

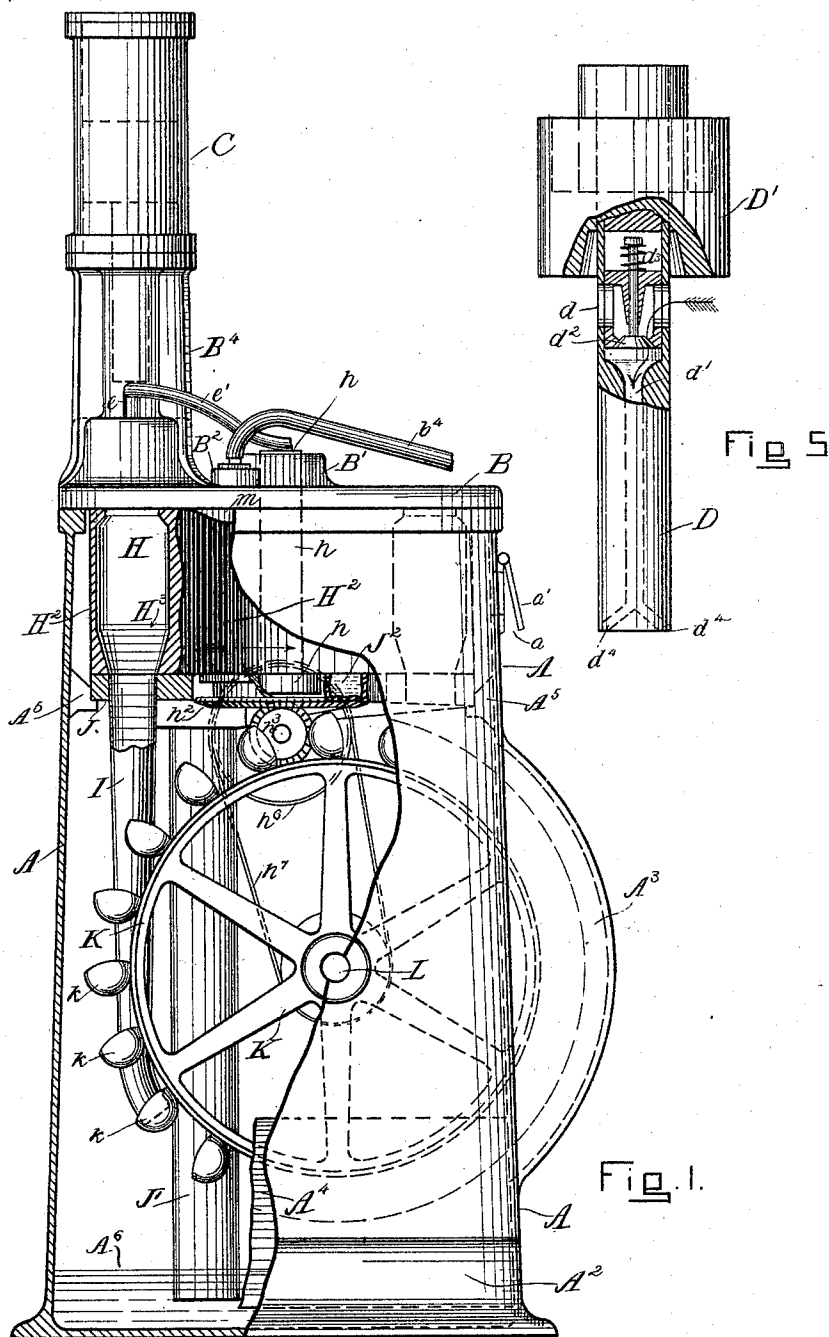
(No Model.)

3 Sheets—Sheet 1.

H. B. STEELE.
GAS ENGINE.

No. 585,601.

Patented June 29, 1897.



WITNESSES
E. L. Harlow.
L. H. Brown.

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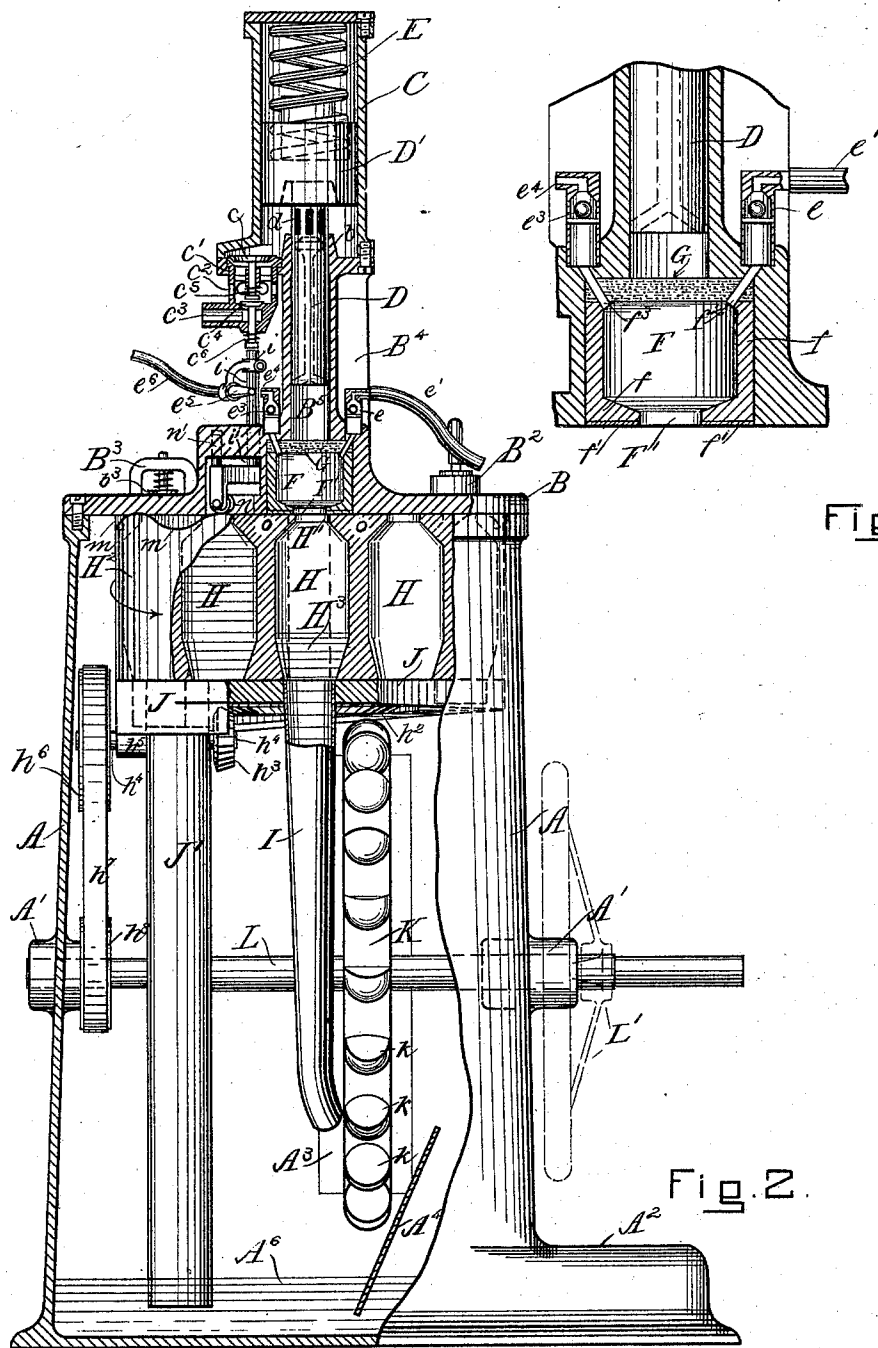
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3 Sheets—Sheet 2.

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(No Model.)

3 Sheets—Sheet 3

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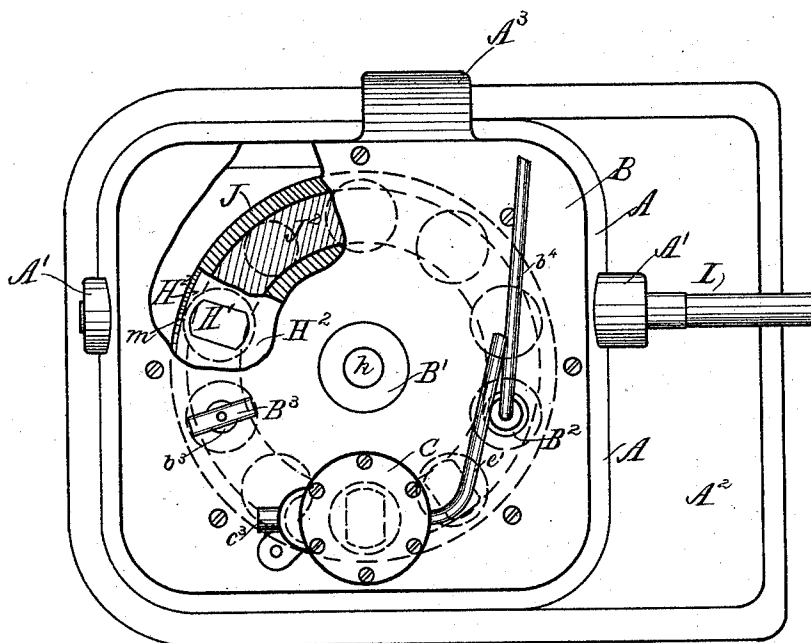


Fig. 3.

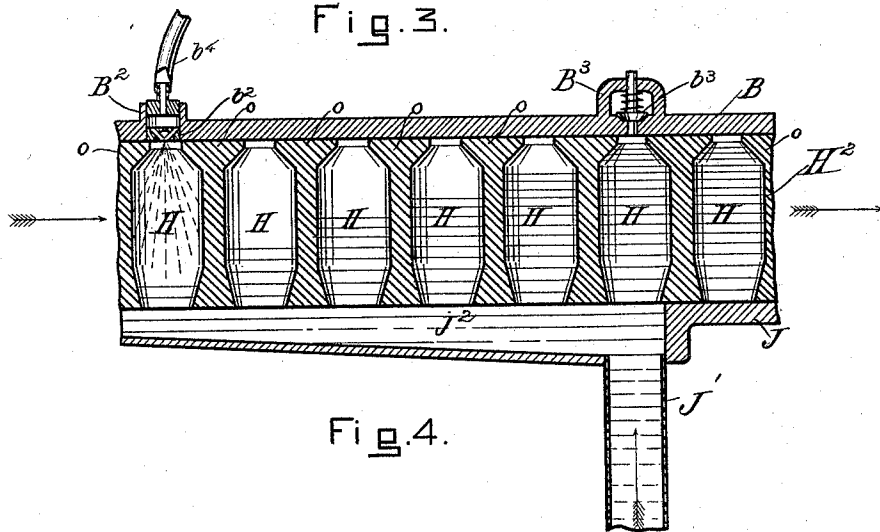


Fig. 4.

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UNITED STATES PATENT OFFICE.

HERBERT B. STEELE, OF MALDEN, MASSACHUSETTS.

GAS-ENGINE.

SPECIFICATION forming part of Letters Patent No. 585,601, dated June 29, 1897.

Application filed December 10, 1895. Serial No. 571,628. (No model.)

To all whom it may concern:

Be it known that I, HERBERT B. STEELE, of Malden, county of Middlesex, and State of Massachusetts, have invented new and useful
5 Improvements in Gas-Engines; and I hereby declare that the following is a full, clear, and exact description of the invention, which will enable others skilled in the art to which it ap-
10 pertains to make and use the same.

My invention relates to that class of combustion-engines in which the combustion takes place at approximately constant volume and in which the mixed charge of gas and air is compressed previous to explosion.

15 My invention consists of certain novel features hereinafter described, and particularly pointed out in the claims.

The principal loss in the existing type of gas-engines, and which it is sought to remedy, is due to the radiation from the exceedingly
20 hot gases to the cooler walls, which is proportional in amount to the difference in temperature between the two and to the time during which the exchange of heat can take
25 place—that is, the greater the difference of temperature and the longer the time the gases are exposed to it the greater such loss and the less the time and difference the less the loss. Now in the existing type, embodying
30 more or less heavy or directly-connected reciprocating or rotating parts, the expansion of the gases can proceed and their energy be developed only as fast as these parts and the load move and the intensely hot gases
35 are exposed to this loss during the entire time of a stroke or beat of the machine, so that in order to shorten the time of exposure the duration of each stroke must be shortened, which is identical with an increase in
40 the speed of the engine, so that in the present type of gas-engines the difficulties attendant upon an increase in speed, nicety of proportion and construction, and doubtful lubrication place a bar to the material lessening
45 of this loss through shortening the time during which it can take place. Such efforts as have been made look more to reducing the difference in temperature, and as the containing-walls could not be allowed to accumulate sufficient heat to materially affect
50 the same, they being used also for compression, and the heat then causing loss of power

or premature explosion, the expedient of reducing the difference by lessening the temperature of combustion through dilution of
55 the exploding charge with excess of air or with burned gases was adopted. Such expedients, however, are futile, because of the amount of heat it takes to raise this dilutant to the working temperature, which is carried
60 by it to waste.

From the necessity of clearing the cylinder of the products of combustion and from the use of the motor-cylinder in compressing the
65 gases arises the practice of making but half of the strokes motor-strokes and of storing for a time the power for compression. The result is to make the friction loss large in proportion to size and power, because of the
70 idle strokes and the double transmission of the power of compression, while the small number of impulses per unit of time makes the regulation difficult.

Another and very palpable loss in the present type of engines is the practice of throwing
75 away the gases before expansion is carried to atmospheric pressure and while yet considerable pressure remains available in them, and this practice arises from the difficulty of providing sufficient room or length of cylinder
80 and stroke for such an expansion and because the power saved, should such length of stroke be provided, would be largely offset by the increased frictional loss of the longer stroke, by the longer time of such stroke, which, as we
85 have seen, aggravates radiation, and by the bulk of machine for the power. Neither is any attempt made to utilize what power might be had from the condensation of the discharged
90 gases.

Now the present invention seeks to lessen the loss from radiation by making the time during which the loss can occur, and which we have seen in the old style is determined by inertia of moving parts and by the load,
95 much shorter than heretofore by divorcing at that time the motor-piston—that is, the piston by which the power is developed and which, as hereinafter recited, is composed of a liquid—from all mechanical connection with
100 the other parts of the engine, so that at the time of expansion of the charge it becomes a body free to move and subject to such of the laws of motion as refer particularly to the re-

lation of its mass (mass of the motor-piston) to the applied force, (force of the exploding charge,) so that the explosive force of the charge is entirely taken up in giving velocity to the piston and that the energy of the charge for an assignable time and space previous to its transformation to useful effort is entirely stored in the piston in the form of kinetic energy. As the piston is a free body and its velocity governed by the relations of its mass to the force of the explosive charge, by changing these relations the velocity of the piston and consequently the duration of the time in which the loss can occur may be made briefer and the loss therefore smaller than heretofore without the necessity of encountering the difficulties attendant upon greatly increasing the speed of the machine; and I still further lessen this loss from radiation by lessening the difference in temperature between the gases and their inclosing wall at the time this loss is most serious, and by providing separate chambers for the different stages in the use of the gas and advancing the gas stage by stage from one to the other, so that the walls may be of a temperature appropriate to their individual use and so that the combustion-chamber, where this loss is most felt, may be allowed to accumulate heat till the difference between it and the gases is much smaller than at present, and because of the separation without danger of communicating heat to the gases prematurely and losing power as existed heretofore; and I seek to lessen the frictional loss by taking the power for compressing directly from the exploding gases by a separate piston from that utilizing the expansion for driving the load, which is integral with the compressing-piston, and placing this preferably in a vertical position, by which its own friction is minimized, and by which I save all frictional loss due in the present style of engine to storing this power for a time and transmitting it to and fro.

As it is desirable that the pistons or bodies of matter should move forward and perform their office of absorbing the power of the expanding gases with great rapidity, a velocity much higher than that at present in use is attained by them, and as these pistons must be brought to a stop in order that they may yield up the power they have absorbed in useful work on the load, and in order to avoid the great shock and accompanying noise and wear upon any positive mechanism for bringing a solid piston to rest, I make them of some liquid, as water; and that sufficient time may be allowed to permit the use of the waste gases by condensing them, and that the piston-chamber be cleared of the products of combustion and the pistons be returned back to their original height without deducting from the useful time of the machine, I use a number of piston-chambers embodied in a translating device, so that while one is in action the others are being prepared at another place; and as I make the operations of re-

turning the pistons to the original height, discharging the burned gases, and translating the pistons into place continuous the result is a continuous succession of pistons to be acted upon by the exploding gases and be driven by them in one direction through the machine; and as the number of chambers in the translating device may be large enough to afford adequate time for cooling the contained waste gases and the channels leading the liquid to them may be of sufficient size the number of new pistons used in a given time may be as large as desired; and as the compressing is done by a direct-acting piston, governed in its time only by its weight and the elastic force of its cushion-spring, any number of charges of compressed gas may be delivered to the combustion-chamber. As the number of charges and the number of pistons are not limited, any required number of motor strokes may be made per unit of time, giving the utmost facility for regulation; and I overcome the difficulty of insufficient expansion in the existing class of engines by providing other chambers for the operations heretofore imposed upon the expansion-chamber—namely, compression, admission, and discharge of gas—and remove the restrictions of fixed stroke by having the piston free and arranging the mechanism so that the pistons go through the expansion-chamber from end to end in one direction and never backward; and being thus free of restrictions I make the expansion-chamber of sufficient size and shape that the expansion may be carried to atmospheric pressure, thus saving a large amount of power heretofore thrown away.

The construction and operation of the engine as I have found best to make it will be understood from the following specification and accompanying drawings, in which—

Figure 1 is a side and Fig. 2 a front elevation of my improved gas-engine, in both views of which a portion of the casing is broken out to show the interior construction and other parts broken away to exhibit vertical sections on the center line of compression and expansion chambers. Fig. 3 is a plan view in which parts are broken away to show the interior construction. Fig. 4 is a diagrammatic view, being the development of a section through the consecutive center lines of the piston-chambers and the liquid-carrying channel beneath. Fig. 5 is an enlarged detail view of the compressing-piston partially broken away to show the interior construction, and Fig. 6 is a detail of the combustion-chamber enlarged from Fig. 2.

Like letters of reference refer to like parts throughout the several views.

In the drawings, A is the frame or inclosing case, made somewhat box-like in general shape, with rounded vertical edges and provided with bosses A', forming bearings for the main shaft and having a forward extension of the base A², on which, should it be

desirable to a drive a machine by direct connection, the same may be fastened. The case is provided with a swell A^3 , conforming roughly to the inclosed wheel, and I place an inclined plate or partition A^4 , which is shown integral with the case, across the bottom of the same, whose office is to prevent the agitation of the liquid A^6 , which collects in base, by allowing the discharge from the wheel to impinge on it instead of directly entering the liquid-reservoir A^6 .

A^5 are lugs cast on the frame to serve as supports for parts to be later mentioned. The whole case is better made in one piece, but if in several the joints should be sufficiently tight to restrain the liquid in the base and any spray which may at any time form, as well as to deaden any noise.

B is the top or cover to the casing A and is attached to it by screws. It is formed with a central boss B^1 , carrying an interior supporting-pivot, and a boss B^2 for the connection of a water-pipe, a spanner-frame B^3 for a valve, and on the active side of the machine it forms a column B^4 , in the interior of which is my explosion-chamber and other parts, and which column carries the compression-chamber C upon its upper end. The upper interior portion of the column B^4 is bored to form a chamber B^5 and to receive the piston D, that it may reciprocate therein.

The compression-chamber C is over and attached to the upper end of the columnar portion B^4 , concentric with the bore for the piston D. It has in its interior and closely fitted thereto, but so that it can slide therein, the reciprocating piston D' .

The pistons D and D' are united solidly in one construction (see Fig. 5) and reciprocate as such in the chambers C and B^5 . They are provided with ports d near the upper end of the piston D, leading to a central passage d' , controlled by a check-valve d^2 , which opens to permit the downward motion of gases through said passage and is closed to prevent the reverse flow by a light spring d^3 , the said passage d' opening in the bottom face of the piston D in a number of mouths d^4 , (shown dotted in Fig. 5,) that merely divide and disperse gases flowing down the passage d' , so that they do not mix completely with those preceding.

An annular sleeve b (see Fig. 2) is raised from the column B^4 in the cylinder C, surrounding and fitting the piston D, of such a height that it will cover the ports d and prevent further flow through them when the piston in descending nears the end of its stroke and thereafter until the same point is reached in the upstroke, and the sleeve is thus arranged in order that the gases then in the lower part of the cylinder C will be confined and form a cushion, so that the metallic piston D' may not strike the bottom of the cylinder.

In the upper end of the chamber C is the heavy spring E of such a length that it is

substantially uncompressed when the piston D' is at the lower end, but offers an increasing resistance to its upward motion, the effect of which may be enhanced, if so desired, by imprisoning air in the portion of the chamber C surrounding the spring E above the piston.

The pistons D and D' are propelled upward by the force of the explosion operating on the under side of piston D and move so far vertically against the action of the spring E as the force of the explosion determines, and the extent of this motion varies with the variation of this force, and during their upward stroke mixed gas and air are drawn from suitable valves into the lower part of chamber C, vacated by the piston, and when the upward impulse of pistons has spent itself the spring forces the pistons back, compressing the gases which have entered the chamber and forcing them to flow through the ports d and passage d' of the piston D, as shown by arrow in Fig. 5, from the compressing-chamber to beyond the end of the piston D.

The admission of gas and air into the lower end of the chamber C is accomplished by placing an ordinary circular poppet-valve c in a valve-casing c' , which is inserted in the upper part of the column B^4 , with its upper end opening into an extension of the cavity of the chamber C, and this valve rises when the piston D' moves upward, because of the vacuum then formed, and seats itself by aid of a light spring c^5 when the pressure in chamber C reaches that of the atmosphere.

There are a number of openings c^2 in the valve-casing c' , through which air is admitted when the valve is raised and the piston is drawing the same, and there is a second poppet-valve c^4 in the valve-casing c' , underneath the first valve c , through which when the valve is raised gas is admitted to the central cavity of the valve-casing from the passage c^3 , which is to be placed in communication with the supply of gas at atmospheric pressure, and in the valve-casing it mingles with the air from the openings c^2 and passes that into the compressing-chamber. The proportion which the gas and air bear to each other is determined by the ratio of the area of the opening of the valve c^4 to the total area of the openings c^2 (which it would be good practice to make about as one to seven) and to the time the valve c^4 is raised.

In the base of the column B^4 and directly under the piston-chamber B^5 and separated therefrom by a regenerator G, consisting of a compressed layer of wire-gauze or a number of perforated metal plates, is my combustion-chamber F, which is lined with a non-conducting refractory lining f , (see Fig. 6,) such as graphite faced with a metallic shoe f' on the bottom. The chamber F is somewhat contracted at the bottom, thus forming with the lining f and shoe f' a port or opening F' , as shown in Figs. 2 and 6.

Below the chamber F and so that their mouths or ports H' pass and coincide in turn with the port F' are a series of piston-chambers H, whose function is to bring new fluid-pistons to operative position under the combustion-chamber F, and of which in the machine illustrated there are ten embodied in one large cylinder (marked H²) which rotates in a horizontal plane upon the pivot h, the end of which shows in Fig. 3 the head back of the broken gear h² and the body dotted in Fig. 1, which is fast in the central boss B'. The cylinder H² is rotated by the bevel-gear h², which is made fast to it (from the hub of this gear in Fig. 1 a piece is broken) and is driven by the bevel h³, which meshes with it and which is fast to one end of the shaft h⁴, journaled in a projecting boss h⁵ on the liquid-carrying chute or trough. On the other end of this shaft is fast a pulley h⁶, connected by belt h⁷ with a pulley fast on the main shaft. This mechanism of transmission should be so proportioned in a given engine that while the main shaft rotates at the speed desired the number of piston-chambers passing the combustion-chamber in a given time should equal the number of vibrations of the compressing-pistons D D' in the same time, and which we shall see is determined by the weight of the pistons and the strength of the spring E.

Now below the cylinder H² is a plate J, supported by lugs A⁵ on the frame, between the upper surface of which and the under side of the cover-plate B the cylinder H² is accurately fitted to rotate, which plate J, besides supporting the shaft h⁴, serves also as a support for the ejector-tube or expansion-chamber I and as a support for the pipe J', the upper ends of which are firmly fixed therein, while the main body is formed into a trough (seen in Fig. 3, marked J², and as a broken section in Fig. 1) extending circularly around under the cylinder, so as to be always under the mouths of the piston-chambers as they move, shallow at the beginning, corresponding to the position of the chamber removed next but one from the exploding-chamber and increasing in depth as it follows around until it ends in the pipe J' at the other side, where it is about the depth of the diameter of a piston-chamber. The pipe J' is fixed in the deep end of the trough about under the position of the piston-chamber next but one before arriving at the explosion-chamber, and its lower end is near the bottom of the frame, so as to be below the surface of the liquid there. Over the end of pipe J' approximately, but in the cover-plate B, is a puppet-valve b³, (see Figs. 2, 3, and 4,) opening into the atmosphere with only a very light spring to seat it, serving to permit the outward flow of gases from the piston-chambers at this point. Also over the beginning of the trough J² at next position but one after piston-chamber has reached the exploding position there is arranged in the cover-plate a spray-making device B², consisting of two small streams of

water b², fed through tube b⁴, which collide with considerable velocity just above the level of the cylinder, whereby both are dissipated in spray, which fills for a moment each cylinder as it passes under the same.

Now the action of the trough can best be understood from Fig. 4, which represents a section taken circularly around the revolving cylinder H², following the centers of the piston-chambers and unrolled, so that the consecutive positions of the piston-chambers may be exhibited clearly in their proper relation to each other and to the cover-plate above and the trough J² and pipe J' below. In said figure the motion of the piston-chambers is represented as that from left to right, and the first represented is that which after doing service in the explosion and still filled with the hot gases therefrom is now under the spraying device, which is shown projecting its spray throughout this chamber. It will have therefore its gases cooled, and consequently reduced in pressure much below that at which they were received, and will pass from this position at a uniform speed from left to right, and the succeeding steps in its progress will be represented by the other chambers which have preceded it. Below the chambers is seen the trough J², which is in continuous communication with the under side of the piston-chambers. As the piston-chambers pass in regular succession the gases in the chambers are cooled by the spray, each chamber drawing from the channel J² in passing over the same in starting successive portions of air, if such has leaked in while the machine was at rest, and in amount corresponding with the shrinkage of the gases consequent to their cooling until the air, if any, is wholly carried off, causing the liquid to rise in the pipe J' to replace it until the liquid also rises in the chambers on the contraction of the gases. When in full operation, the liquid will rise in pipe J' and flow in the channel J² with some considerable velocity, as the reduction of pressure in the chambers is several pounds per square inch, so that after the liquid has risen in a chamber as far as is called for by the contraction the chamber comes directly over the pipe J' and the liquid impelled forward in its vertical course by the momentum it has acquired ascend in the chamber and ejects the gases remaining in the same into the atmosphere through the puppet-valve b³, nearly filling the chamber, from which time until the chambers pass to the discharging position in line with the explosion-chamber the liquid is retained by the faces of plates J and B, between which the piston-chamber moves. Also fast in the plate J by its upper end and in contact with the piston-chamber piece H² is held the expansion-chamber I, through which each charge of the liquid is propelled when the mouth of the piston-chamber is fair with the opening in same and under the explosion-chamber, and the general shape of the same

is that of a spout or nozzle gradually tapering from the receiving end to a smaller size at the delivery and sufficiently capacious to allow the full expansive effect of the gas to be produced, and its delivery end is slightly curved, so that an expelled charge will strike the cup-shaped vanes *k*, attached to the periphery of an impulse-wheel *K* at the side of both, but as near as may be tangentially to the vanes, which should be practically spherical, as exposed to the action of the ejected liquid, that it may strike into the same without shock and be brought to rest without eddymaking, and the appropriate velocity of the rim of the wheel is one-half the velocity of the issuing charge, which in turn is determined by the weight of charge employed and the expansive force of the explosion; and the size of the wheel should be made such as will give the desired rotative speed and still maintain the velocity of rim of the wheel, as determined above.

The wheel *K* is fast upon the shaft *L*, running in journals in the bosses *A'* of the frame and projecting beyond for connection with the machine driven, and upon which also is the small pulley *h'* for rotating the piston-chambers, as before described.

Now the operation of the machine is as follows: Starting from the time when the previous explosion has taken place, the pistons *D D'* are driven up, compressing the spring *E* and drawing mixed gases into the bottom of the compressing-chamber *C*, and the piston-chambers have rotated sufficiently to bring a solid portion *o* of the upper face of the cylinder *H²* under the opening *F'* of the explosion-chamber. The pistons *D D'* immediately return, driving the new gases in the bottom of chamber *C* and the old gases with which the space *B³* under the piston *D* is filled before them, compressing both and transferring the new charge from chamber *C* through the passages in piston *D* into the cylinder *B⁵* on top of the gases already there, and both through the regenerator *G* into the combustion-chamber *F*, the spent gases preceding the fresh, where now, the piston *D* being down or nearly down to the regenerator and the piston *D'* in the lower part of its cylinder and the oncoming piston-chamber with opening *H'* beginning to uncover the opening *F'* that the gases may have effect, the explosion occurs and the piston is driven on through the expanding-chamber *I*, acquiring a high velocity and impinging upon the impulse-wheel *K*, to which it imparts its momentum and being thereby brought to rest. Upon the occurrence of this explosion the valve *d²* in the passage of piston *D* is closed and the piston is driven up and the cycle repeated. A part of the gases pass through the regenerator upward upon the occurrence of an explosion, yielding up somewhat of their heat, enough to protect the oncoming gases from the temperature of the combustion-chamber while above the regenerator, thus preventing

premature explosion, and the regenerator returns the heat to them after compression, thus securing more powerful explosion. There is no separate device in this engine for securing explosion, this being occasioned by the heat of the combustion-chamber and the compression and occurs when the gases are projected into the chamber at the last of the downward stroke of the piston *D*. It should be understood that this cycle of compression, explosion, and expansion is extremely rapid, so that in engines of, say, twenty horse-power six hundred reciprocations of pistons *D D'* can easily be obtained per minute, and the expansion of the charge is more rapid than indicated by above figures, as the liquid piston is free from all mechanical restraint and takes a velocity proportional to the explosive force.

In Figs. 1 and 2 the explosion is supposed to have occurred, and the pistons *D D'* are shown part way in their upward stroke, drawing in fresh charge through the valve *c*, while the liquid piston (indicated by horizontal lines marked *H³*) is seen about two-thirds expelled from the piston-chamber and partially in the expansion-chamber *I*, while in Fig. 2 a new piston is seen advancing from the left and an empty piston-chamber retreating on the right to move under the spraying device *B²* and reach other mechanism for filling the same. The clearance of the expansion-chamber *I* of waste gases from a discharge is effected by the next piston driving them out and into the case *A*, where they would accumulate and increase in pressure if an opening in same were not provided, which is seen at *a*, and as the gases are of possible utility when supplied under some small pressure the opening is provided with a valve *a'*, which may cause such to accumulate; also, a slight pressure in the case may be used by acting on the face of the liquid in the bottom of the case to raise the same in the tube *J'* and fill the piston-chambers, instead of depending on the cooling of gases, as before described, for accomplishing same, or both can be used jointly.

For convenience in starting I have supplied a passage *f²*, (see Fig. 6,) entering the combustion-chamber, provided with a check-valve *e*, admitting to chamber, but preventing the return flow, to be connected by the tube *e'* to a source of mixed gas and air, and a second passage *f³*, also provided with a check-valve *e³* to resist a flow out from the chamber, but permit a flow thereto, and I clamp a small gas-jet *e⁵*, supplied with gas from the pipe *e⁶*, to the reciprocating rod *i* at such a place on said rod that the flame will pass an orifice *e⁴* of the check-valve *e³* at the same time that a solid portion *o* between two piston-chambers in the cylinder *H²* passes under the mouth *F'* of the combustion-chamber.

In starting first some one of the piston-chambers is brought under the combustion-

chamber and mixed gas and air from the tube e' allowed to enter the combustion-chamber F and fill the same. After doing so they will make their appearance at the orifice e^4 of check-valve e^3 , when they should be lighted, and on so doing the flame will strike back and light what is in the chamber F and the stream coming in through passage f^2 , and this should be allowed to burn until the lining of the chamber F is quite hot, but not enough to ignite mixed gases by contact, and then the supply should be stopped for a moment, when the flame will become extinguished in the chamber F, and upon the mixed gas and air flowing a second time through the passage f^2 the chamber is filled and the mixed gases again issue from the orifice e^4 . The engine is now turned by hand, usually on some of the driven mechanism attached to the shaft L, though a special wheel may be applied at L' should no part of the driven machine be convenient therefor, and when one of the solid partitions o of the cylinder H^2 passes under and closes the opening F' the jet e^5 will come in contact with and ignite the gas issuing from orifice e^4 , as above stated, which will strike back and explode the contents of combustion-chamber F, and the gas now being confined the pressure will rise and close the cheek-valves e and e^3 , and also d^2 in the piston D, driving the latter up a short stroke, whence it will return, driving a compressed charge of gas into the cylinder F, where, if the operator has been expert enough and rotated the cylinder H^2 by his hand, so that the solid portion o is under the part F', the charge will be compressed and exploded, and on the continuation of the rotation of the cylinder H^2 , so that the mouth of a piston-chamber H' is opposite the opening F' of the combustion-chamber F, the piston will be driven out and the machine become self-acting. If the operator is not expert enough to turn the machine at the appropriate speed and the solid part of H^2 does not arrive under the opening of F' in time to allow the descent of the piston D to compress the gases in the chamber F and they do not explode spontaneously, they will be fired by the jet on continuing the motion by hand and at the appropriate time, so that any number of attempts can be made without especial effort by simply turning the machine by hand, or it will now run and accumulate speed as a non-compression engine, and when the proper speed is reached and the combustion-chamber is closed by a solid partition coincident with the downward stroke of pistons D D' it will compress and explode its charge spontaneously and continue self-acting and deliver its power to the load.

The regulation of the speed of this machine is accomplished as follows: The pistons D D', with the spring E, constitute a kind of pendulum, the vibrations of which have a certain periodicity or natural time in which they oc-

cur, which is constant for a given machine or proportion of weight of pistons to strength of spring and independent of the force of the explosion, the effect of explosions of different strength being to cause a greater or less throw to the pistons D D', drawing into the compression-chamber C greater or less charges of gas and air. Further, I cut upon the upper edge of the cylinder H^2 a multiple cam m , having one throw for each piston-chamber embodied in same, and I place above this cam m a cam-roll n and vertical tappet-rod i , held in operative relation by the fitting of the stem i' and plug n' in an enlargement of the cover-plate B, so that the cam m causes a lift to the tappet i for each chamber H, and I make this rise to take place about the time the edge H' of the chamber H passes the edge F' of the explosion-chamber, and I prolong the stem i' of the roll-carrier into a tappet i of such length that it will raise the valve c^4 by striking its stem c^6 on its upward stroke, thus opening the valve c^4 of the passage c^3 .

Now it is evident that should any change occur in the load the engine was driving, as the reciprocations of the pistons D D' are constant, the cylinder H^2 would, when the engine started to change speed, go a little faster or slower than the pistons because of its direct connection with the shaft L, causing a corresponding shifting of the time during which the valve c^4 remained open, making it occur sooner or later than before, thus altering the amount of time during which the valves c^4 and c would both be open, and consequently the amount of gas that would be drawn from c^3 to mingle with the air and pass to the compression-chamber C and form the explosive charge, and the change in strength of the charge causes a change in the stroke of pistons D, resulting in increasing or decreasing the amount of charge supplied by them for the succeeding explosions. So when the cylinder H^2 starts at increased speed the puppet-valve c^4 opens and closes sooner than before, decreasing the amount of gas that can be drawn therefrom, and in the charge which produces an impulse of the pistons D D' less in amount and resulting in its taking in smaller charge of gas and air and lessening the power of machine, and when the cylinder H^2 fell behind the valve c^4 would stay open later, resulting in strengthening the charge of gases and increasing the amount supplied and the power of the machine—that is, the lagging or advance of the cylinder H^2 consequent upon a change of load changes the power of the machine in proportion with the load and without a noticeable change in the speed of the machine.

I do not limit myself to the arrangement and construction shown, as the same may be varied without departing from the spirit of my invention.

Having thus ascertained the nature of my invention and set forth a construction em-

bodily the same, what I claim as new, and desire to secure by Letters Patent of the United States, is—

1. In an explosive-engine, a combustion-chamber, means for introducing air and gas into said chamber, means for exploding said mixture therein, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, and a driving-shaft adapted to be actuated by the liquid expelled from said chambers.

2. In an explosive-engine, a combustion-chamber, means for introducing air and gas into said chamber, means for exploding said mixture therein, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid driven from each piston-chamber by said explosive force in the combustion-chamber.

3. In an explosive-engine, a combustion-chamber, means for introducing air and gas into said chamber, means for exploding said mixture therein, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means for refilling said discharged piston-chambers.

4. In an explosive-engine, a combustion-chamber, means for introducing air and gas into said chamber, means for exploding said mixture therein, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, means on said shaft for receiving the impact of the liquid driven from each piston-chamber by said explosive force in the combustion-chamber, and means for refilling said discharged piston-chambers.

5. In an explosive-engine, a combustion-chamber, means for introducing air and gas into said combustion-chamber, means for exploding said mixture therein, a series of piston-chambers adapted to be filled with a liquid and to be successively brought under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, means on said shaft for receiving the impact of the liquid driven from each piston-chamber by the said explosive force in the combustion-chamber,

and mechanism actuated by said shaft for moving said piston-chambers.

6. In an explosive-engine, a combustion-chamber, means for introducing air and gas into said combustion-chamber, means for exploding said mixture therein, a cylinder mounted on a pivot and provided with a series of piston-chambers adapted to be filled with a liquid, means for moving said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid driven from each piston-chamber by the said explosive force in the combustion-chamber.

7. In an explosive-engine, a combustion-chamber, means for introducing air and gas into said combustion-chamber, means for exploding said mixture therein, a series of piston-chambers adapted to be filled with a liquid and to be successively brought under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and a wheel fast on said shaft and provided with vanes for receiving the impact of the liquid driven from each piston-chamber by the said explosive force in the combustion-chamber.

8. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, means for controlling the admission of said air and gas to said chamber, a piston located in said chamber, means acting on said piston for compressing and forcing said mixture of air and gas from the said compression-chamber into the said combustion-chamber, a series of piston-chambers adapted to be filled with a liquid and to be successively brought under the combustion-chamber to receive the explosive force of the air-and-gas mixture, and a driving-shaft adapted to be actuated by the liquid expelled from said chambers.

9. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, means for controlling the admission of said air and gas to said chamber, a piston located in said chamber, means acting on said piston for compressing and forcing said mixture of air and gas from the said compression-chamber into the said combustion-chamber, a series of piston-chambers adapted to be filled with a liquid and to be successively brought under the combustion-chamber to receive the explosive force of the air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chamber by the said explosive force in the combustion-chamber.

10. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, means for controlling the ad-

mission of said air and gas to said chamber, a piston located in said compression-chamber, means acting on said piston for compressing and forcing said mixture of air and gas from the said compression-chamber into the said combustion-chamber, a passage from the said compression-chamber to the said combustion-chamber, a valve located in said passage adapted to permit the flow of the air-and-gas mixture into the combustion-chamber and to prevent the return flow of said mixture into the compression-chamber from the combustion-chamber, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chambers by said explosive force in the combustion-chamber.

11. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, means for controlling the admission of said air and gas to said chamber, a piston located in said compression-chamber, means acting on said piston for compressing and forcing said mixture of air and gas from the said compression-chamber into the said combustion-chamber, a passage from the said compression-chamber to the said combustion-chamber through the said piston, a valve located in said passage adapted to permit the flow of the air-and-gas mixture into the combustion-chamber and to prevent the return flow of said air-and-gas mixture into the compression-chamber from the combustion-chamber, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chambers by said explosive force in the combustion-chamber.

12. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving the air and gas, means controlling the admission of said air-and-gas mixture to said chamber, a piston located in said compression-chamber having one part closely fitting in said chamber and the other part of a lesser diameter and provided with an internal passage leading from said compression-chamber to the said combustion-chamber, means acting on said larger part for compressing and forcing said air-and-gas mixture through said passage, a valve located in said passage adapted to permit the flow of the air-and-gas mixture into the combustion-chamber and to prevent the return flow of said air-and-gas mixture into the compression-chamber, a series of piston-chambers adapted to be filled with the

liquid and to be successively brought under the combustion-chamber to receive the explosive force of the air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chambers by the said explosive force in the combustion-chamber.

13. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, means for controlling the admission of said air and gas to said chamber, a piston located in said compression-chamber, means acting on said piston for compressing and forcing said mixture of air and gas from the said compression-chamber into the said combustion-chamber, the said piston being adapted to be given a return movement against said means by the pressure of the explosion in the combustion-chamber, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chambers by said explosive force in the combustion-chamber.

14. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, means for controlling the admission of said air and gas to said compression-chamber, a piston located in said compression-chamber, means acting on said piston for compressing and forcing said mixture of air and gas from the said compression-chamber into the said combustion-chamber, the said piston being adapted to be given a return movement against said means by the pressure of the explosion in the combustion-chamber and adapted in said return movement to cause the admission of air and gas into said compression-chamber, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chambers by said explosive force in the combustion-chamber.

15. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, means for controlling the admission of said air and gas to said compression-chamber, a piston located in said compression-chamber, means acting on said piston for compressing and forcing said air-and-gas mixture into the combustion-chamber and adapted in said movement to prevent the admission of air and gas into the compression-chamber, the said piston being adapted to be

given a return movement against said means by the pressure of the explosion in the combustion-chamber and adapted in said return stroke to cause the admission of air and gas into the said compression-chamber, a series of piston-chambers adapted to be filled with a liquid and to be successively brought under the combustion-chamber to receive the explosive force of the air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chambers by the said explosive force in the combustion-chamber.

16. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, means for controlling the admission of said air and gas to said compression-chamber, a piston located in said compression-chamber, means acting on said piston for compressing and forcing said air-and-gas mixture into the combustion-chamber and adapted in said movement to cut off the passage of air and gas from the compression-chamber to the combustion-chamber, the said piston being adapted to be given a return movement against said means by the pressure of the explosion in the combustion-chamber, a series of piston-chambers adapted to be filled with a liquid and to be successively brought under the combustion-chamber to receive the explosive force of the air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chambers by the said explosive force in the combustion-chamber.

17. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, means for controlling the admission of said air and gas to said compression-chamber, a passage leading from said compression-chamber to the said combustion-chamber, a valve located in said passage adapted to permit the flow of the air-and-gas mixture into the combustion-chamber and to prevent the return flow of said mixture into the compression-chamber, a piston located in said compression-chamber, means acting on said piston for compressing and forcing said air-and-gas mixture into the combustion-chamber and adapted in said movement to prevent the admission of air and gas into the compression-chamber and to cut off the passage of air and gas from the compression-chamber to the combustion-chamber, the said piston being adapted to be given a return movement against said means by the pressure of the explosion in the combustion-chamber and adapted in said return stroke to cause the admission of said air and gas into the compression-chamber, a series of piston-chambers adapted to be filled with a liquid and to be successively brought under the combustion-chamber to receive the explosive force of the air-and-gas mixture, a driving-shaft adapted

to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid drawn from said piston-chambers by the said explosive force in the combustion-chamber.

18. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, valves for controlling the admission of air and gas into the compression-chamber, a passage leading from said compression-chamber to the said combustion-chamber, a valve located in said passage adapted to permit the flow of the air-and-gas mixture into the combustion-chamber and to prevent the return flow of said air-and-gas mixture into the compression-chamber, a piston located in said compression-chamber, means acting on said piston for compressing and forcing said air-and-gas mixture into the combustion-chamber and adapted in said movement to close said valves to prevent the admission of air and gas into the compression-chamber and to cut off the passage of air and gas from the compression-chamber to the combustion-chamber, the said piston being adapted to be given a return movement against said means by the pressure of the explosion in the combustion-chamber and adapted in said return stroke to open said valves and thereby allow the admission of said air and gas into the compression-chamber, a series of piston-chambers adapted to be filled with a liquid and to be successively brought under the combustion-chamber to receive the explosive force of the air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid drawn from said piston-chambers by the said explosive force in the combustion-chamber.

19. In an explosive-engine, a combustion-chamber provided with a lining of non-conducting, refractory material, means for heating said lining, a compression-chamber for receiving air and gas, means for controlling the admission of air and gas into the said chamber, means for compressing and forcing said mixture of air and gas from the compression-chamber into the said combustion-chamber, a series of piston-chambers adapted to be filled with a liquid and to be successively brought under the combustion-chamber to receive the explosive force of the air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chambers by the said explosive force in the combustion-chamber.

20. In an explosive-engine, a combustion-chamber, means for introducing air and gas into said chamber, means for exploding the said mixture therein, a liquid-reservoir, a series of piston-chambers adapted to be filled with the liquid from said reservoir and to be successively brought under the combustion-

chamber to receive the explosive force of the air-and-gas mixture, water connections between said reservoir and the discharged piston-chambers, means for spraying water into each piston-chamber after the discharge of the liquid contained therein to produce a vacuum to draw water into said discharged piston-chambers from said reservoir, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chambers by the said explosive force in the combustion-chamber.

21. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, a passage leading from said compression-chamber to the said combustion-chamber, a valve in said passage adapted to permit the flow of the air and gas from the compression-chamber to the combustion-chamber and to prevent the return flow of air and gas from the combustion-chamber to the compression-chamber, means for forcing said mixture of air and gas from said compression-chamber into said combustion-chamber, a liquid-reservoir, a series of piston-chambers adapted to be filled with the liquid from said reservoir and to be successively brought under the combustion-chamber to receive the explosive force of the air-and-gas mixture, water connections between said reservoir and the discharged piston-chambers, means for spraying water into each piston-chamber after the discharge of the liquid contained therein to produce a vacuum to draw water into said discharged piston-chambers from said reservoir, a driving-shaft adapted to be actuated by the liquid expelled from said chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chambers by the said explosive force in the combustion-chamber.

22. In an explosive-engine, a combustion-chamber, means for introducing air and gas into the said combustion-chamber, means for exploding the said mixture therein, a liquid-reservoir, a series of piston-chambers adapted to be filled with the liquid and to be successively brought under the combustion-chamber to receive the explosive force of said air-and-gas mixture, water connections between said liquid-reservoir and the discharged piston-chambers, means for spraying water into each piston-chamber after the discharge of the liquid contained therein to produce a vacuum to draw water into the said discharged piston-chambers from the said reservoir, means for permitting the escape of the air from each piston-chamber as it approaches the combustion-chamber, a driving-shaft adapted to be actuated by the liquid expelled from the said chambers, and means on the said shaft for receiving the impact of the liquid driven from said piston-chambers by the explosive force in the combustion-chamber.

23. In an explosive-engine, a combustion-

chamber, a compression-chamber for receiving air and gas, a passage leading from said compression-chamber to the said combustion-chamber, a valve in said passage adapted to permit the flow of the air and gas from the compression-chamber to the combustion-chamber and to prevent the return flow of air and gas from the combustion-chamber to the compression-chamber, means for forcing said mixture of air and gas from said compression-chamber into said combustion-chamber, a liquid-reservoir, a series of piston-chambers adapted to be filled with the liquid from said reservoir and to be successively brought under the combustion-chamber to receive the explosive force of the air-and-gas mixture, water connections between said reservoir and the discharged piston-chambers, means for spraying water into each piston-chamber after the discharge of the liquid contained therein to produce a vacuum to draw water into said discharged piston-chambers from said reservoir, means for permitting the escape of the air from each piston-chamber as it approaches the combustion-chamber, a driving-shaft adapted to be actuated by the liquid expelled from the said chambers, and means on the said shaft for receiving the impact of the liquid driven from said piston-chambers by the explosive force in the combustion-chamber.

24. In an explosive-engine, a combustion-chamber, means for introducing air and gas into said combustion-chamber, means for exploding said mixture therein, a series of piston-chambers adapted to be filled with a liquid, an expansion-chamber adapted to receive the liquid discharged from said piston-chambers, means for moving said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture and over said expansion-chamber to receive the liquid driven from each piston-chamber by said explosive force, a driving-shaft adapted to be actuated by the liquid expelled from said chambers through said expansion-chamber, and means on said shaft for receiving the impact of the liquid driven from each piston-chamber through the expansion-chamber by the explosive force in the combustion-chamber.

25. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, a passage leading from said compression-chamber to the said combustion-chamber, a valve in said passage adapted to permit the flow of air and gas from the compression-chamber to the combustion-chamber and to prevent the return flow of air and gas from the combustion-chamber to the compression-chamber, means for forcing said mixture of air and gas from the said compression-chamber to the said combustion-chamber, a series of piston-chambers adapted to be filled with a liquid, an expansion-chamber adapted to receive the liquid discharged from said piston-chambers, means for moving

said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture and over said expansion-chamber to receive the liquid driven from each piston-chamber by said explosive force, a driving-shaft adapted to be actuated by the liquid expelled from said chambers through said expansion-chamber, and means on said shaft for receiving the impact of the liquid driven from each piston-chamber through the expansion-chamber by the explosive force in the combustion-chamber.

26. In an explosive-engine, a combustion-chamber, a chamber for receiving air and gas, means for controlling the introduction of air and gas into said receiving-chamber, means for exploding the said mixture in said combustion-chamber, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, mechanism actuated by the movement of said piston-chambers for actuating said controlling means to regulate the amount of air and gas introduced into the receiving-chamber, and a driving-shaft adapted to be actuated by the liquid expelled from said piston-chambers.

27. In an explosive-engine, a combustion-chamber, a chamber for receiving air and gas, means for controlling the introduction of air and gas into said receiving-chamber, means for exploding the said mixture in said combustion-chamber, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, mechanism actuated by the movement of said piston-chambers for actuating said controlling means to regulate the amount of air and gas introduced into the receiving-chamber, a driving-shaft adapted to be actuated by the liquid expelled from said piston-chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chambers by said explosive force in the combustion-chamber.

28. In an explosive-engine, a combustion-chamber, a chamber for receiving air and gas, valves for controlling the introduction of air and gas into said receiving-chamber, means for exploding the said mixture in said combustion-chamber, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a rod having on its lower end a roller, a cam-surface on said piston-chambers with which said roller is in contact and adapted in the movement of the piston-chambers to cause said rod to actuate said controlling-valves to regulate the amount of air and gas introduced into the receiving-chamber, a driving-

shaft adapted to be actuated by the liquid expelled from said piston-chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chambers by said explosive force in the combustion-chamber.

29. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, a piston located in said compression-chamber, means acting on said piston adapted to be compressed by the explosion in the combustion-chamber and upon the expansion thereof to cause said piston to compress and force said mixture of air and gas from the said compression-chamber into the said combustion-chamber for the next explosion, a driving-shaft, a liquid adapted to be actuated by the explosive force of the air-and-gas mixture in the combustion-chamber, and means on said shaft for receiving the impact of the liquid actuated by the said explosive force in the combustion-chamber.

30. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, a piston located in said compression-chamber, means acting on said piston adapted to be compressed by the explosion in the combustion-chamber and upon the expansion thereof to cause said piston to compress and force said mixture of air and gas from the said compression-chamber into the said combustion-chamber for the next explosion, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from the said piston-chambers, and means on said shaft for receiving the impact of the liquid driven from said piston-chambers by said explosive force in the combustion-chamber.

31. In an explosive-engine, a combustion-chamber, means for introducing air and gas into said chamber, means for exploding said mixture therein, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said piston-chambers, and means for forming a new liquid piston in each piston-chamber from which the liquid has been expelled by said air-and-gas explosion.

32. In an explosive-engine, a combustion-chamber, means for introducing air and gas into said chamber, means for exploding said mixture therein, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said piston-chambers,

and means for forming a succession of liquid pistons in the piston-chambers after the liquid has been driven from said chambers by the explosion.

- 5 33. In an explosive-engine, a combustion-chamber, a compression-chamber for receiving air and gas, means for controlling the admission of air and gas to said chamber, means acting on said piston adapted to be com-
10 pressed by the explosion in the combustion-chamber and upon the expansion thereof to cause said piston to compress and force said mixture of air and gas from the said compression-chamber into the said combustion-
15 chamber for the next explosion, a series of piston-chambers adapted to be filled with a liquid, means for bringing said piston-chambers successively under the combustion-chamber to receive the explosive force of said
20 air-and-gas mixture, a driving-shaft adapted to be actuated by the liquid expelled from said piston-chambers, and means for forming a new liquid piston in each piston-chamber from which the liquid has been expelled by
25 said air-and-gas explosion.

34. In an explosive-engine, a combustion-chamber, means for introducing air and gas into said combustion-chamber, means for exploding said mixture therein, a series of piston-chambers adapted to be filled with a liquid, an expansion-chamber adapted to receive the liquid discharged from each piston-chamber, means for moving said piston-chambers successively under the combustion-
30 chamber to receive the explosive force of said air-and-gas mixture and over said expansion-chamber to receive the liquid driven from each piston-chamber by said explosive force,

a driving-shaft adapted to be actuated by the liquid expelled from said chambers into
40 said expansion-chamber, means on said shaft for receiving the impact of the liquid driven from each piston-chamber through the expansion-chamber by the explosive force in the combustion-chamber, a liquid-reservoir
45 into which the liquid from the expansion-chamber passes, water connections independent of said expansion-chamber between said reservoir and the discharged piston-chambers, and means for forming a new liquid
50 piston in each piston-chamber from which the liquid has been expelled by said air-and-gas explosion.

35. In an explosive-engine a combustion-chamber, a compression-chamber for receiving
55 gas and air, a piston located in said compression-chamber adapted to transfer the gas and air from the compression-chamber to the combustion-chamber and adapted to compress the said gases in the said combustion-
60 chamber, the said piston also adapted to be actuated in one direction by the explosion in the combustion-chamber, and a spring as E adapted to absorb force from the explosion
65 and to absorb the momentum of the piston on the explosion stroke and to return the piston and compress the gases in the combustion-chamber on the return stroke.

In testimony whereof I have signed my name to this specification, in the presence of
70 two subscribing witnesses, on this 6th day of December, A. D. 1895.

HERBERT B. STEELE.

Witnesses:

W. E. BARNARD,
S. H. TROW.