No. 865,725. PATENTED SEPT. 10, 1907.

H. M. POPE & H. P. MAXIM.

GENERATION OF VAPOR.

APPLICATION FILED JUNE 29, 1897.

2 SHEETS—SHEET 1.

Fig. 1.

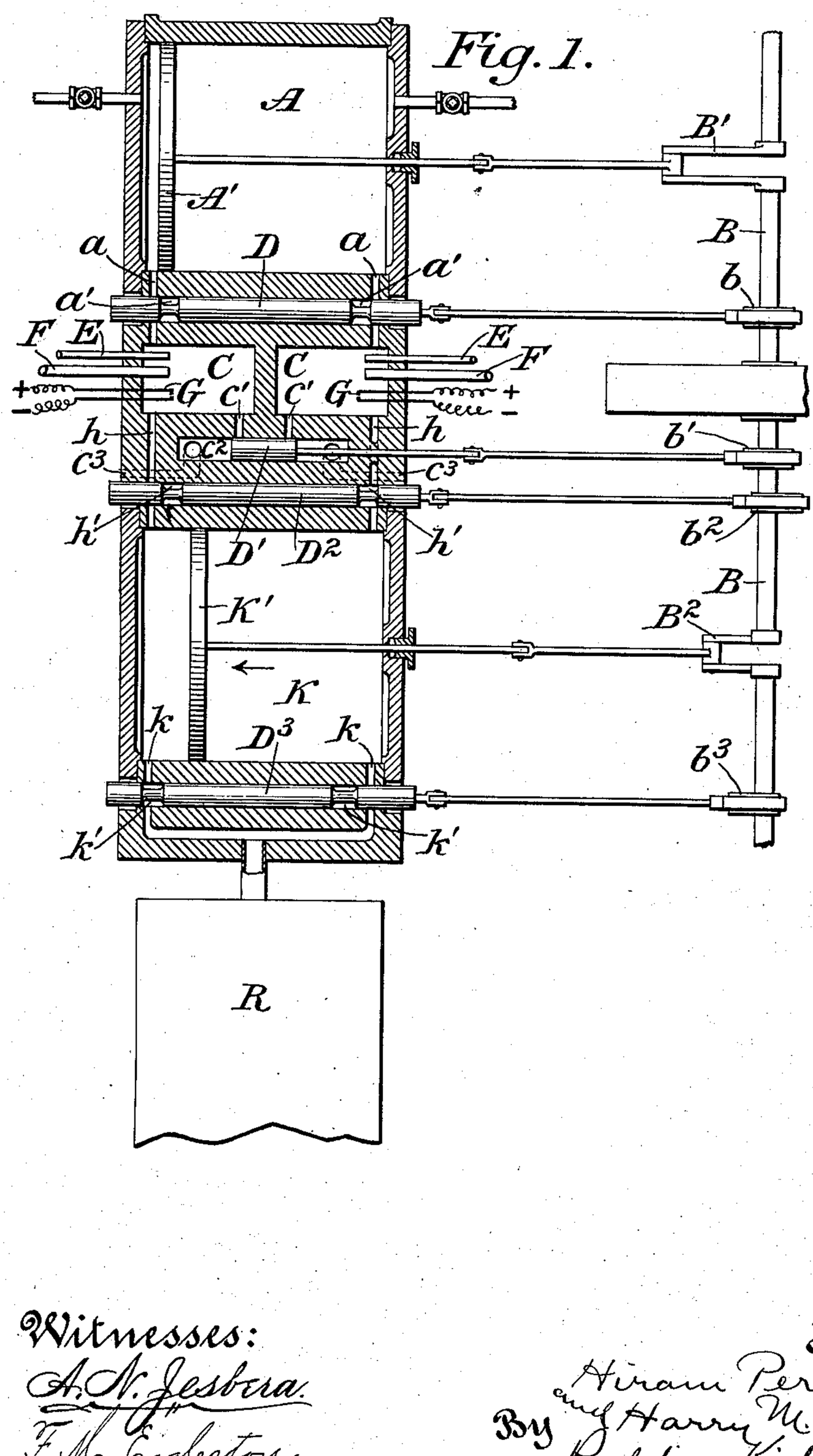
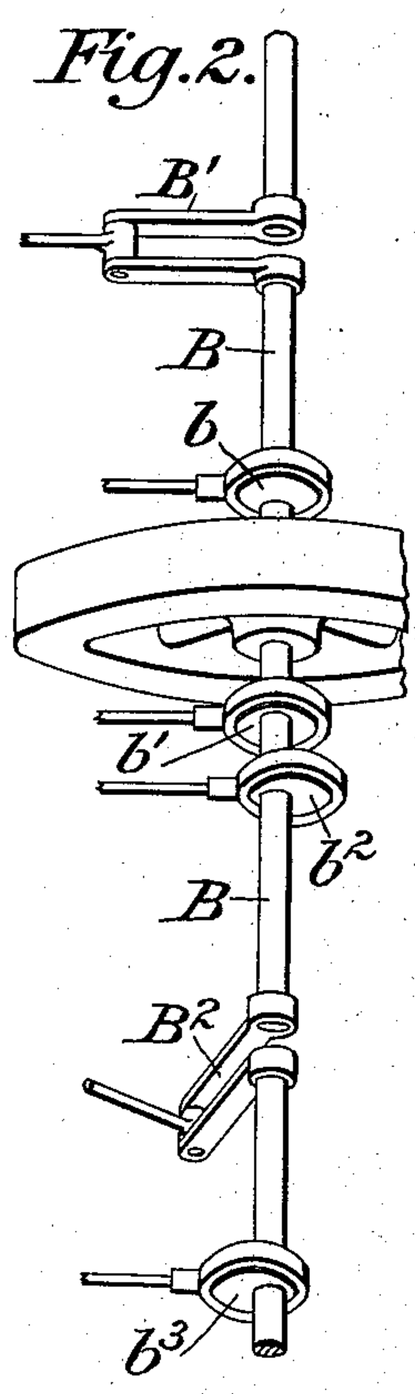


Fig. 2.



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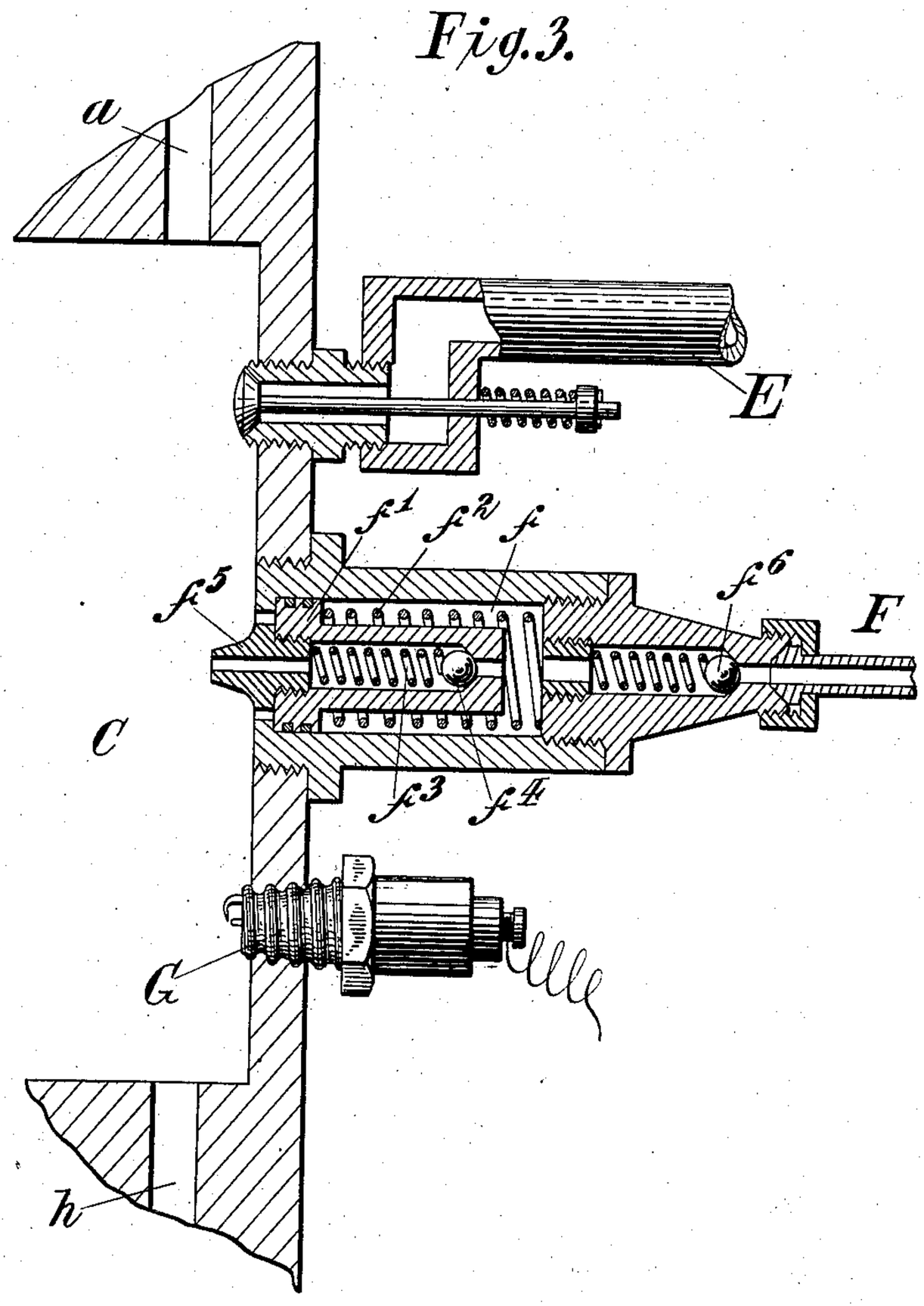
2 SHEETS—SHEET 2.

Fig. 3.



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UNITED STATES PATENT OFFICE.

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GENERATION OF VAPOR.

No. 865,725. Specification of Letters Patent. Patented Sept. 10, 1907.

Application filed June 29, 1897. Serial No. 642,799

To all whom it may concern:

Be it known that we, HARRY M. POPE and HIRAM PERCY MAXIM, both citizens of the United States, and residents of the city and county of Hartford, in the State of Connecticut, have invented certain new and useful Improvements in the Generation of Vapor, of which the following is a specification, reference being had to the accompanying drawing, forming a part hereof.

This invention relates to the generation of vapor in the nature of steam, whether the same be required for the development of power in a suitable engine or for any one of a great variety of other purposes.

Our primary object has been to dispense with the cumbersome boiler which is commonly used at present in the generation of steam and must carry a large quantity of water and must receive careful and intelligent attention at all times, and also to dispense with the furnaces and other forms of boiler heaters now commonly employed, which also require careful and intelligent attention.

It has also been our object to make the apparatus in which our invention may be embodied perfectly safe and free from danger to person or property, even in the hands of the unintelligent or mechanically unskilful.

Still another object has been to make the practice of our invention, when embodied in suitable mechanical devices, practically automatic, so that the supply of vapor shall at all times be proportioned to the demand therefor, in whatever manner the vapor may be used.

We have developed our invention with especial reference to the use of the vapor in an engine or motor of some kind, such as are now operated by steam from a boiler or by successive explosio of a suitable gas or gaseous mixture, although we do not intend to limit our invention to the development of power, since the vapor generated may be used for any one of a great variety of special purposes.

Explosive engines, of any one of several well known forms also make it possible to dispense with boilers, but, as is well understood, they are open to serious objections; the walls of the explosion chamber become heated to such a high temperature that much of the energy transformed into heat is wasted either by direct radiation or by absorption by a water jacket or other means employed to keep the temperature of the walls of the explosion chamber within reasonable limits, whereby the efficiency of the engine or other prime mover is correspondingly reduced; furthermore, the initial pressure of the exploding gas or gaseous mixture and the peculiarities of the expansion of such gas or gaseous mixture are such that it is very difficult to convert the pressure obtained into available energy of motion with efficiency, uniformity and accuracy. Steam, on the contrary, has vast advantages in a prime mover by reason of the absence of peculiarities of expansion and by reason of the physical qualities which render it adaptable to a wide range of uses and controllable with comparative ease. Of the two sources of power steam is therefore generally preferred and would be in all cases but for the bulkiness of the generator and its inefficiency.

We have sought to overcome, as far as possible, the objections incident to the use either of steam or of an explosive gas or gaseous mixture, while combining the advantages of both, and our invention accordingly consists in certain general features of construction, as explained hereinafter.

For the purpose of explaining our invention we have illustrated in the accompanying drawing one form of an apparatus in which our said invention may be embodied, no attempt being made to represent the parts of the apparatus in detail or with mechanical precision, since all of such parts, considered separately, may be of ordinary construction and arrangement and, moreover, since any one of a great variety of mechanical arrangements may be employed in the practice of our invention, as will clearly appear hereinafter.

In said drawing,—Figure 1 is a general view of such an apparatus as that referred to herein, representing some of the parts as if in horizontal section, while other parts are represented in plan; Fig. 2 is an exaggerated perspective view of the shaft shown in Fig. 1 and the parts carried by it, showing the relations of such parts. Fig. 3 is a detail view, on an enlarged scale, of a device which may be employed for the admission of water at the proper instant.

In the apparatus chosen for illustration of our invention and illustrated in the drawing, a source of air under pressure is shown as an air compressor comprising a cylinder A in which a piston A′ is reciprocated by suitable connections to a crank B′ of a shaft B.

Ports *a a* lead from the respective ends of the cylinder A to corresponding explosion chambers C C which are independent of each other. It will be obvious, as this description proceeds, that a single explosion chamber and its co-acting parts would effect the result desired, but in the form of apparatus shown we prefer the employment of two separate explosion chambers and their respective co-acting parts.

A valve D, having by-passes *a′*, is arranged to control the ports *a a* and is operated through suitable connections by an eccentric or cam *b* on the shaft B, to open and close the said ports at the proper time.

Each chamber C is provided with a fluid fuel supply, represented by the pipe E, through which the

proper quantity of fluid fuel, such as a suitable hydro-carbon, is delivered at the proper time and in proper quantity to form an explosive compound in the chamber. A water supply is also connected to the explosion chamber, being represented in the drawing by a pipe F through which the requisite quantity of water, preferably in a condition of pulverization, is delivered to said chamber. An igniter, represented at G, which may be of any suitable kind, is also provided for the purpose of producing the explosion in the explosion chamber at the proper instant. The fuel supply, the water supply and the igniter may be controlled or operated by hand or by any other suitable means. A form of means which may be employed for the supply of fuel, and for the control of such supply, is shown in Letters Patent of the United States No. 606 425 granted June 28, 1898 upon the application of the above-mentioned H. P. Maxim, and to such Letters Patent reference may be had for a fuller description of such means. Means for the admission of water at the proper instant which have been contemplated in the present case are represented in detail in Fig. 3 of the drawings, being merely indicated diagrammatically in Fig. 1.

As represented in Fig. 3, the water supply pipe F communicates with a chamber f which in turn communicates with the interior of the explosion chamber C and receives a plunger f' which is pressed normally toward the explosion chamber and against its seat by a spring f^2. The plunger is bored longitudinally, as at f^3, and is provided with a check valve f^4 and a spray nozzle f^5. A check valve f^6 is also interposed between the pipe F and the chamber f. When the explosion takes place in the chamber C, the spring f^2 is compressed by the pressure against the face or head of the plunger f' and a small quantity of water is forced into the bore of the plunger and is discharged into the explosion chamber as fine spray or in a condition of pulverization immediately after the explosion takes place. The operation of the igniter is as usual in motors of the type referred to and need not be further explained herein.

Each explosion chamber is provided with two outlets, one being through the port c', intermediate chamber c^2 and exhaust port c^3 to the open air, while the other is through a port h to another chamber K. The exhaust port or channel c' c^3 is controlled by a valve D′, which may be operated by suitable connections from an eccentric or cam b' on the shaft B, and the port h is controlled by a valve D^2 which may be operated by suitable connections from an eccentric or cam b^2 on the shaft B, said valve having a suitable by-pass h' for each port h. The chamber K is shown as a cylinder having a piston K′ which is reciprocated by suitable connections from a crank B^2 of the shaft B. Ports k at the respective ends of said cylinder K communicate with a common reservoir R and are controlled by a valve D^3 which may be operated by suitable connections from an eccentric or cam b^3 on the shaft B, said valve having suitable by-passes k'.

The mode of operation of the apparatus hereinbefore described will now be readily understood. The proper charge of air under pressure is introduced into one of the explosion chambers C and is there mixed with the proper quantity of hydro-carbon from a source of supply indicated by the pipe E, or the explosive mixture or compound or substance of whatever nature is otherwise introduced into the explosion chamber, the port a being then closed by the valve D. The mixture or compound or other substance of whatever nature in the explosion chamber is then exploded by a spark from an igniter, as at G, or by any other suitable means, and simultaneously therewith, or preferably an instant thereafter, so that the maximum amount of heat shall be generated by the explosion, a proper quantity of water is introduced into the explosion chamber, it being desirable for the best results that the water shall be in a state of very fine pulverization. The water so introduced is instantly converted into steam and the explosion chamber then contains a steam-like vapor composed of the steam and the products of combustion of the hydro-carbon. The quantity of water to be introduced will depend upon the amount of heat developed by the explosion, and it will be evident that if the quantity of water be regulated within reasonable limits, not only will a quantity of steam-like vapor be generated and available either for immediate use or for storage, but the heat developed by the explosion will be absorbed by the water and the loss of heat and consequent loss of efficiency through radiation through the walls of the explosion chamber or through absorption by a water jacket will be reduced to a minimum and will become practically a negligible quantity.

As stated above, the steam-like vapor generated in the explosion chamber in the manner described, becomes immediately available for use, but though available, it could not be practically utilized except with proper provision for its transfer or further storage preparatory to application to a prime mover or the like. As the great advantage in the use of steam, or like elastic fluid, is its flexibility in consumption or application, its generation must be followed by proper storing, or conducting in order to obtain that advantage. We provide for its removal from the explosion chamber and storage in a suitable reservoir, and also for the clearing out of the explosion chamber preparatory to the introduction of a fresh charge, so that such fresh charge will not be adulterated by the products of combustion already contained in the explosion chamber, in some such manner and by some such means as indicated in the drawing and described hereinafter. As the explosion takes place in the explosion chamber, the piston K′ in the cylinder K is approximately at the limit of its stroke. As the piston recedes and the valve D^2 opens the port h (immediately after the water is introduced), the vapor generated in the explosion chamber exhausts into the cylinder K and expands therein as the receding piston K′ leaves a larger space. The parts are preferably so proportioned that when the piston K′ reaches the other limit of its stroke the vapor in the cylinder K is reduced approximately to atmospheric pressure, so that when the valve D^2 closes the port h, which now takes place, only a relatively small quantity of the generated vapor remains in the explosion chamber. During its next forward movement the piston K′ recompresses the vapor in the cylinder K and, the port k being opened by the valve D^3, drives the vapor into the reservoir R, where it can be stored and, if necessary, be kept at high pressure by reheating, and from which it can be drawn as required for the operation of the engine or other prime mover or for any other desired purpose. To effect the complete removal of the vapor

which remains in the explosion chamber after the closing of the port *h* by the valve D^2, the parts are arranged and operate, in the apparatus represented in the drawing, as will now be described. The piston A^1 in the cylinder A is a little in the lead of the piston K′ in the cylinder K and therefore has returned slightly from the end of its stroke at the time when the vapor in the explosion chamber C and in the cylinder K has been reduced approximately to atmospheric pressure and after the valve D^2 has closed. The port *a* is then opened by the valve D and a scavenging puff of the air already slightly compressed in the cylinder A is allowed to pass through the port *a* into the explosion chamber C and out through the exhaust port or channel $c' c^3$, which has been opened by the movement of the valve D′, carrying with it the vapor which remains in the explosion chamber C. This scavenging is accomplished very quickly and the scavenger valve D′ closes the exhaust channel $c' c^3$ very soon after it was opened, so that the compression of the air in the explosion chamber C, by reason of its communication with the cylinder A is immediately carried on to the point necessary for producing the best results when the next explosion takes place.

The introduction of the hydro-carbon into the explosion chamber C from the supply E may take place simultaneously with the compression of the air, and when the piston A′ has reached the proper point in its stroke the port *a* is closed by the valve D and the charge in the explosion chamber is immediately exploded, as stated above.

It will be understood that although the method of generation may be carried on successfully with a single explosion chamber and its adjuncts, better results may be produced by the use of two explosion chambers, as represented, because the vapor is being expanded on one side of the piston K′ while on the other side it is being recompressed and driven into the reservoir R, whereby the loss due to the expansion and recompression of the vapor amounts only to the aggregate of the slight heat losses, the friction and the necessary power consumed in the generator, which is only that used in the compression of the air. It will further be understood that the shaft shown in the drawing serves as a convenient means or connection for promoting or effecting the movements of the parts of the apparatus in necessary relation and may be replaced by other devices.

It will be evident that when the pressure in the reservoir R is reduced by reason of large drafts upon it, the resistance to recompression in front of the advancing piston K′ will be correspondingly low, so that as the demand is increased, the generator automatically speeds up and supplies vapor more rapidly to make up for the draft upon the reservoir. On the other hand, when the pressure in the reservoir R is comparatively high, the resistance to recompression in front of the advancing piston K′ is correspondingly high, thereby increasing the drag on the piston and thus on the generator and slowing it down. In this manner the generator is self-regulating according to the demands made upon it. If no vapor is being drawn from the reservoir, the pressure therein rapidly increases and when it has reached a point at which the resistance to the forward movement of the piston K′ is equal to the driving power, the generator is stalled and the generation of vapor ceases. The vapor, however, is kept under pressure in the reservoir and it will therefore be necessary, when the motor is to be started again or the draft upon the reservoir is resumed for any other purpose, simply to give the generator shaft B or its equivalent a slight impulse, after which the generator will automatically continue its work.

The reservoir may be such as to retain its vapor pressure for a considerable length of time, so that the engine or other motor driven by the vapor can be stopped and started as often as may be desired, and for a long or short period of time as may be required. Under these conditions it becomes possible to start up the motor at any moment and to obviate the necessity, as in ordinary explosive engines, of keeping the motor running and of effecting a disconnection between the motor and the driven part when it is desired to stop for a short time.

It will now be understood that we do not intend to restrict ourselves to the precise details of construction and arrangement herein shown and described, as such construction and arrangement have been chosen merely for purposes of explanation of the general nature of our said invention.

We claim as our invention:—

1. An apparatus for generating and storing vapor comprising two explosion chambers, means for supplying an explosive mixture to each of said explosion chambers, an igniter and a water supply for each of said explosion chambers, a cylinder having one of said explosion chambers connected thereto at one end and the other at the other end, a compressing piston in said cylinder and a reservoir connected to said cylinder, into which the piston forces the gases of explosion.

2. An apparatus for generating vapor comprising an explosion chamber, means for supplying hydro-carbon vapor to said explosion chamber, an igniter, a water supply, an air compressor connected to said explosion chamber, a valve interposed between said air compressor and said explosion chamber means to operate said valve, whereby said valve is opened after the explosion and a puff of air is admitted to the explosion chamber to clear out said chamber, and an independent exhaust port for such scavenging puff of air.

3. An apparatus for generating vapor comprising an explosion chamber, means for supplying hydro-carbon vapor to said chamber, an igniter, a water supply, an air compressor connected to said chamber, a cylinder connected to said chamber, a piston in said cylinder, a shaft operatively connected to said piston, a valve between said air compressor and said chamber and a scavenger valve for said chamber both of said valves being operatively connected to said shaft.

4. An apparatus for generating and storing vapor comprising two explosion chambers, means for supplying an explosive mixture to said chamber, an igniter and a water supply for each of said chambers, a cylinder having one of said chambers connected thereto at one end and the other at the other end, a compressing piston in said chamber and a shaft operatively connected to said piston, and a reservoir connected to opposite ends of said cylinder, into which the piston forces the gases of explosion.

5. An apparatus for generating and storing vapor comprising two explosion chambers, means for supplying hydro-carbon vapor to said chambers, an igniter and a water supply for each of said chambers, a cylinder having one of said explosion chambers connected thereto at one end and the other at the other end, a compressing piston in said cylinder, a shaft operatively connected to said piston and an air compressor connected to each of said explosion chambers and operatively connected to said shaft and a reservoir connected to opposite ends of said cylinder, into which the piston forces the gases of explosion.

6. An apparatus for generating vapor comprising an explosion chamber, means for supplying hydro-carbon vapor to said explosion chamber, an igniter, a water supply, an

air compressor connected to said explosion chamber, a valve interposed between said air compressor and said explosion chamber, means to operate said valve, whereby said valve is opened after the explosion and a puff of air is admitted to the explosion chamber a separate valve for the discharge of such scavenging puff of air to clear out said chamber and means for effecting proper relative movement of the moving parts.

7. An apparatus for generating vapor comprising an explosion chamber, means for supplying hydro-carbon vapor to said explosion chamber, an igniter, means for introducing water into said chamber upon the explosion, a discharge valve, means to operate said discharge valve, a chamber to receive the vapor from the first-named chamber and to permit it to expand therein, and means to re-compress such vapor.

8. An apparatus for generating vapor comprising an explosion chamber, means for supplying hydro-carbon vapor to said explosion chamber, an igniter, means for introducing water into said chamber upon the explosion, a discharge valve, means to operate said discharge valve, a chamber to receive the vapor from the first-named chamber and to permit it to expand therein, means to re-compress such vapor, and a reservoir to receive the re-compressed vapor.

9. An apparatus for generating vapor comprising an explosion chamber, means for supplying hydro-carbon vapor to said explosion chamber, an igniter, means for periodically introducing water into said chamber upon the explosion, a discharge valve, means to operate said discharge valve and keep it closed at predetermined times, a chamber to receive the vapor through said discharge valve, an air compressor, a scavenging valve, and means to operate said scavenging valve, whereby a puff of air is discharged through said explosion chamber independently of the second chamber.

10. An apparatus for generating vapor comprising an explosion chamber, means for supplying hydro-carbon vapor to said explosion chamber, a periodically operative igniter, means for periodically introducing water into said chamber upon the explosion, a chamber to receive the vapor from the explosion chamber, two separate discharge valves from said explosion chamber, one connecting with the second chamber, and means for operating said discharge valves separately.

11. An apparatus for generating vapor comprising a periodically sealed explosion chamber, means for supplying hydro-carbon vapor to said explosion chamber, an igniter, means for introducing water into said chamber upon the explosion, a second chamber to receive the vapor from the explosion chamber, and a storage reservoir to receive the vapor from the second chamber.

12. An apparatus for generating vapor comprising an explosion chamber, means for supplying hydro-carbon vapor to said explosion chamber, an igniter, means for introducing water into said chamber after the explosion, an air compressor connected to said explosion chamber, and means to receive and store the vapor from the explosion chamber.

13. An apparatus for generating vapor comprising an explosion chamber, means for supplying hydro-carbon vapor to said explosion chamber, an igniter, means for introducing water into said chamber after the explosion, an air compressor connected to said explosion chamber, and a second chamber connected with the explosion chamber to receive thte vapor therefrom.

This specification signed and witnessed this 15th day of May A. D. 1897.

HARRY M. POPE.
HIRAM PERCY MAXIM.

In the presence of—
ALBERT P. DAY,
HERMANN F. CUNTZ.