No. 627,857. Patented June 27, 1899.

H. A. KNOX.

GAS ENGINE.

(Application filed July 13, 1897.)

(No Model.) 3 Sheets—Sheet 1.

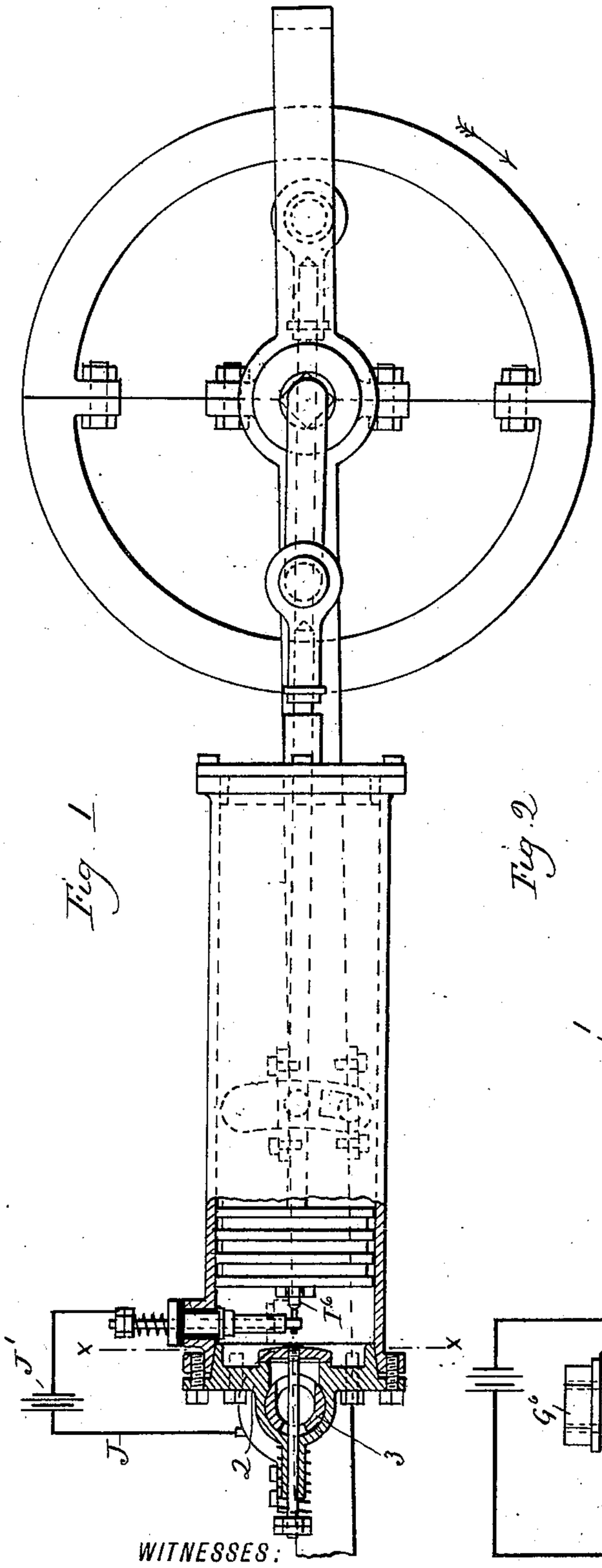


Fig. 1.

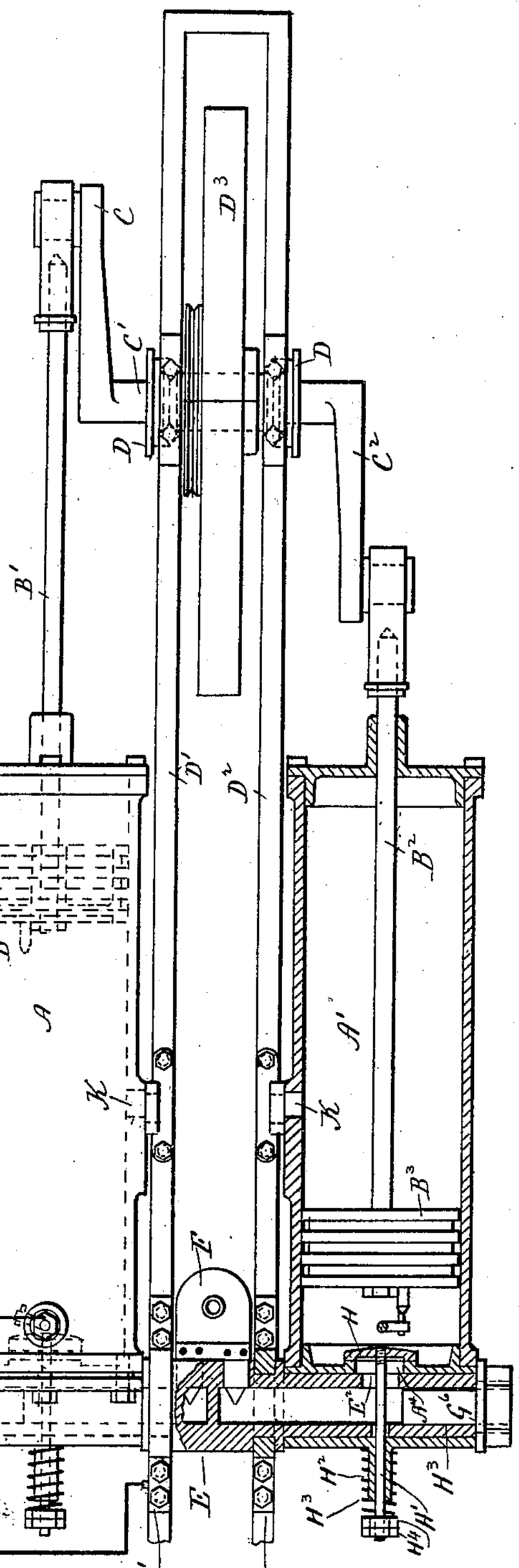


Fig. 2.

WITNESSES:

F. N. Shumway.
Lillian D. Kelsey.

Harry A. Knox.
Inventor.
BY
Earle Seymour
ATTORNEYS.

No. 627,857. Patented June 27, 1899.

H. A. KNOX.

GAS ENGINE.

(Application filed July 13, 1897.)

(No Model.) 3 Sheets—Sheet 2.

Fig. 3

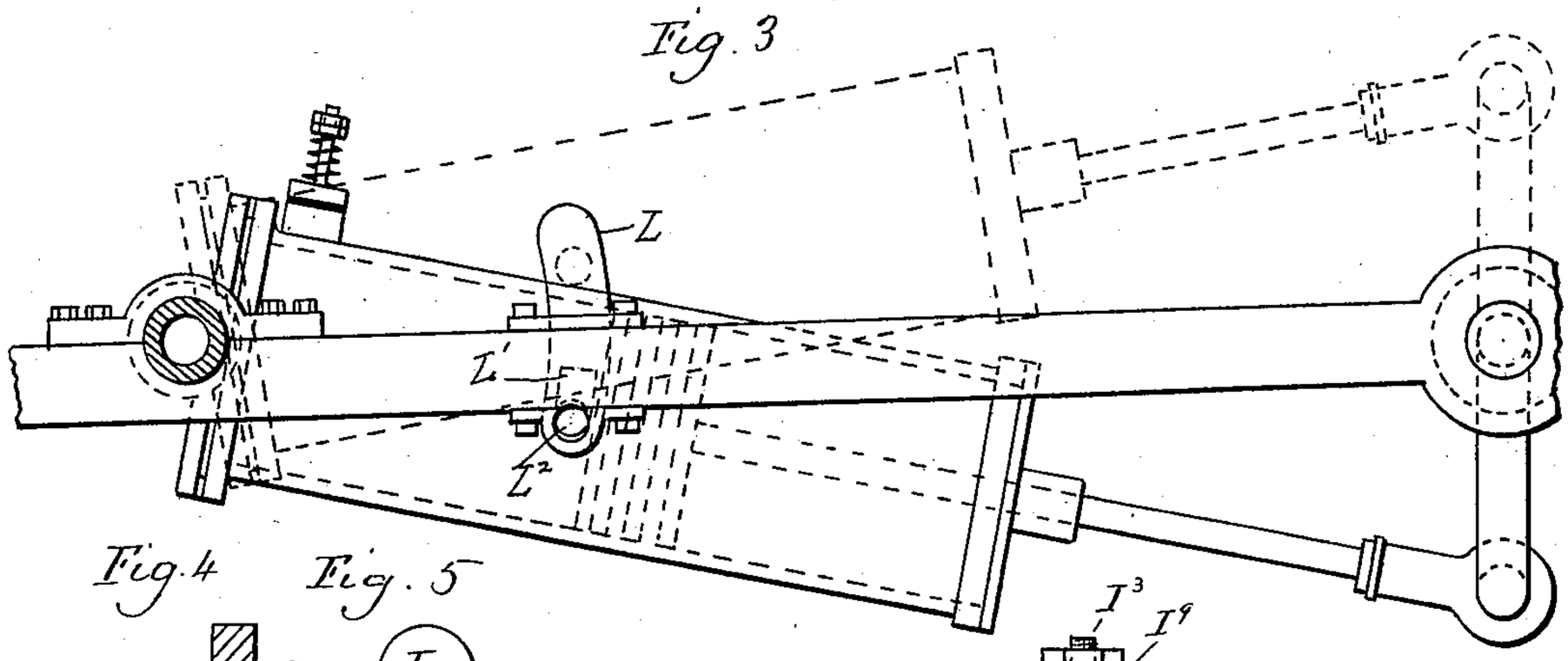


Fig. 4

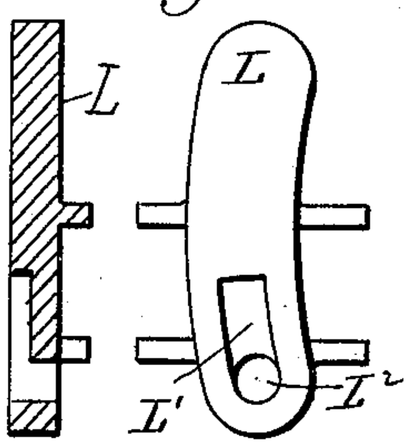


Fig. 5

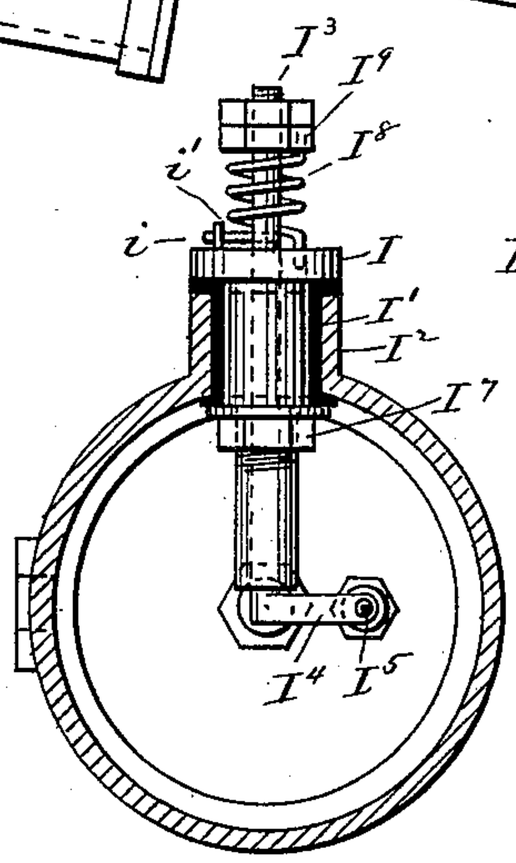


Fig. 6

Fig. 7

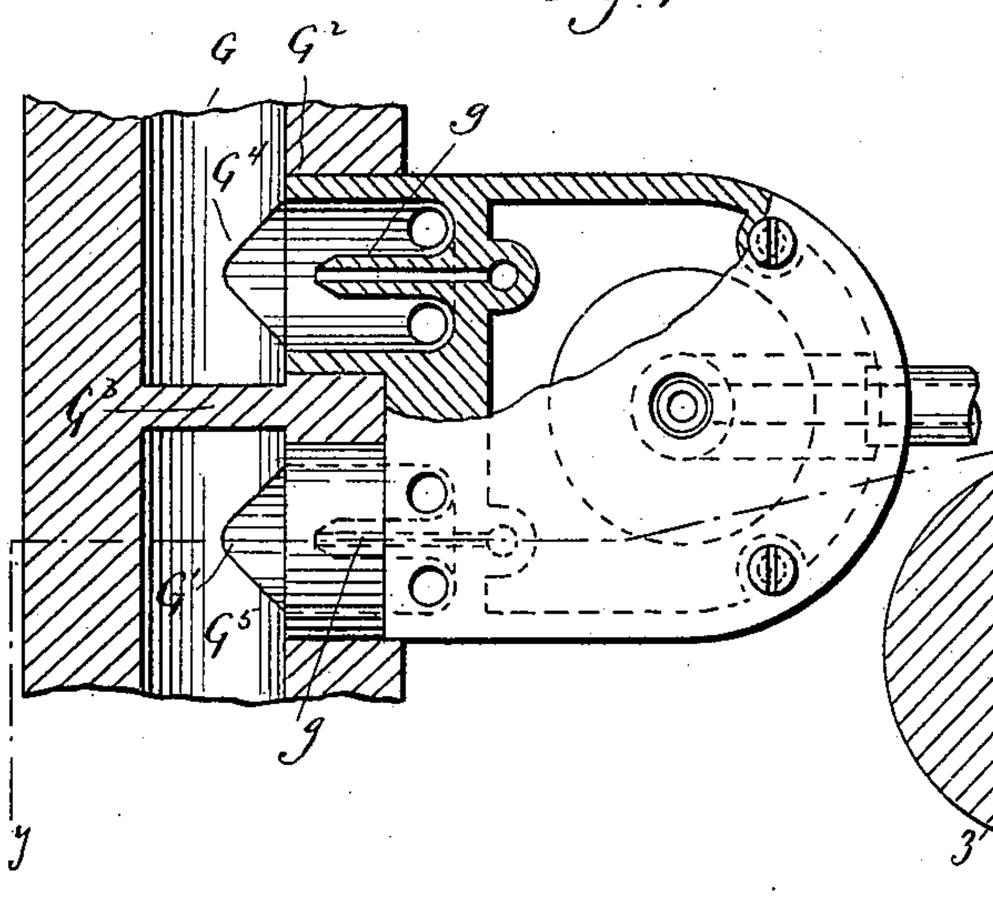
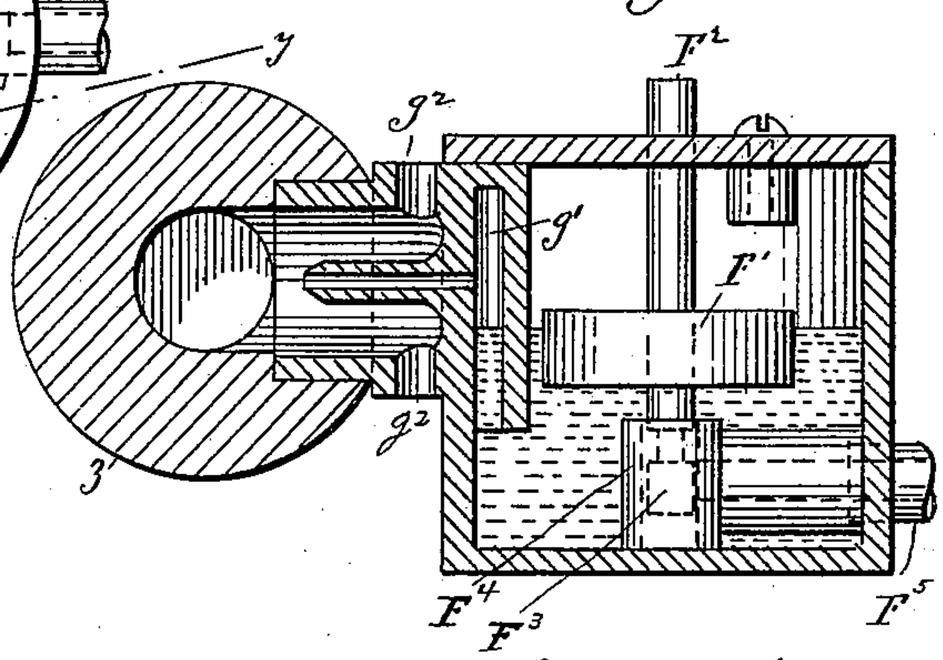


Fig. 8



WITNESSES:

J. F. Shumway.
Lillian D. Kelsey.

Harry A. Knox.
Inventor.
BY
Earle & Seymour
ATTORNEYS.

No. 627,857. Patented June 27, 1899.

H. A. KNOX.

GAS ENGINE.

(Application filed July 13, 1897.)

(No Model.) 3 Sheets—Sheet 3.

Fig. 9

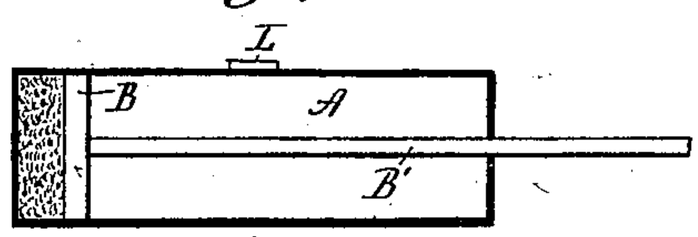


Fig. 10

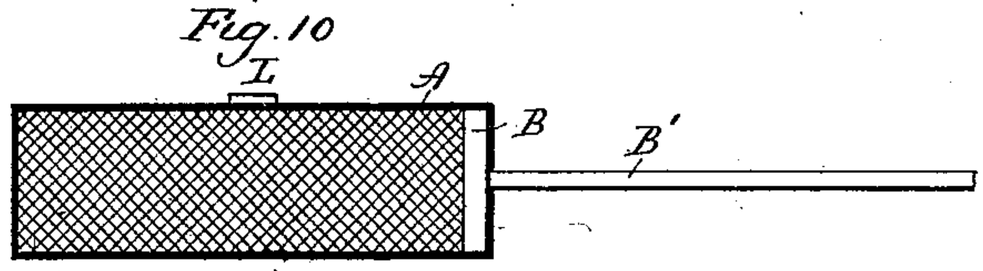


Fig. 11

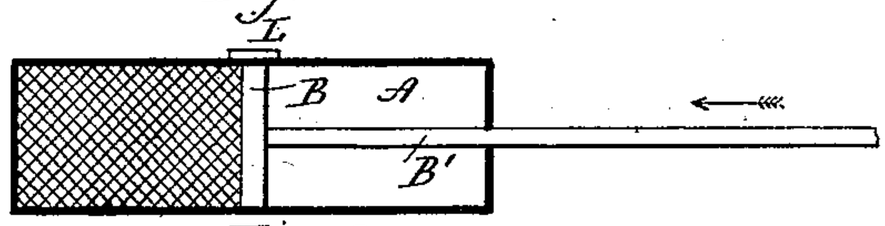


Fig. 12

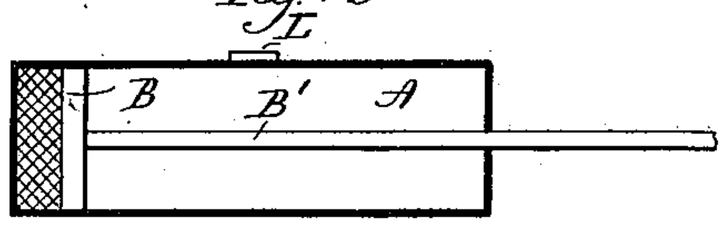


Fig. 13

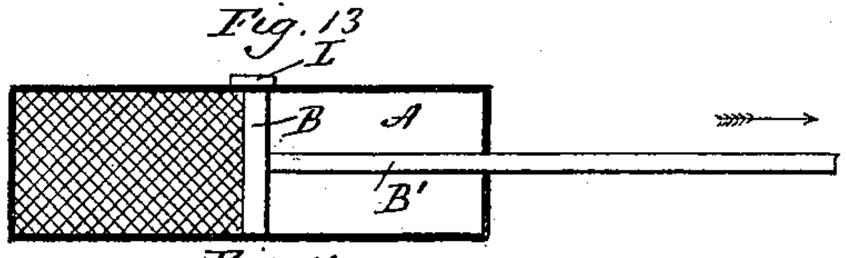


Fig. 14

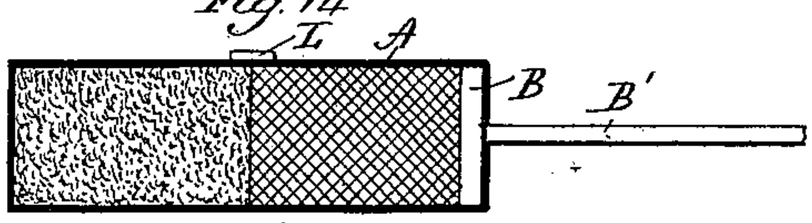


Fig. 15

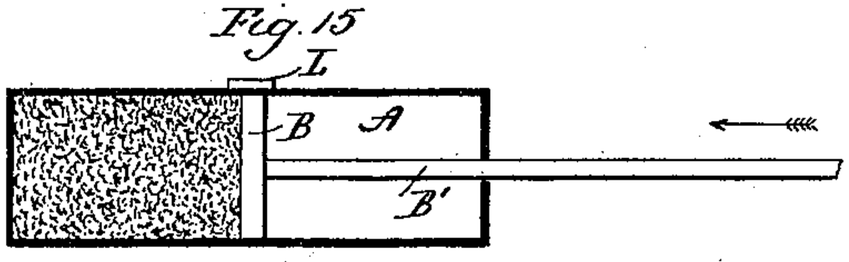
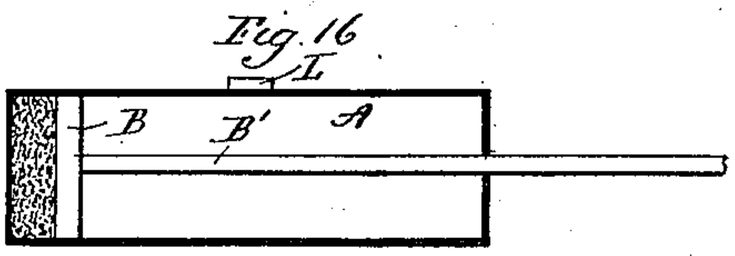


Fig. 16



Witnesses.
J. H. Shumway
Lillian D. Kelsey

Harry A. Knox.
Inventor.
By atty. Earle Seymour

UNITED STATES PATENT OFFICE.

HARRY A. KNOX, OF SPRINGFIELD, MASSACHUSETTS, ASSIGNOR OF FOUR-FIFTHS TO THE OVERMAN WHEEL COMPANY, OF HARTFORD, CONNECTICUT, AND CHICOPEE FALLS, MASSACHUSETTS.

GAS-ENGINE.

SPECIFICATION forming part of Letters Patent No. 627,857, dated June 27, 1899.

Application filed July 13, 1897. Serial No. 644,394. (No model.)

To all whom it may concern:

Be it known that I, HARRY A. KNOX, of Springfield, in the county of Hampden and State of Massachusetts, have invented a new Improvement in Gas-Engines; and I do hereby declare the following, when taken in connection with the accompanying drawings and the letters of reference marked thereon, to be a full, clear, and exact description of the same, and which said drawings constitute part of this specification, and represent, in—

Figure 1, a view, partly in side elevation and partly in section, of one form which a gas-engine constructed in accordance with my invention may assume; Fig. 2, a similar plan view thereof; Fig. 3, a view in side elevation, showing the extreme positions as to elevation and depression of one of the cylinders and the intermediate positions of the piston-rod; Fig. 4, a detached sectional view of the stationary exhaust-valve; Fig. 5, a view thereof in inside elevation; Fig. 6, a view in transverse section on the line *x x* of Fig. 1, showing the igniter; Fig. 7, a detached broken view, partly in plan and partly in section, showing the atomizer in its relation to the trunnion of the cylinder; Fig. 8, a detached view, in vertical section, showing the atomizer in its relation to the trunnion. Figs. 9 to 16, inclusive, are diagrammatic representations of a cylinder and its piston and rod, showing one cycle of its operation, which covers two revolutions of the crank-shaft to which its rod is connected.

My invention relates to an improvement in gas-engines, which as ordinarily constructed are objectionable on account of the noise accompanying their exhaust and on account of the necessity of making provision for keeping their cylinders cool and for the reason that considering the units of fuel expanded their efficiency is low.

The object of my invention is to produce a gas-engine in which the noise of exhaust will be reduced to the minimum, which will require no cooling-jackets or other means for keeping the temperature of the cylinder down, and which will operate with a very high degree of efficiency considering the units of fuel employed.

With these ends in view my invention consists in an expansive-gas engine having a cylinder furnished with an exhaust-port located about midway of its length and a valve arranged to coact with the said port and close the same during the forward stroke of the piston and open the same for the exhaustion of one-half of the combustion products during the first half of the back stroke of the piston.

My invention further consists in certain details of construction and combinations of parts, as will be hereinafter described, and pointed out in the claims.

I may here explain that my improved engine is characterized in its operation by its fractional or piecemeal ejection of the combustion products and by the utilization for this purpose of the incoming explosive mixture to assist in ejecting the combustion products without being mixed to any substantial degree therewith.

It may also be well for me at this time to explain that I shall use the word "exhaust" in connection with the ejection of the combustion products, because that term is commonly used and well understood in this art; but, strictly speaking, in the operation of my machine the combustion products are ejected rather than exhausted, if by the term "exhausted" the operation of atmospheric action is to be understood.

In carrying out my invention as herein shown I employ two cylinders A and A′, though my invention may be embodied in engines having one cylinder or more than two. As these two cylinders are substantially alike both in their general and detail construction, it will suffice for me to describe one of them.

The cylinder A is provided with a piston B, secured to the inner end of a piston-rod B′, the outer end of which is connected with the crank-arm C of the shaft C′, which is also furnished with a corresponding oppositely-extending crank-arm C^2, to which is connected the piston-rod B^2 of the piston B^3 of the cylinder A′. The said shaft C′ is mounted in ball-bearings D D, attached to the long frame-pieces D′ D^2 of the machine-frame. A heavy fly-wheel D^3, located between the said frame-

pieces, is secured to the shaft C′ and by its inertia carries the engine by its dead-points. The two cylinders are arranged to have limited oscillating movements in parallel vertical planes upon a long horizontally-arranged trunnion E, which is mounted in the said frame-pieces D′ and D², to which it is secured by caps E′ E′, the cylinders being connected with the respective ends of the said trunnion by means of their heads A² and A³, the outer faces of which are formed with chambered extensions for the reception of the ends of the trunnion. A mixture of gas and air is supplied to the engines from an atomizer located between the frame-pieces D′ and D² of the machine-frame and at a point closely adjacent to the inner face, so to speak, of the trunnion E. The said atomizer may of course be of any suitable construction and adapted to use any form of fuel, such as gasolene, and to mix it in any desired proportions with a given quantity of air. As herein shown, the atomizer consists of a tank F, containing a float F′, secured to a vertically-movable shaft F², the lower end of which is furnished with a valve F³ and plays up and down in a valve-box F⁴, so as to control the inlet of liquid fuel into the tank through the supply-pipe F⁵, which intersects the valve-box F⁴ and the central longitudinal passage of which is opened or closed, according to the position of the float, by the valve F³. When the float falls, the valve opens the passage in the pipe F⁵ sufficiently to allow the liquid fuel to flow into the tank, the inflow of liquid being then cut out by the lifting of the valve under the action of the float. The said tank is formed with two corresponding mixing-chambers G and G′, located within stems or projections which pass through apertures G² G², formed to receive them in the trunnion on opposite sides of the transverse web G³, which divides the central longitudinal bore or passage of the trunnion into the chambers G⁴ and G⁵, the outer ends of which are closed by plugs G⁶ G⁶. The said mixing-chambers G and G′ are provided with centrally-arranged nozzles *g g*, the inner ends of the longitudinal passages of which intersect vertical passages *g′ g′*, the lower ends of which extend below the surface of the liquid fuel in the tank. The rear end of each mixing-chamber is provided with a pair of upper and a pair of lower air-inlet ports *g*², which are located opposite the bases or inner ends of the nozzles *g g*. When in the operation of the engine a vacuum is produced in the chambers G⁴ G⁵ of the trunnion, the pressure of the atmosphere upon the liquid fuel will cause the same to be ejected from the nozzles *g g* and at the moment of its ejection therefrom be commingled with air, which will rush in to fill the vacuum through the air-inlet ports *g*². An explosive mixture is thus formed for the charging of the respective cylinders. I may here say, however, that I do not limit myself to the use of any particular form of atomizer nor to any particular way of introducing charges of explosive vapor into my improved engine. The explosive vapor, having been admitted into the inner ends of the passages G⁴ G⁵, flows thence outwardly and passes through transverse ports E² E², formed in the ends of the trunnions, into ports A⁴, formed in the cylinder-heads A³, the ports A⁴ being closed by inwardly-opening valves H, secured to the projecting inner ends of valve-stems H′, the outer ends of which have bearing in hollow stems H², formed integral with the respective heads and encircled by springs H³, the outer ends of which impinge against nuts H⁴, applied to the ends of the valve-stems. Each cylinder is also provided upon the upper face of its inner end with an igniter comprising a box I, inclosed in a packing I′, of insulating material, and mounted in an upwardly-projecting hub I², formed integral with the cylinder. An igniting-rod I³, mounted in the said box I, projects above and below the same, its lower end being furnished with an offsetting rod I⁴, carrying the contact-point I⁵, which coacts with a corresponding contact-point I⁶, mounted in the piston-head. The inner end of the box I is reduced for the application to it of a nut I⁷, by means of which the box is clamped in place. The projecting upper end of the rod is furnished with a spring I⁸, the upper end of which is connected with a nut I⁹, mounted upon the extreme upper end of the rod, while its lower end is fixed in the top of the said box I. Against the tension of this spring the rod is rotated on its longitudinal axis within the limits afforded by a stop-pin *i*, which plays in a staple *i′*. The said pin and staple may of course be replaced by a variety of devices for the purpose of limiting the rotary movement of the igniter-rod, which is located in an electric circuit J, containing a battery J′. Before the piston of either cylinder reaches the limit of its exhaust-stroke or instroke its contact-point I⁶ engages with the contact-point I⁵ of the igniter and swings the igniter outward against the tension of its spring I⁸, which on the other hand causes the rod to be oppositely turned and the contact-point I⁵ to follow the contact-point I⁶ without breaking contact until after the piston has begun its outstroke and until after its crank has passed the dead-center, when the contacts separate with the effect of producing the spark which explodes the charge.

By deferring the production of the spark and the ignition of the explosive mixture until after the piston has begun its outstroke I avoid that shock to and strain of the working parts of the engine due to producing the spark and igniting the explosive mixture before the piston has completed its instroke, which must then be completed against the force of the explosion, whereby a shock is caused and power is lost. The fact that by deferring the ignition of the explosive mixture until after the piston has begun its outstroke cuts something off from the effective length of that

stroke is immaterial in my improved engine for the reason that the cylinder is so long that ample opportunity is given for the complete ignition and expansion of the entire charge of explosive mixture. Each cylinder is also furnished at a point about midway of its length with an exhaust-port K, the location and operation of which is the most important feature of my present invention. These ports are alternately opened and closed by the sliding contact of the cylinders as they vertically oscillate with segmental valves L, secured to the outer faces of the frame-pieces D′ and D² of the machine-frame. Each of the said valves has a segmental recess L′, intersecting at its lower end a port L², opening outward into the atmosphere. The exhaust-ports K before mentioned are formed in large flat bosses formed upon the inner faces of the cylinders and constituting valve-seats for sliding coaction with the valves L.

I should now explain that in carrying out my invention I shall employ cylinders relatively long in proportion to their diameter and made of a metal of high heat conductivity and such great tensile strength as to enable them to have very thin walls. By making the cylinders long in proportion to their diameter I am enabled to secure the maximum of expansive force of the heated gas. Furthermore, by making the cylinders relatively long and of a metal of high heat conductivity the heat of the gas is so rapidly taken up and radiated that the temperatures of the cylinders may be kept within proper limits without the assistance of a cold-water jacket or of other means for the purpose, whereby the double advantage is effected of using the gas under the high temperature that is most favorable to a high efficiency and of dispensing with the use of water for keeping the temperature down. The use of a cooling-jacket adds weight to the engine and is peculiarly objectionable on account of the difficulty of carrying water when the engine is to be used for the propulsion of vehicles such as horseless carriages.

Before proceeding to the description of the operation of the engine it may be well to say that it is constructed and arranged for the ignition and explosion of a charge upon every alternate outstroke of the piston of each cylinder instead of upon every outstroke thereof, so that one "cycle" in the operation of the engine, if I may use that term, comprises two complete strokes of the piston, each complete stroke covering a forward stroke and a back stroke.

For convenience in describing the operation of the engine I have provided the drawings accompanying this description with a series of diagrammatic representations of one cylinder, showing the several phases through which it passes in one cycle of its operation, which must be understood to cover two revolutions of the crank-shaft, to which its piston-rod is connected. These diagrammatic drawings are numbered 9 to 16, inclusive. In making them I have indicated the explosive mixture by stippling and the combustion products by hatching. Beginning with Fig. 9, the same shows the cylinder with its piston at the limit of its back stroke and containing a compressed charge of explosive mixture. It may now be supposed that the ignition and explosion of the said charge of explosive material takes place with the effect of pushing the piston to the limit of its outstroke, this being what I may term the "power" stroke of the piston. Fig. 10 shows the cylinder after the piston has thus been driven to the limit of its outstroke, the cylinder itself being filled with combustion products. In Fig. 11, which represents the next phase of the operation of the cylinder, the piston has reached the intermediate position of its next back stroke and forced one half of the combustion products out through the exhaust-port, leaving the remaining half or remnant of the combustion products within the inner portion of the cylinder. The piston continuing its back stroke compresses the remaining remnant of the combustion products in the extreme inner end of the cylinder, as shown in Fig. 12. Now during the first half of the next succeeding outstroke of the piston the said remnant of combustion products just compressed, as above stated, are allowed to expand, as shown in Fig. 13. A partial vacuum is thus created within the cylinder, permitting the pressure of the atmosphere to open the valve of the atomizer, whereupon a charge of explosive mixture enters the inner end of the cylinder and pushes the now expanded remnant of the said combustion products from the inner end of the cylinder to the outer end thereof, as clearly shown in Fig. 14, which represents the inner end of the cylinder as filled with explosive mixture and the outer end of the cylinder as filled with combustion products. There is a clear line of demarcation between the mixture and products, for I have found that in the operation of the engine the explosive mixture and combustion products do not mix, at least not to any substantial degree. The piston now begins its second back stroke in this cycle of its operation and ejects through the exhaust-port of the cylinder the said remnant of combustion products, leaving nothing in the cylinder but the recently-introduced charge of explosive mixture, as shown in Fig. 14. Now as the piston completes this second back stroke the said charge is compressed preparatory to ignition and explosion, as shown in Fig. 16, which exactly corresponds to Fig. 9.

What I wish to call particular attention to in connection with the operation above described is that the combustion products are not exhausted or ejected all at one time, as has been universally done heretofore, so far as I am informed, but fractionally or by piecemeal. As herein shown, half of the combustion products are ejected at one time and half

at another time, though I conceive that this particular mode of fractional riddance of the products need not be followed. I also wish to emphasize the fact that to assist in the fractional ejection of the combustion products I utilize the pressure of the incoming explosive mixture for pushing the last half or remnant of combustion products from the inner end of the cylinder to the outer end thereof and into position for their ejection. I am enabled to utilize the explosive mixture in assisting the piston in getting rid of the combustion products because I have found that the explosive mixture and combustion products do not, at least in the brief time allowed, mix together to any substantial degree.

The positions of the valve during the above-described phases in the operation of the cylinder are indicated on the diagrams constituting Figs. 9 to 16, inclusive, by writing. I may add that the positions are indifferent as regards the work of the piston, except that the valve should be closed before the piston passes it on its outward stroke, that it should remain closed until the piston reaches nearly the limit of its outstroke, and that the valve should be wide open until after the piston passes it on its back stroke. The explosion takes place while the valve is closing and while it is still open; but this does not interfere with the effective action of explosion nor allow the escape of the gases when they reach the port, since the valve must fully close the port before the piston and the gases behind it can reach the port. By providing for the closing of the valve before the piston and the gases behind it reach the port and keeping it closed until at or about the time the piston reaches the limit of its outstroke no part of the heated gas is allowed to escape, but is permitted to expand to practically its full capacity for expansion and almost downpressure. By utilizing the expansion of the heated gas from the point of its highest tension down to atmospheric pressure I secure a very high degree of efficiency considering the units of fuel employed.

It will be understood from the foregoing description that in my improved engine I exhaust only one-half of the combustion products at each revolution of the shaft. By this fractional or piecemeal mode of exhausting the combustion products I reduce the noise of the exhaust, first, by reducing the amount of the exhaust at any one time, and, second, by reducing the pressure of the products exhausted by giving them time to part with their heat to the cylinder and piston. Obviously the lower the temperature of the products exhausted the less the pressure and consequently the noise of their exhaust.

It is apparent that in carrying out my invention a variety of changes from the construction herein shown and described may be made. Thus the atomizer and igniter may be replaced by any other suitable devices for the purpose. As before stated, I do not limit myself to the use of two cylinders, as one may be employed, if preferred. Furthermore, I do not limit myself to making the cylinders of any particular metal, though I prefer bronze, nor do I limit myself to constructing them in any particular proportions, as their proportions will depend upon the dictation of circumstances. I would therefore have it understood that I do not limit myself to the exact construction herein shown, but hold myself at liberty to make such changes as fairly fall within the spirit and scope of my invention.

I may add in conclusion that my improved engine is particularly well adapted to use as the motor of horseless carriages for the reason that its operation is attended with the minimum production of noise and shock. Furthermore, the absence of water-jackets or cooling devices renders this form of engine particularly adapted to the requirements of a motor-vehicle. For horseless carriages I should prefer to employ a two-cylinder engine, so that the two cylinders might be arranged, as shown, to act alternately and reciprocally, so that the action of one cylinder would assist the other cylinder in passing its dead-point, and vice versa.

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

1. In an explosive-gas engine, the combination with a cylinder having an exhaust-port located about midway the length of the stroke of the piston within the cylinder, and means coacting with the said exhaust-port for closing the same throughout each full forward stroke of the piston, and for opening the same during the first half of each backward stroke of the piston, whereby the half portion of the combustion products lying next to the piston is ejected through the said port during the first half of every backward movement of the piston.

2. In an explosive-gas engine, the combination with an oscillating cylinder hung at its inner end and having an exhaust-port located about midway the length of the stroke of its piston, of a valve with which the said port coacts, whereby the said port is closed throughout each full forward stroke of the piston and opened during the first half of each backward stroke of the piston, whereby the half portion of the products of combustion lying next to the piston is ejected through the said port during the first half of every backward movement thereof.

3. In an explosive-gas engine, a cylinder having an exhaust-port located about midway the length of the stroke of its piston, and a valve arranged to coact with the said port to close the same throughout each full forward stroke of the piston, and to open the same during the first half of each backward stroke of the piston, whereby the half portion of the combustion products lying next to the piston is ejected through the said port

during the first half of each backward movement thereof, the said valve comprising a recess and an opening communicating with the air.

4. In an explosive-gas engine, the combination with a cylinder having an exhaust-port, of a piston, a crank-shaft connected therewith, and means substantially as described for causing and controlling the following cycle of events in each period of two complete revolutions of the said crank-shaft, namely, first, explosion of compressed charge, second, expansion of gases following the piston throughout its forward stroke, third, ejection of a half portion of burned gas by first half of back stroke, fourth, compression of second half portion of burned gas by last half of back stroke, fifth, expansion of burned gas at first half of second forward stroke, sixth, inspiration of fresh charge behind the half portion of burned gas; seventh, ejection of second half of burned gas by first half of second back stroke, eighth, compression of charge and completion of cycle at end of second half of back stroke.

In testimony whereof I have signed this specification in the presence of two subscribing witnesses.

HARRY A. KNOX.

Witnesses:
D. C. REUSCH,
C. E. W. WOODWARD.