No. 708,637. Patented Sept. 9, 1902.

W. HECKERT.

COMBINED GAS AND STEAM ENGINE.

(Application filed Oct. 29, 1901.)

(No Model.) 5 Sheets—Sheet 1.

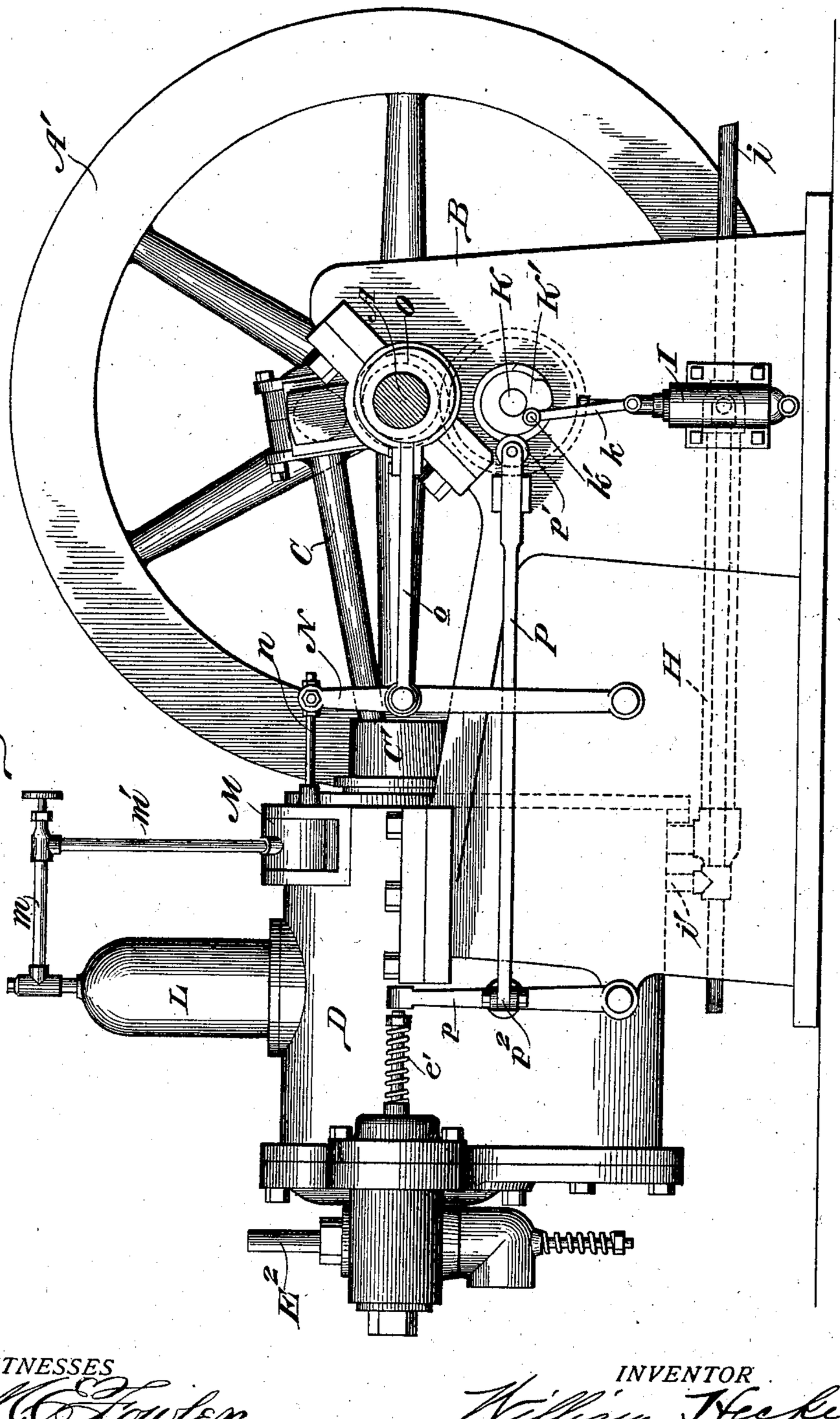

Fig. 1.

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(No Model.) 5 Sheets—Sheet 2.

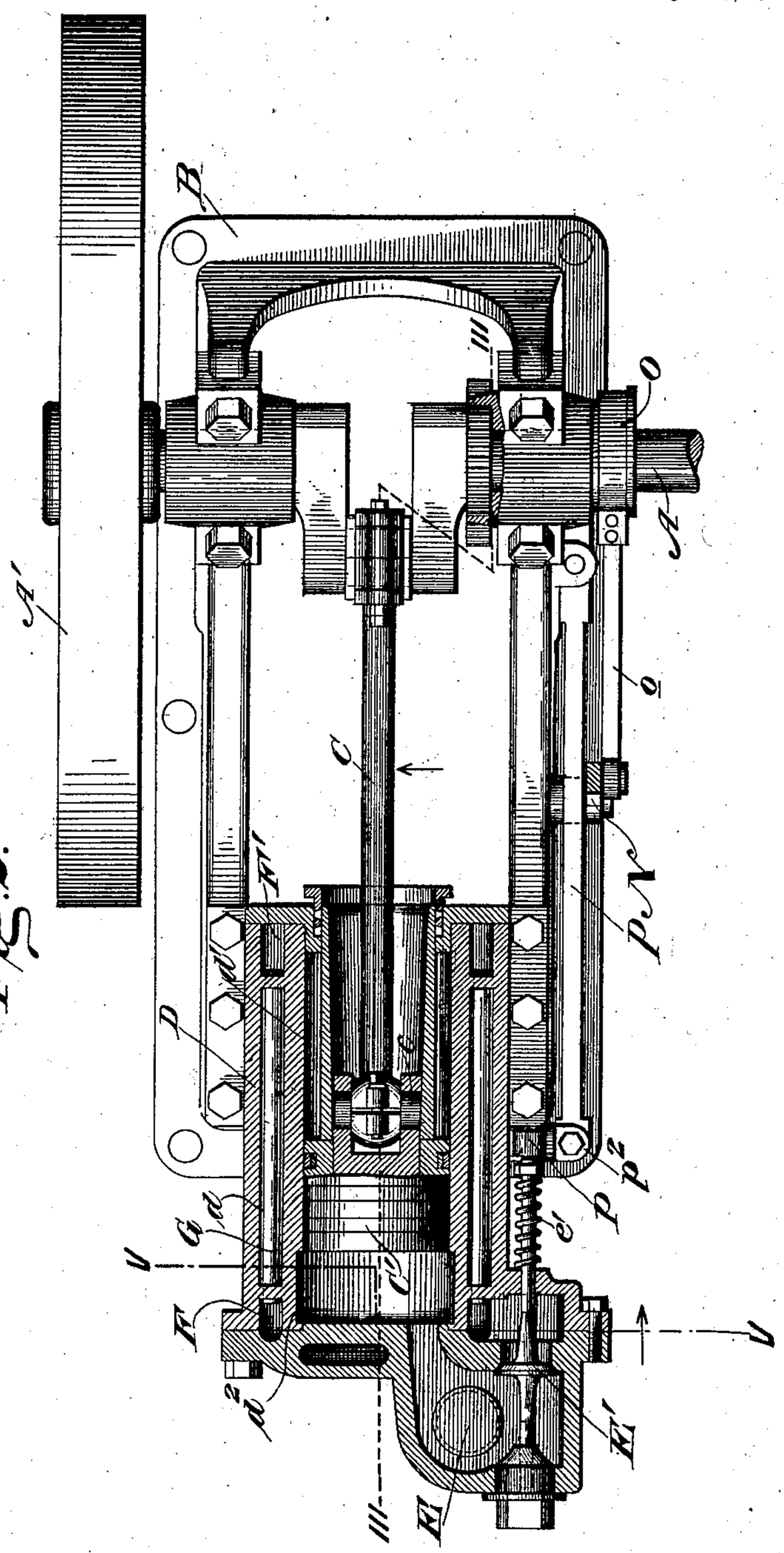

Fig. 2.

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(No Model.) 5 Sheets—Sheet 3.

Fig. 3.

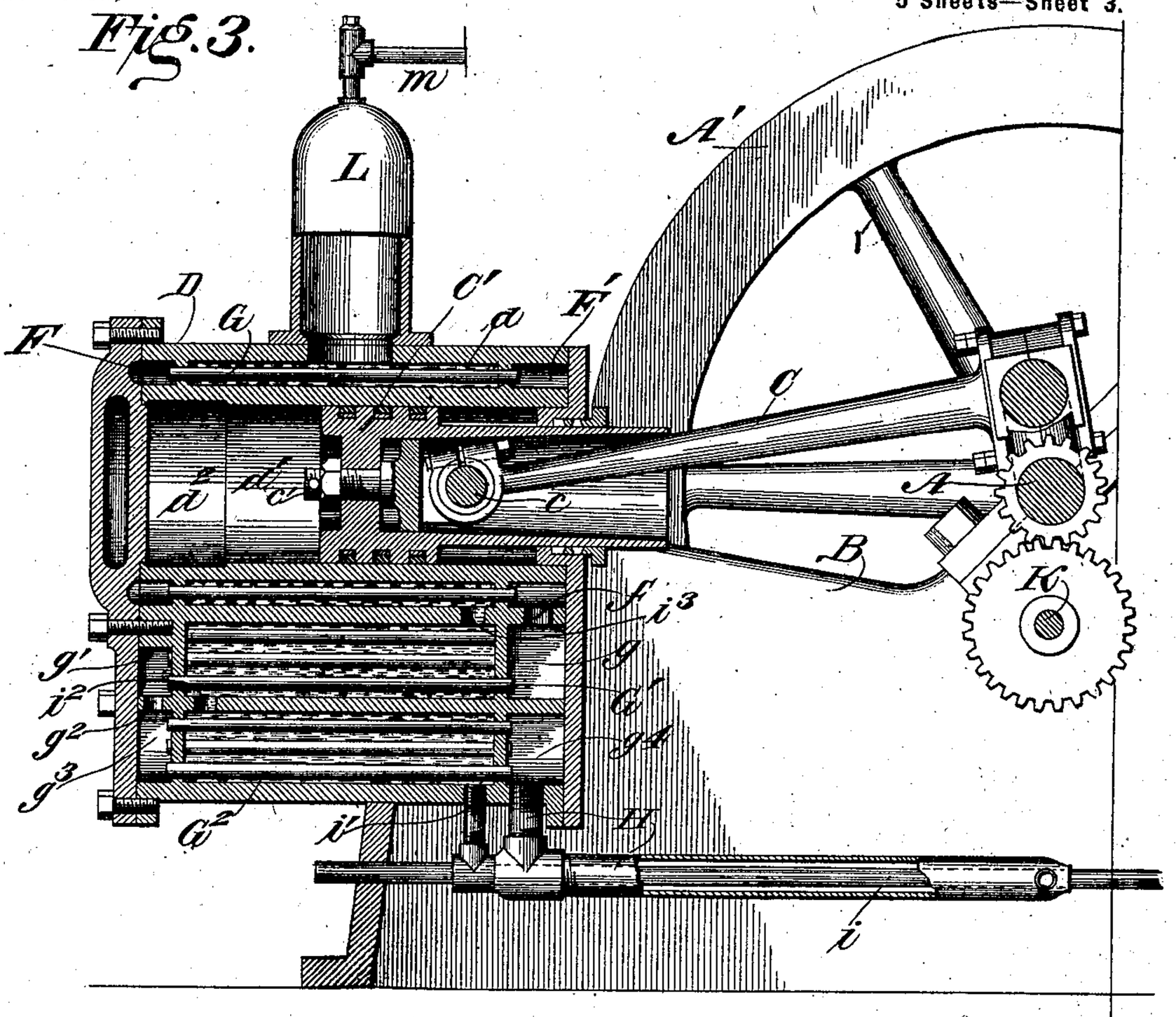
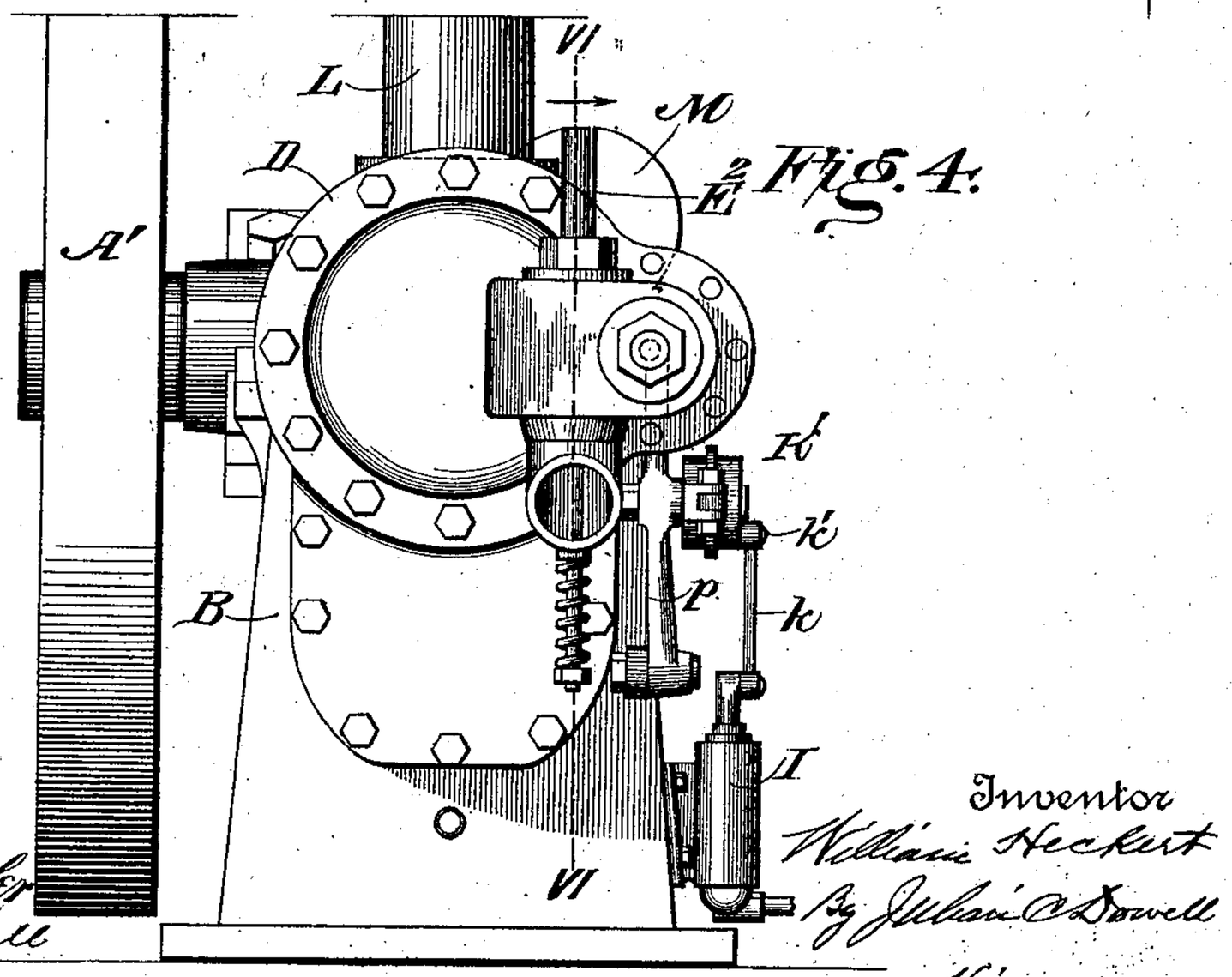


Fig. 4.



Witnesses
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No. 708,637. Patented Sept. 9, 1902.

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COMBINED GAS AND STEAM ENGINE.

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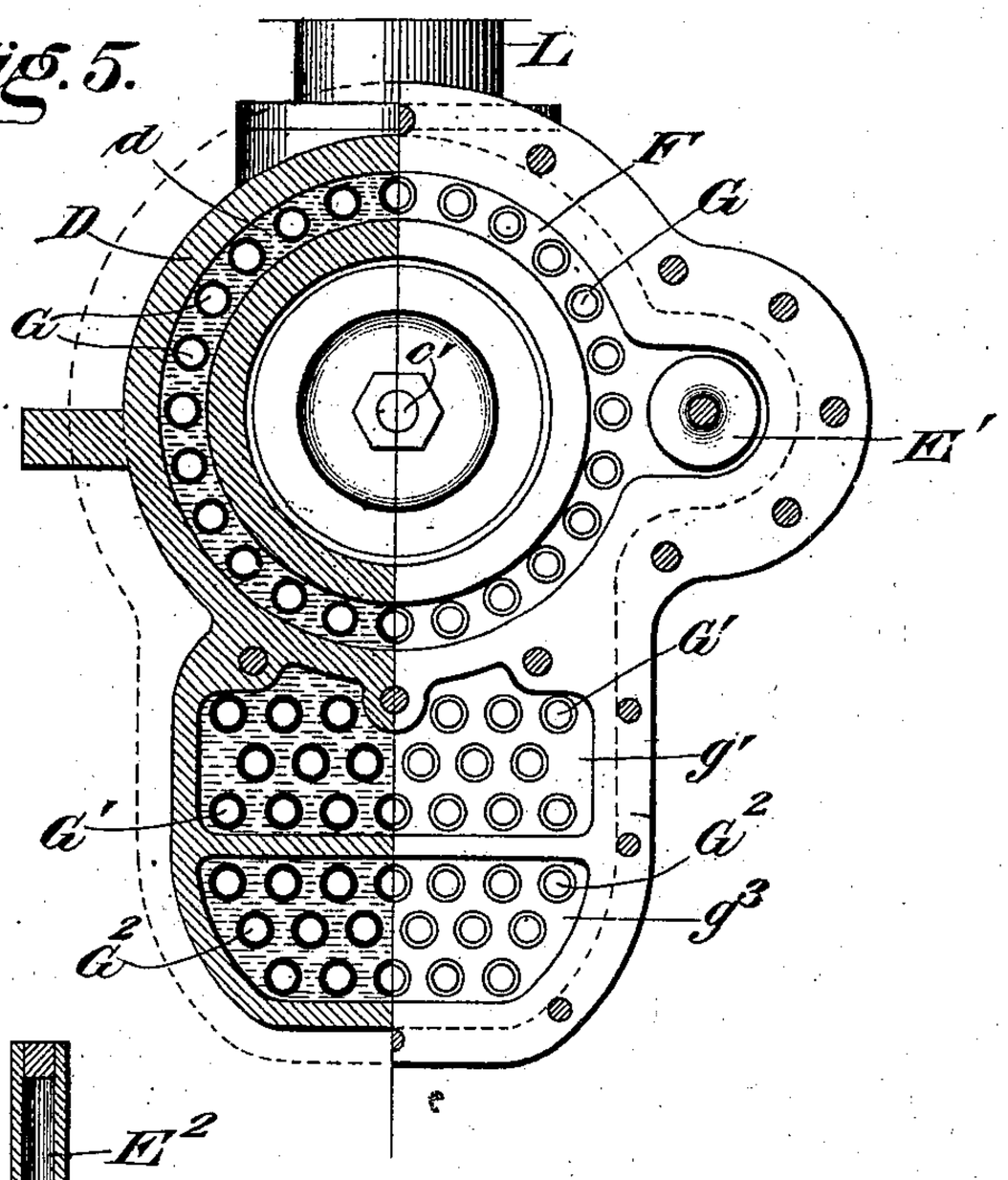
(No Model.) 5 Sheets—Sheet 4.

Fig. 5.



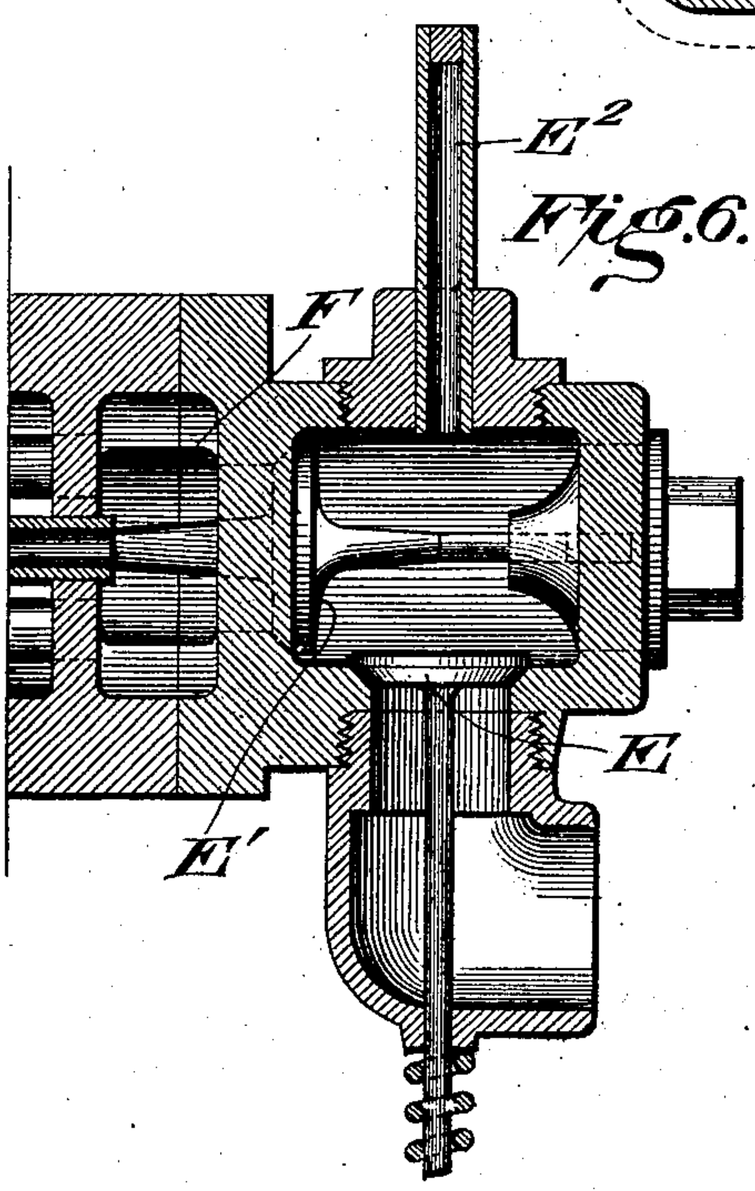
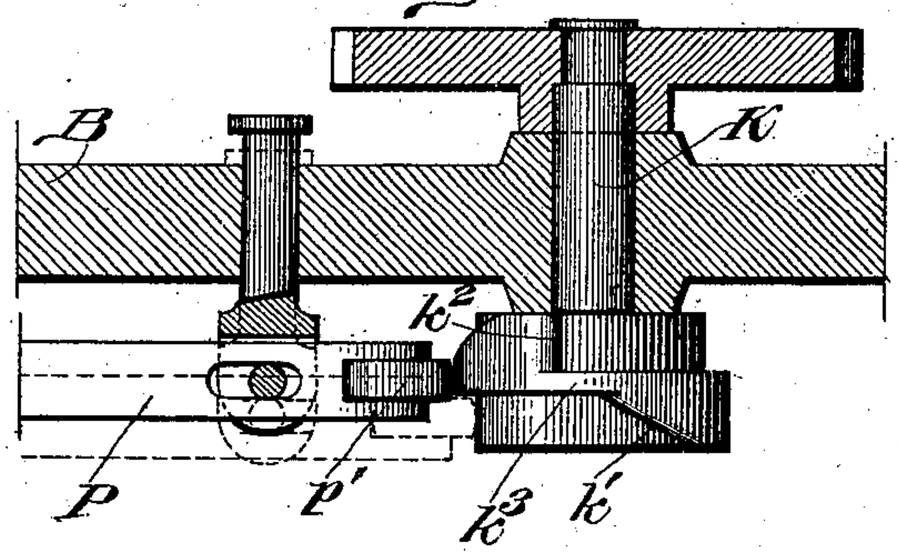


Fig. 6.

Fig. 7.



WITNESSES

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No. 708,637. Patented Sept. 9, 1902.

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COMBINED GAS AND STEAM ENGINE.

(Application filed Oct. 29, 1901.)

(No Model.) 5 Sheets—Sheet 5.

Fig. 9.

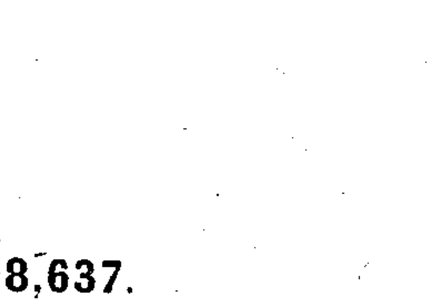
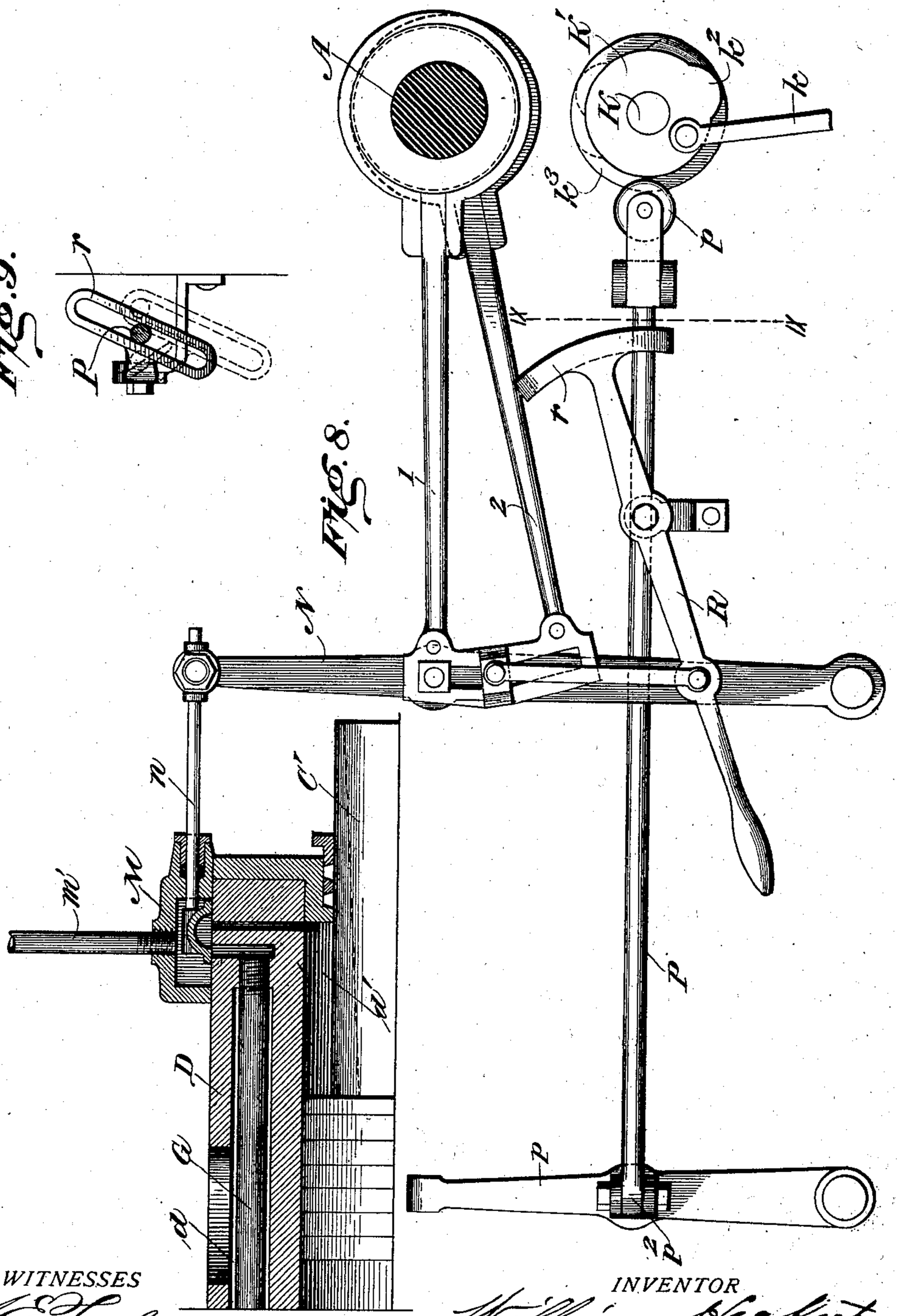


Fig. 8.



WITNESSES

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Osgood A. Powell

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By William A. Powell

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UNITED STATES PATENT OFFICE.

WILLIAM HECKERT, OF FINDLAY, OHIO, ASSIGNOR OF ONE-HALF TO HENRY W. SENEY, OF TOLEDO, OHIO.

COMBINED GAS AND STEAM ENGINE.

SPECIFICATION forming part of Letters Patent No. 708,637, dated September 9, 1902.

Application filed October 29, 1901. Serial No. 80,433. (No model.)

To all whom it may concern:

Be it known that I, WILLIAM HECKERT, a citizen of the United States, residing at Findlay, in the county of Hancock and State of Ohio, have invented certain new and useful Improvements in a Combined Gas and Steam Engine; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to steam and gas engines or motors, and more particularly to a combined gas and steam engine.

The principal objects of the invention are to produce a highly efficient and economical engine or motor combining all in one compact arrangement a gas-engine and a steam engine and boiler and to provide means for economizing in the use of fuel and more completely utilizing the heat of the gas-engine or expansive gases, which is usually wasted in generating steam as a further motive power for driving the engine.

Other objects are to provide for continuously and economically heating the feed-water during its passage to the boiler and for preliminarily heating the propelling gas or gases before admission thereof into the piston-cylinder, to utilize to the best advantage the combined action of steam and explosive gases as a motive power, and to further utilize the heat of the expanded gases in reheating or superheating the steam which is being used as a propelling force, and thereby lowering the temperature of the piston-cylinder, and finally to provide an improved machine of the character referred to which shall occupy but little space while possessing great power.

In carrying my invention into effect the gas and steam are automatically and at different intervals introduced into a piston-cylinder at opposite sides of the working piston, which is thus impelled in reverse directions by the said motive forces, and said cylinder is preferably provided with an outer shell or casing the intervening space between which and the inner shell or cylinder proper is conveniently utilized as a water-chamber, serving the double function of a water-jacket and steam-boiler. Any suitable charge of gas and air, vaporized naphtha, or other fuel used in any of the known gas, air, or oil engines may be intermittently admitted into the gas end of the cylinder, the fuel or mixture used being preferably determined and regulated with reference to obtaining the greatest production of heat and the highest expansive power at each ignition or explosion, and said gases after expanding and spending their force against the piston instead of being exhausted and wasted at a high temperature, as in the ordinary gas-engines, are utilized as furnace-gases of combustion, being conveyed in suitable fire-flues which pass through the water-boiler and then preferably further conveyed through succeeding series of tubes or flues which pass through and gradually heat the feed-water on its passage to the boiler and are finally exhausted at a low temperature into the atmosphere. The heat taken up by the cylinder-walls is of course transmitted to the surrounding water, while that absorbed by the cylinder-head at the gas end is employed in heating the fuel before its admission into the cylinder, the fuel being first introduced into a chamber adjacent to said cylinder-head. The steam generated is preferably collected in a steam-dome mounted on the boiler, and conveyed directly to a steam-chest for introduction in the usual manner into the steam end of the cylinder, where it impels the piston at each forward stroke of the engine, and to use the steam to better advantage the space between the piston-rod and cylinder-walls is preferably reduced at the steam end, thus confining the expansion of the steam within limits suitable to the amount generated at each gas-exhaust stroke of the piston. After exhaust the steam may be condensed and returned to the boiler by the feed-pump. It will thus be observed that a highly efficient and economical motor is provided the relative power of which developed from a given amount of fuel is greatly increased beyond that of either the gas or steam engine, the motor having an additional impulse over the gas-engine at each forward stroke, thus securing more uniform speed, as well as greater power, and the heat of the motive gases being completely utilized. Moreover, the heat

taken up by the cylinder-walls at each ignition of the gas serves to reheat or superheat to an extent the steam next admitted and increase its expansive power, while the steam, in connection with the surrounding boiler, reduces the cylinder-walls to a practical working temperature unattainable by water-jackets in the ordinary gas-engines, and serves also to lubricate and preserve the sides of the cylinder, thus considerably prolonging the life of the motor. Any suitable means may be provided for automatically controlling the supply and exhaust of gas and steam to their respective ends of the cylinder and for reversing and stopping or starting the motor, rendering the same adaptable for propelling street-cars and other vehicles.

The invention consists in certain novel features and combinations, which will first be hereinafter more particularly described with reference to the accompanying drawings, forming a part of this specification, and then pointed out in the claims following the description.

In said drawings, which illustrate one form of embodiment of my invention, and in which corresponding parts are designated by similar letters of reference in different views, Figure 1 is a side elevation of a combined gas and steam engine with boiler embodying my invention. Fig. 2 is a sectional plan view of the same with parts broken away, the piston-cylinder being shown in horizontal section. Fig. 3 is a vertical longitudinal sectional view taken on the line 3 3 of Fig. 2. Fig. 4 is a front view. Fig. 5 is a detail sectional view taken on the line 5 5 of Fig. 2 looking in the direction of the arrow. Fig. 6 is a detail sectional view taken on the line 6 6 of Fig. 4 looking in the direction of the arrow. Fig. 7 is a detail of the cams and connections for operating the exhaust-valve of the gas-explosion chamber and the feed-pump. Fig. 8 is a side elevation, partly in section, illustrating the application of a link motion and coöperating devices for reversing the engine; and Fig. 9 is a detail end view of the reversing-lever.

In said drawings the letter A denotes an ordinary engine crank-shaft with a fly-wheel A′ thereon, mounted on a bed-frame B. C denotes a rod or pitman extending from the crank on said shaft and having a direct connection with the piston C′ by means of a wrist-pin c, fitted in openings in the bifurcated head of a bolt c', inserted through an opening in the head of the piston and secured by a nut at the opposite side; but any suitable connection may be employed.

D denotes the cylinder in which the piston works, having a water-space d between its inner and outer walls and preferably constructed in two diameters internally, the reduced portion d' being of a length equal to the distance traveled by the piston, which fits snugly therein, and the larger portion d^2 providing a suitable chamber for receiving the usual charge of gas and air or vaporized naphtha, as in ordinary gas-engines, the admission of mixed gas and air to such chamber being controlled by a valve E and the exhaust by a valve E′. These valves may be automatically operated at the proper time by any suitable mechanism, such as ordinarily employed for such purposes in gas and other engines, and which are so well known in the art that no description thereof herein is deemed necessary. The residue of combustion or waste products of the explosions are exhausted through the valve E′ and pass into a space F, formed around the end of the water-space d, Figs. 2 and 3, and thence into fire-flue tubes G, connecting the space or flue F with a similar space F′ at the opposite end of the cylinder, said tubes passing through said water-space d. From this latter space the gases pass through an opening f down into a space g at one end of a subjacent tube-chamber consisting, preferably, of upper and lower compartments and each containing a series or bank of tubes, through the first series of which the gases pass from the space g to a similar space g' at the other end of the tube-chamber and thence downward through an opening g^2 to the space g^3, from which the lower bank of tubes conduct the gases back again into a space g^4, which communicates with the exhaust-pipe H. (Shown in dotted lines in Fig. 1 and in full lines in Fig. 3.) The intermediate series or bank of tubes are denoted by the letter G′ and the lower bank by the letter G².

I denotes an ordinary water-boiler feed-pump which may be connected with any convenient water-supply and driven by a counter-shaft K, geared to the engine crank-shaft, the piston of the pump being connected by a rod k with crank-pin k' on a cam K′, carried by the said counter-shaft K, the latter being so geared to the main crank-shaft A that the latter will make two revolutions to one revolution of the counter-shaft, so as to operate the gas-exhaust at each second reverse stroke of the piston. The pump communicates by a suitable line of pipe, as i, with the lower tube-chamber, as at i', into which chamber the feed-water enters and passes thence through a suitable opening or openings, as at i^2, at the front of the boiler, into the central tube-chamber, and thence back and up through an opening or openings i^3 into the water-space d around the cylinder D. The water-space d communicates through a suitable opening in the top or outer wall of the cylinder D with a steam-dome L, from which a suitably-valved conduit or pipe $m\,m'$ leads to a valve-chest M, which may contain any suitable valve, connected with the crank-shaft of the engine in any desired manner for controlling the admission and exhaust of steam, as in ordinary steam-engines. In Fig. 1 of the drawings I have shown a rod n con-

necting a slide-valve within the steam-chest with a valve-operating lever N, pivotally supported at one end on the bed-frame and pivotally connected at an intermediate point with the rod *o*, which connects with an eccentric O on the crank-shaft; but a rotary valve of any desired and suitable construction may be employed, both rotary and slide valves suitable for the purpose being so well known in the class of machines to which this invention relates that a specific description of any particular form herein is deemed unnecessary. Steam being admitted behind the piston B in the usual way, said piston will be driven forward, imparting motion to the crank-shaft, and as the piston begins its first reverse stroke mixed gas and air will be admitted through the valve E, and on the next forward stroke said gases will be compressed in the explosion-chamber d^2 and at the proper time exploded by means of the well-known hot-tube igniter, such as at E^2, to force back or impel the piston in a direction opposite to that in which it is impelled by the steam, gas being admitted on the first, third, and fifth reverse strokes, and so on, as in the well-known Otto type of engine. Thus on the first reverse stroke, with reference to the steam side, gas is admitted in the explosion-chamber. On the forward stroke it is compressed. On the second reverse stroke it expands and does its work on the piston, and on the return stroke it is exhausted, and during the next stroke gas is again admitted, and so on, steam being admitted at the opposite side of the piston at each forward stroke and exhausted through flues or pipes common to both exhaust-valves. In Fig. 8 is shown a section of the steam-valve and its exhaust through some of the tubes through which the gases at the other end of the cylinder escape. In this latter view I have shown for the purpose of permitting the engine to be reversed a well-known form of link-motion in place of the single eccentric and connections shown in Fig. 1 and which I will presently describe.

P denotes a rod which is jointed at one end to the exhaust-valve-operating lever *p*, which may be pivoted at one end on the bed-frame, and has its free end arranged in position to open the valve E′ against the pressure of the spring *e′* thereon to exhaust the contents of the explosion-chamber, the valve being operated at the proper time by the cam K′ engaging a friction-roller *p′* on the rear end of the rod P. A universal-joint connection between the valve-operating rod and lever at p^2 permits the opposite end of the rod, with its roller *p′*, to be moved horizontally or from side to side to cause the roller *p′* to engage either one or the other of the two cam-surfaces on the cam K′, so as to run the engine either forward or back by causing said roller to act on either the right or the left hand cam at will. The construction of said cam is shown more clearly in Fig. 7. As will be seen, it is double or has reversely-inclined cam-surfaces k' k^2, with a dividing-flange k^3 between them. When the roller *p′* on the end of the rod P, operating the exhaust of the gas-explosion chamber, runs on the said dividing-flange, the exhaust will be held open continuously, and when the roller is shifted to the left-hand cam the engine will run to the left, and when the roller is shifted to the right-hand cam the engine will run to the right, or in a reverse direction.

In Fig. 8 I have shown a link-motion and operating-lever whereby both the steam and exhaust valves are shifted at the same time for reversing the engine when desired, and especially when used to operate street-cars, or for other purposes where it is desired to run at different speeds or reverse the motors. In connection with the double eccentrics and connections 1 and 2 with the link-motion for operating the steam-valve I have shown an operating-lever R fulcrumed beside the exhaust-valve-operating rod P, the said lever R having an obliquely-arranged open-slotted end *r* to receive said rod, so that when the lever is raised or lowered for the purpose of shifting the steam-valve the end of the rod P carrying the cam-engaging roller *p′* will be shifted laterally to cause the roller to be engaged by the cam-surface at the other side of the cam K′.

From the foregoing description, taken in connection with the accompanying drawings, the operation of the engine will be readily understood and its advantages appreciated. The admission of gas and air to the gas-engine end of the apparatus being regulated so as to provide an accurate mixture giving the best results insures the liberation of the greatest amount of heat at the highest attainable temperature from a given amount of fuel at each intermittent explosion in the expansion-chamber, thereby giving, first, the most power attainable from the expansion of the gases in said chamber. Old-style gas-engines usually discharge the resulting gases into the atmosphere at not less than 800° Fahrenheit, while in my engine such heated gases are treated the same as the hot gases of combustion under or in an ordinary boiler and are passed through fire-flues surrounded by water to receive said heat and generate steam in the water-space around or surrounding the cylinder, such cylinder now being considered as the combustion-chamber of an internally-fired boiler, and as such no former method of firing boilers uses fuel with equal perfection of combustion and development and utilization of heat, every part of the combustion-chamber being surrounded by water, through which the heated gases must pass at their highest temperature, thence pass down to the central bank of tubes surrounded by still colder water, thereby insuring a continued flow of heat from gases to water while passing through this second set of tubes, then

passing to a lower bank of tubes surrounded by cold feed-water, where practically all available heat is recovered from the gases. The steam may be exhausted in the same way or it may be condensed, so as to permit the pump to return the water to the boiler, and thereby reduce both amounts of fuel and water required by all steam-motors by more than one-half in the development of the same horse-power. The heated cylinder of gas-engine, which the usual water-jacket fails to keep sufficiently cool, is by the introduction of steam at the opposite end of the same cylinder reduced to practical working temperature of best engine-surface, while increased energy is given the motor by introducing steam in the boiler's combustion-chamber, and thereby further raising the temperature of the steam acting on the piston therein. With perfect mixture of gas and air compressed and consumed or exploded in engine-cylinder almost perfect combustion is insured, and as a result a high temperature in such combustion-chamber, and on the return stroke steam admitted at the other end of the cylinder comes in direct contact with the heated walls of this cylinder or part of combustion-chamber directly following after the heated gases are being pushed out by the other side of the piston, the steam being superheated and the intense hot walls of gas-engine lowered in temperature much more than by water-jacket alone. The combination of steam and gas motor requires much less fuel than is required by either of the old styles of engines giving or designed to give the same power, since the heat of combustion used by gas-engines is not available with steam-engines, but passes up the stack with the heated and expanded nitrogen, which does the work of the gas-engines. In my motor these separate portions of heat are each utilized, thereby giving twice the power from a given amount of fuel. It is also apparent that with my motor, using steam at each outward stroke and gas at every other reverse stroke, a more uniform speed is secured and that such steam-supply will admit of motors being stopped, started, and reversed the same as any locomotive when supplied with double or triple cylinders and link-valve motions, as hereinbefore stated.

It will be understood, of course, that numerous changes may be made in the details of construction and general arrangement of parts without departing from the spirit or scope of my invention, and I do not desire to be limited to the construction shown and described.

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

1. A self-contained motor or engine comprising in a unitary structure a cylinder having a water-space around the same, a subjacent water way or passage extending upwardly in a serpentine or zigzag course from a source of supply to said water-space, heat-flues extending downwardly from said cylinder to the exhaust through said serpentine or zigzag waterway, and a piston working in said cylinder having a suitable connection with the driving-shaft, together with mechanism for automatically controlling the admission and exhaust of steam at one side and of explosive gases at the other side of the piston to actuate the latter by the expansive force of said gases and steam operating alternately to drive the piston in opposite directions; substantially as described.

2. A self-contained motor or engine comprising in a unitary structure a cylinder having a water-space around the same opening into a steam-dome at the top, a subjacent water way or passage extending upwardly in a serpentine or zigzag course from a source of supply to said water-space, heat-flues forming a descending passage for the residue of heat and products of combustion from said cylinder through said water-space and subjacent water-passage, and a reciprocating piston working in said cylinder having a suitable connection with the driving-shaft, together with mechanism for automatically controlling the admission and exhaust of steam at one side and of explosive gases at the other side of the piston to actuate the latter by the expansive force of said gases and steam operating alternately to drive the piston in opposite directions; substantially as described.

3. A self-contained motor or engine comprising in a unitary structure a cylinder, a subjacent waterway ascending step by step in reverse directions from a source of supply to a water-space at the boiler, a passage for the residue of heat and products of combustion descending step by step through said ascending waterway, and a piston working in said cylinder having a suitable connection with the driving-shaft, together with means for automatically admitting explosive gases and exploding the same at every second reverse stroke of the piston, for effecting such reverse stroke, and means for automatically admitting steam at the other side of the piston for impelling it at each forward stroke, substantially as described.

4. A self-contained motor or engine comprising in a unitary structure, a cylinder having a water-space around the same opening into a steam-dome at the top, a subjacent waterway gradually ascending from a source of supply to said water-space, a heat-passage gradually descending through said waterway to the exhaust, and a reciprocating piston working in said cylinder having a suitable connection with the driving-shaft, together with means for automatically admitting explosive gases and exploding the same at every second reverse stroke of the piston, for effecting such reverse stroke, and means for auto-

matically admitting steam at the other side of the piston for impelling it at each forward stroke, substantially as described.

5. A motor or engine comprising in a unitary structure a cylinder having a surrounding water-space and air spaces or flues at its ends, tubes connecting said air-spaces through said water-space, a subjacent ascending waterway connecting said water-space with a feed-pipe, and other tubes passing through said subjacent waterway and connecting the air-spaces with the exhaust; a piston working in said cylinder, means for automatically admitting explosive gases at one end of said cylinder and for exhausting the residues of combustion into and out through said air-flues and tubes, and means for automatically controlling the admission and exhaust of steam at the other side of the piston for impelling the latter in a direction opposite to the action of the expansive gases, substantially as described.

6. A motor or engine consisting of a cylinder having a surrounding water-space and fire-flues separated therefrom, one at each end, a subjacent waterway ascending from a feed-pipe to said water-space, fire-flue tubes connecting said flues through said water-space, other tubes connecting similar flues at opposite ends of the cylinder with an exhaust-pipe and passing downwardly through said subjacent waterway, means for automatically admitting explosive gases at one end of said cylinder and igniting the same, and mechanism for automatically controlling the admission and exhaust of steam at the other end of said cylinder to effect the movements of the piston in one direction only, together with means for exhausting the residues of combustion through said fire-flues and fire-flue tubes, substantially as described.

7. In a combined gas and steam engine, a cylinder having a piston-chamber, and an explosion-chamber at one end, together with a water-space around the cylinder and flues at each end separated from said water-space by suitable partitions or webs between the inner and outer walls of the cylinder, a series of fire-flue tubes connecting said flues through said water-space, and a subjacent water-chamber with fire-flue tubes therein connecting a flue at the outlet from said first-mentioned flues, with a similar flue at the other end of said water-chamber; the latter flue communicating with the exhaust, so as to provide a zigzag course for the escape of the residues of combustion, together with a feed-pipe for supplying said water-space through said fire-flue-tube-containing water-chamber, substantially as described.

8. In a combined gas and steam engine, a cylinder having a piston-chamber, and an explosion-chamber at one end, together with a water-space around the cylinder and flues at each end separated from said water-space by suitable partitions or webs between the inner and outer walls of the cylinder, a series of fire-flue tubes connecting said flues through said water-space, and a subjacent water-chamber with fire-flue tubes therein connecting a flue at the outlet from said first-mentioned flues with a similar flue at the other end of said water-chamber; the latter flue communicating with the exhaust, so as to provide a zigzag course for the escape of the residues of combustion, together with a feed-pipe for supplying said water-space through said fire-flue-tube-containing water-chamber, and a steam-dome mounted on said cylinder in communication with the water-space around the same, substantially as described.

9. In combination with the piston-cylinder and piston working therein and a steam-dome at the top, a water-space around said cylinder, flues through said water-space, a subjacent ascending water-passage connecting said water-space with a feed-pipe at the bottom or lowest point in the circuit, and heat-flues extending downwardly through said subjacent water-chamber at the ends thereof, tubes connecting said flues, an inlet-valve for the admission of explosive gases at one side of the piston, a valve at the same side for exhausting the residues of combustion through said flues and tubes, and a valve at the other end of the cylinder for admitting steam to impel the piston in a direction opposite to the direction given by the expansive gases, whereby the heat and residues of combustion resulting from the explosion of the gases is utilized in heating the feed-water and reheating or superheating the steam, substantially as described.

10. In combination with the cylinder having a water-space around the same, a steam-dome mounted thereon, flues at the ends thereof, and tubes connecting said flues through said water-space, a subjacent water-chamber having a series of tubes therein which communicate with the outlet from said flues at one end and with a similar flue at the other end, other tubes connecting the latter flue through said subjacent chamber with the exhaust, and means for feeding the water in a zigzag course through said subjacent chamber in contact with said tubes and the walls of said flues, substantially as described.

11. In a combined gas and steam engine a piston having a reduced area working in the steam end of cylinder and an enlarged portion or area in end forming a gas-explosion chamber, said piston having a hollow extension or trunk extending through stuffing-box in one head of cylinder to receive the connecting-rod of engine and provide reduced steam-piston area around said extension in cylinder, as and for the purpose described.

12. In combination with the cylinder and its surrounding water-space and subjacent water-chamber, flues at the ends of the cylin-

der and subjacent chamber communicating at opposite ends, and a series of pipes forming a zigzag course for the escape of the residues of combustion through said water-space and subjacent chamber, together with a boiler feed-pipe and means for supplying water in a zigzag course through said subjacent water-chamber and water-space in contact with the fire-flues, whereby the feed-water is gradually heated as it ascends to the water-space at the top of the boiler, substantially as described.

In testimony whereof I affix my signature in presence of two witnesses.

WILLIAM HECKERT.

Witnesses:
LUCY WILSON,
JOHN M. HAMLIN.