, the outward motion of the governor-plates draws endwise the sleeve Q′, thereby bringing the smaller part of the cam opposite said lever and lessening the stroke of the pump and reducing the quantity of the fuel fed thereby.

As a separate and further improvement in the regulating devices of the engine I have provided a means by which the same may be controlled by hand as well as by the governor-weights, this construction being more especially applicable to engines used for vehicle-motors to provide for an increase or decrease of the speed of the engine, as desired, independently of the action of the governor, but being also adapted for use in connection with engines used for other purposes. This feature of the invention, as embodied in the drawings, consists of a lever U, which is pivoted to the bracket *u* on the machine-frame and which is engaged by means of a slot-and-pin connection with a collar U′, which engages a groove in the sleeve Q′. To the said lever U is connected an actuating-rod U^2, which leads to a suitably-arranged hand-lever or other actuating device. (Not shown in the drawings.) By application of hand-power to the lever U the governor-cam Q can be shifted on the shaft and the quantity of fuel fed to the pump thereby varied to increase or decrease the power developed by the engine. Such variations of power may be necessary in a vehicle-motor, for instance, to give increased speed for special occasions or to give greater power when more power is needed, as in ascending a hill. It will of course be seen that when the hand controlling device is used the governor-weights will be moved inwardly or outwardly thereby, in one case against the centrifugal action of the weights and in the other case against the action of the governor-spring F^3.

As an improved means for supplying lubricant to an explosive-engine of the general character herein described, I have provided an oil reservoir or tank having feed-pipes leading to the parts requiring lubricating and which is connected with the air-compression cylinder by means of a passage provided with a check-valve which opens toward the tank, so that an air-pressure will be maintained in the lubricant-tank at all times. I also provide in connection with such a tank means for preventing feeding of oil except when the engine is running, the same consisting of a minute escape-orifice in the top of the tank, which is so small as to have no appreciable effect on the air-pressure therein at the time when the engine is in operation, but which permits leakage of the air from the tank so as to quickly relieve the pressure therein when the engine has ceased to operate.

The lubricating device embracing features of construction as above described, which is shown in the accompanying drawings, is made as follows: V is a closed tank for lubricant, having a filling-orifice provided with a cup or plug *v*, in which is a minute orifice *v′*. Said tank V is connected with the pipe G by means of a pipe V', opening into the top of the tank and provided with a check-valve V^2. An oil-supply pipe V^3 is shown as leading from the bottom of the tank V to the side of the cylinder, where it communicates with an orifice which passes through the cylinder and communicates with a channel on the outside of the piston B, which channel leads to a central bore *e* in the pivot-pin E of the connecting-rod D. From said central port *e* radial passages *e'* lead to the bearing-surfaces between the connecting-rod and the said pivot-pin. At each outward stroke of the piston the air will be forced from the pipe G through the check-valve to the top of the tank V, so that pressure within the said tank will soon equal that within the compression-chamber. The continuous air-pressure thus produced on the top of the oil within the tank will serve to force the same through the pipe V^3 to the bearings to be lubricated in an obvious manner. I have shown only one pipe leading to a single bearing to be lubricated for purpose of illustration; but it will of course be understood that other supply-pipes may lead to all bearings of the engine. By the use of such lubricating device, operated by air-pressure from the engine, the necessity for frequent filling of feed-cups or other hand lubrication is avoided and the engine may be allowed to run without attention for a period of time depending upon the quantity of oil which the tank may hold, and the latter may be of any size which is found practicable or desirable.

The purpose of the minute orifice *v'* is to permit the air to soon escape from the oil-tank after the stoppage of the engine, so that the tank will be relieved from pressure and the oil will cease to flow when the engine is not running. Obviously such minute orifice will not interfere with the operation of the tank in the usual working of the engine, the escape of air therethrough being so small in proportion to the supply as to be of no consequence at such time.

In the use of gas instead of a volatile liquid in an engine of the kind described the gas will be delivered to the passage L through a valved supply-passage controlled by the motion of the crank-shaft and corresponding with the supply-pipe and feeding devices herein shown, the feed-pump herein illustrated serving to show also a controlling-valve such as would be used for gas and means for actuating such a valve. Where gas is used, it is commonly supplied under sufficient pressure to enter the said passage without the use of any forcing means, so that a regulating-valve only will be required for controlling the supply of gas, it being obvious that at the time the charge is permitted to enter the tube L said tube will be practically free from pressure, because the charge is admitted after the previous charge has been permitted to expand into the mixing-chamber. Ordinarily, therefore, gas will be delivered directly to the passage L by its own pressure, and a regulating-valve controlled by the governing device such as that described will be employed to limit the supply in accordance with the needs of the engine.

I claim as my invention—

1. An explosive-engine comprising a power-cylinder, provided with a piston and with a mixing-chamber in open communication therewith, a perforated plate interposed between the mixing-chamber and the cylinder, means for introducing charges of gas or vapor into the mixing-chamber and means for supplying air under pressure to the cylinder to force the spent gases therefrom.

2. An explosive-engine comprising a power-cylinder provided with a piston and with a mixing-chamber in open communication therewith, a charge-measuring chamber connected with the mixing-chamber by a valved passage, means for supplying gas or vapor to said charge-measuring chamber, means for supplying air under pressure to said charge-measuring chamber and means for supplying air under pressure to the cylinder at the termination of each outward stroke of the piston.

3. An explosive-engine comprising a power-cylinder provided with a piston and with a mixing-chamber in open communication therewith and having in its side wall air inlet and exhaust ports which are uncovered by the piston at the outer limit of its stroke, an air-compression chamber in open communication with the air-inlet port and means for supplying gas or vapor to the mixing-chamber, said exhaust-port extending nearer the inner end of the cylinder than the air-inlet port so that it is opened before the air-inlet port in the outward stroke of the piston.

4. An explosive-engine comprising a power-cylinder provided with a piston and with a mixing-chamber in open communication therewith and having air inlet and exhaust ports which are located in position to be uncovered by the piston at the outward limit of its stroke, an air-compression chamber in open communication with the air-inlet opening and in communication with the mixing-chamber by a passage having a check-valve which opens toward the mixing-chamber and means for supplying vapor to the mixing-chamber.

5. An explosive-engine comprising a power-cylinder provided with a piston and with a mixing-chamber in open communication therewith and having air inlet and exhaust ports which are uncovered by the piston at the outward limit of its movement, an air-compression chamber in open communication with the air-inlet opening, a charge-measuring chamber connected with the mixing-chamber by a valved passage and connected also with the air-compression chamber by a passage provided with a check-valve which opens toward the charge-measuring chamber and means for supplying gas or vapor to the said charge-measuring chamber.

6. An explosive-engine comprising a power-

cylinder provided with a mixing-chamber in open communication therewith, a charge-mixing chamber connected therewith by a passage provided with a check-valve, opening toward the mixing-chamber, an air-compression chamber connected with the charge-measuring chamber by a passage provided with a check-valve opening toward the charge-measuring chamber and means for supplying gas or vapor to the said charge-measuring chamber.

7. An explosive-engine comprising a power-cylinder provided with a mixing-chamber in open communication therewith and with air inlet and exhaust ports, a piston in the cylinder, an air-compression chamber, in communication with the air-inlet port, said ports being uncovered by the piston at the outer limit of its stroke, a charge-measuring chamber connected with the air-chamber and with the said mixing-chamber, by passages provided with check-valves, means for supplying gas or vapor to the said charge-measuring chamber and an ignition device in the said mixing-chamber.

8. An explosive-engine comprising a power-cylinder provided with a mixing-chamber in open communication therewith and with air inlet and exhaust ports, a piston in the cylinder, an air-compression chamber in communication with the air-inlet port, said ports being uncovered by the piston at the outer limit of its stroke, a charge-measuring chamber connected with the air-chamber and with the said mixing-chamber, by means of passages provided with check-valves, means for supplying gas or vapor to the said charge-measuring chamber and a perforated plate located between the said mixing-chamber and the cylinder.

9. An explosive-engine comprising a power-cylinder provided with a mixing-chamber in open communication therewith and with air inlet and exhaust ports, a piston in the cylinder, an air-compression chamber, in communication with the air-inlet port, said ports being uncovered by the piston at the outer limit of its stroke, a charge-measuring chamber connected with said air-chamber and mixing-chamber by means of passages provided with check-valves, means for supplying gas or vapor to the said charge-measuring chamber, said charge-measuring chamber having the form of a pipe connecting the air-compression chamber with the mixing-chamber.

10. An explosive-engine comprising a power-cylinder provided with a mixing-chamber in open communication therewith and with air inlet and exhaust ports, a piston in the cylinder, an air-compression chamber in communication with the air-inlet port, said ports being uncovered by the piston at the outer limit of its stroke, a charge-measuring chamber connected with the air-chamber and mixing-chamber by passages provided with check-valves and means for supplying gas or vapor to the said charge-measuring chamber embracing a supply-passage provided with a check-valve opening toward the said charge-measuring chamber.

11. An explosive-engine comprising a power-cylinder provided with a piston and with a mixing-chamber in open communication therewith, means for supplying air under pressure to the cylinder, and means for introducing charges of vapor into the mixing-chamber, comprising a feed-pump, a revolving shaft, a cam on the shaft which actuates the pump, said cam having an inclined or oblique cam projection and being constructed to move endwise on the shaft and a centrifugal governor connected with said cam to give endwise movement thereto.

In testimony that I claim the foregoing as my invention I affix my signature, in presence of two witnesses, this 11th day of December, A. D. 1895.

GEORGE W. LEWIS.

Witnesses:
WILLIAM L. HALL,
WILLIS D. SHAFER.