No. 858,046. PATENTED JUNE 25, 1907.

H. O. WESTENDARP.

VAPORIZER FOR EXPLOSIVE ENGINES.

APPLICATION FILED JUNE 13, 1904.

5 SHEETS—SHEET 1.

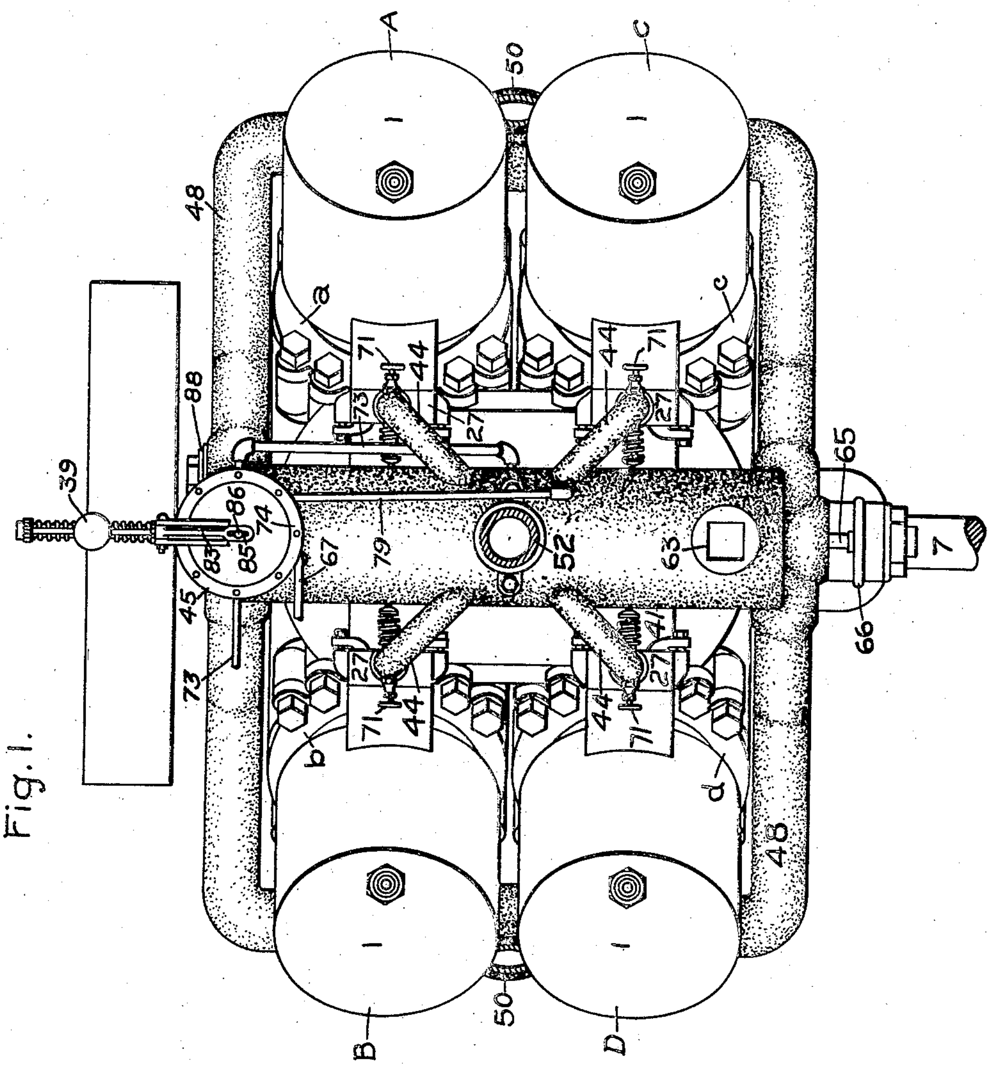


Fig. 1.

Witnesses:
Irving E. Steers.
C. Bradway

Inventor.
Henry O. Westendarp.
by Albert G. Davis
Att'y.

No. 858,046. PATENTED JUNE 25, 1907.

H. O. WESTENDARP.

VAPORIZER FOR EXPLOSIVE ENGINES.

APPLICATION FILED JUNE 13, 1904.

5 SHEETS—SHEET 2.

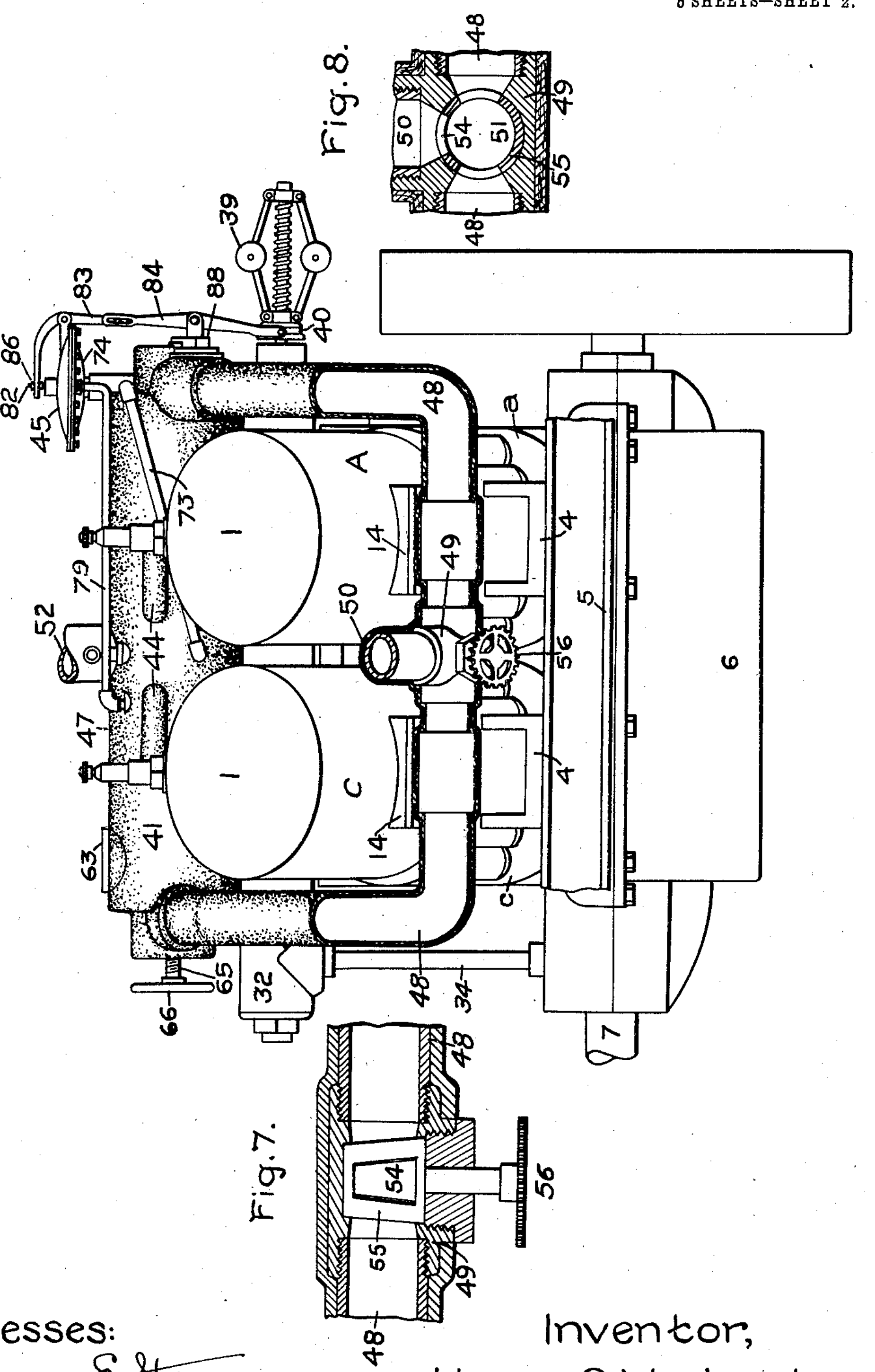


Fig. 8.

Fig. 2.

Fig. 7.

Witnesses:

Irving E. Steers.

C. Bradway

Inventor,

Henry O. Westendarp.

by Albert G. Davis

Att'y.

No. 858,046. PATENTED JUNE 25, 1907.

H. O. WESTENDARP.

VAPORIZER FOR EXPLOSIVE ENGINES.

APPLICATION FILED JUNE 13, 1904.

6 SHEETS—SHEET 3.

Fig. 3.

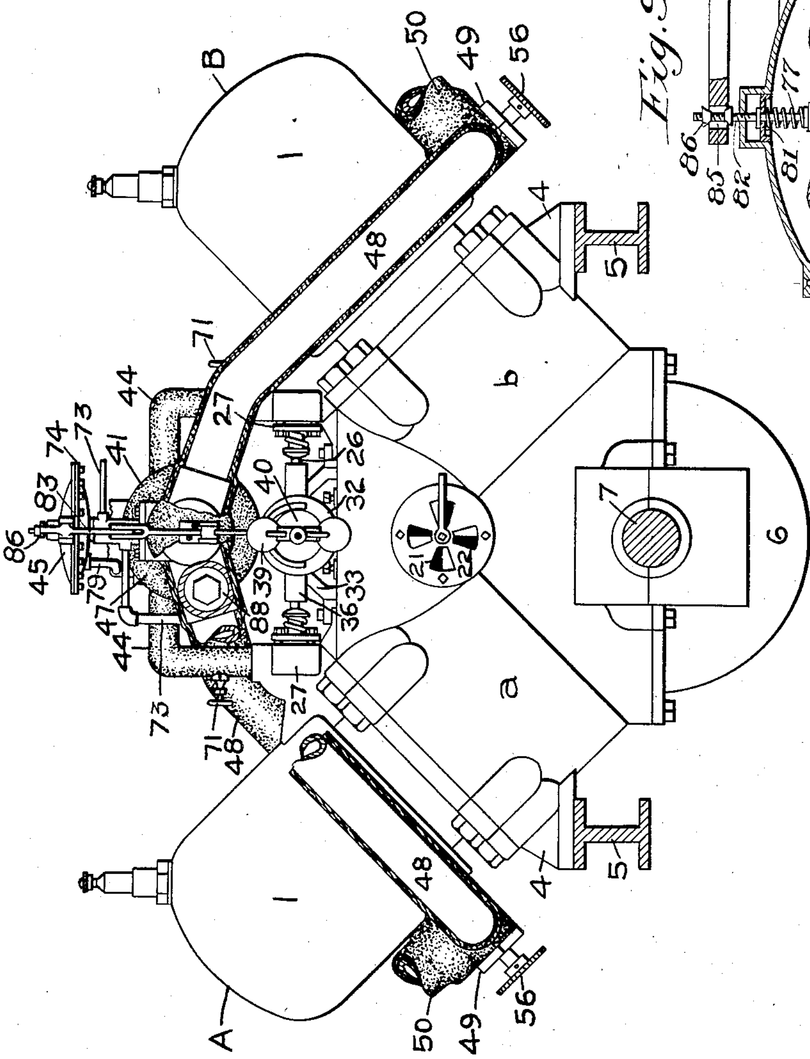
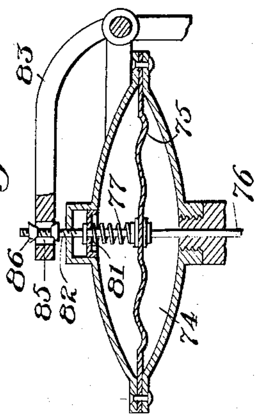


Fig. 9.



Witnesses:
Irving E. Steers.
C. Bradway.

Inventor,
Henry O. Westendarp.
by Albert G. Davis
Att'y.

No. 858,046. PATENTED JUNE 25, 1907.

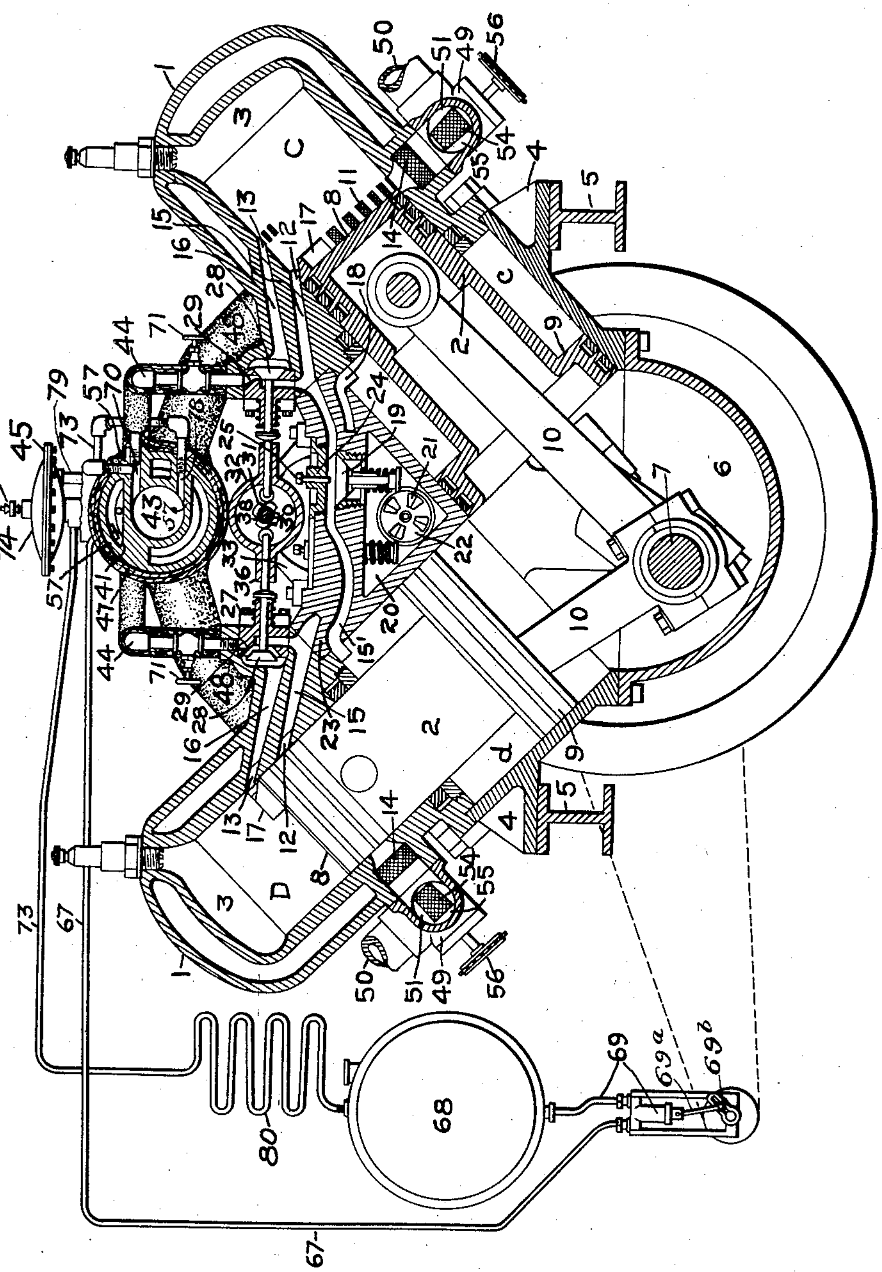
H. O. WESTENDARP.

VAPORIZER FOR EXPLOSIVE ENGINES.

APPLICATION FILED JUNE 13, 1904.

5 SHEETS—SHEET 4.

Fig. 4.



Witnesses:

Irving E. Steers.

C. Bradway.

Inventor,

Henry O. Westendarp.

by Albert G. Davis

Att'y.

No. 858,046. PATENTED JUNE 25, 1907.

H. O. WESTENDARP.

VAPORIZER FOR EXPLOSIVE ENGINES.

APPLICATION FILED JUNE 13, 1904.

5 SHEETS—SHEET 5.

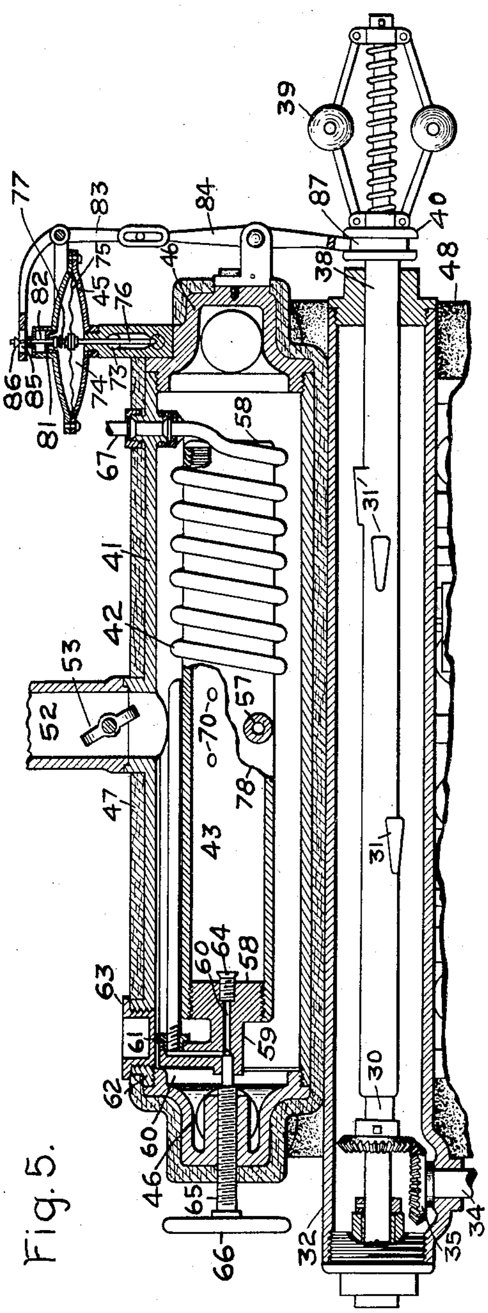


Fig. 5.

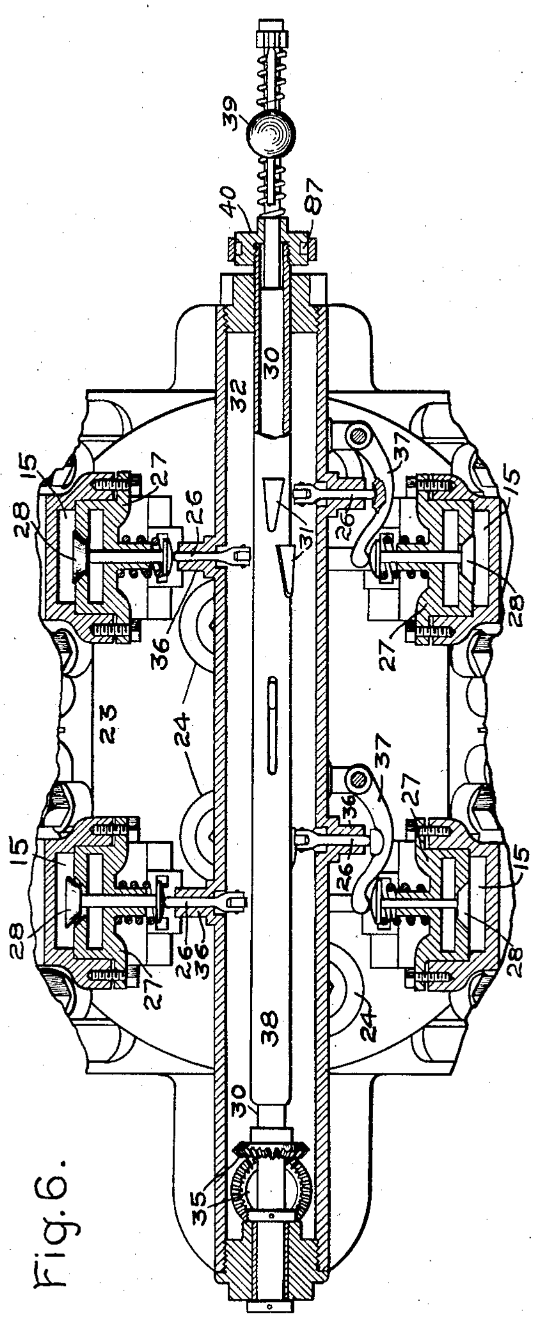


Fig. 6.

Witnesses
Lloyd C. Bush
C. Bradway.

Inventor
Henry O. Westendarp.
By Albert G. Davis
Att'y.

UNITED STATES PATENT OFFICE.

HENRY O. WESTENDARP, OF SAUGUS, MASSACHUSETTS, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

VAPORIZER FOR EXPLOSIVE-ENGINES.

No. 858,046. Specification of Letters Patent. Patented June 25, 1907.

Original application filed November 4, 1903, Serial No. 179,771. Divided and this application filed June 13, 1904. Serial No. 212,230.

To all whom it may concern:

Be it known that I, HENRY O. WESTENDARP, a citizen of the United States, residing at Saugus, county of Essex, and State of Massachusetts, have invented certain new and useful Improvements in Vaporizers for Explosive-Engines, of which the following is a specification.

The present invention is a division of my pending application, Serial No. 179,771, filed Nov. 4, 1903, and is made under the requirements of the United States Patent Office under provision of Rule 41.

My invention relates to a fuel vaporizing system for vapor consumption devices, such as gas engines, turbines and the like apparatus.

One of the objects of the invention is to provide a particular form of vapor generator for use in this connection. The vaporizer is of the flasher type which is designed to supply kerosene or alcohol vapor to the engine in superheated state, preferably unmixed with air and at a predetermined pressure. The temperature of the vaporizer is maintained substantially constant by the heat of the exhaust gases regulatively supplied to the vaporizer, and a fuel supply system feeds a constant supply of liquid kerosene or alcohol thereto in definite quantity relatively to the vapor generating capacity of the vaporizer, so that the rate of vaporization is approximately constant, irrespective of variations in demand for vapor fuel. The amount of vapor in continuous generation is sufficient to supply the maximum demand created by the engine, as at maximum load, but at normal load the demand for vapor may be any proportionate quantity of the maximum vapor supply and the quantity of vapor in excess over the normal demand is permitted to escape from the vaporizer, preferably back to the source of fuel so as to prevent loss.

A further object of the invention is to provide a speed controlling system in connection with the present form of vaporizer whereby extreme sensitiveness to load changes is obtained. In the state of normal operation the quantity of vapor kerosene is practically constant as to the portion supplied to the explosion chamber or chambers of the engine and the excess of vapor that is generated is allowed to discharge from the vaporizer by way of a by-pass valve. This by-pass valve has the function of a throttle for controlling the excess of vapor and is adapted to be held in a predetermined position by the pressure of the vapor in the vaporizer acting upon a diaphragm to which the valve is fixed. When the vapor pressure tends to rise, the by-pass valve opens wider, and vice versa when the pressure tends to lower, thus maintaining the vapor normally at substantially constant pressure. There are conditions, however, which demand more positive control of the by-pass arising from changes in speed of the engine due to variation in load. That is to say, in case of overload the demand for vapor immediately increases, whereas at underload the demand decreases. To satisfy these conditions, the governor which controls the cut-off mechanism is operatively related to the by-pass valve and is adapted to so act upon the same that at overload the valve is caused progressively to close so as to prevent the usual excess of vapor from wholly or partially by-passing, and consequently as the vapor pressure is increased a larger quantity of vapor will be injected into the explosion chamber and thereby produce more powerful explosive impulses. In case of underload, the by-pass valve is opened wider in response to the governor, whereby the pressure of the vapor is lowered so as to enable less vapor to pass to the explosion chamber and cause less powerful explosive impulses. This positive actuation of the by-pass valve is desirable for close regulation because the pressure of the vapor acting on the diaphragm of the valve varies with an appreciable lag upon sudden variations in demand for vapor.

The various novel features of construction and combination of parts will be more fully described hereinafter and finally pointed out in the claims.

In the accompanying drawings which illustrate one embodiment of my invention, Figure 1 is a top plan view of an engine of the four-cylinder type with my improved vaporizer applied thereto; Fig. 2 is a side elevation; Fig. 3 is a front elevation with a part of one exhaust pipe broken away; Fig. 4 is a section taken on one plane centrally through one pair of cylinders and on a different plane through the vaporizer to plainly show the pipe connections therewith; Fig. 5 is a central vertical section of the vaporizer on an enlarged scale, with the valve governing device; Fig. 6 is a detail view of the inlet valves with the secondary shaft and cut-off mechanism parts shown in section and plan; Figs. 7 and 8 are enlarged detail views of a three-way valve in the exhaust pipes for regulating the supply of exhaust gases to the heating chamber of the vaporizer; and Fig. 9 is a detail sectional view of a pressure regulator for the vaporizer.

The vaporizing system was designed with particular reference to my two-cycle kerosene-vapor four-cylinder engine, which is the subject-matter of my pending application hereinbefore referred to, and I have elected to illustrate and describe my invention applied thereto. I do not wish to be understood, however, as limiting the invention to this particular use, as the same is capable of several applications, as well as several embodiments with respect to its broad features.

Referring to the drawings, 1 represents the cylinders of the engine and 2 the pistons. These are both of the differential type and they co-operate to form explosive chambers A, B, C and D, and air chambers *a*, *b*, *c* and *d*. The differential cylinders are each composed of two castings bolted together, one being an explosive cylinder and the other a pump cylinder relatively of large diameter. The explosion cylinder is designed for single acting work, and is accordingly provided with a closed head or compression chamber 3 and the exhaust and admission ports are arranged at the forward or open end to be controlled by the piston by which they are covered and uncovered. The pump cylinders are cast integral and constitute the base of the engine. The engine, as a whole, is supported by means of laterally-extending brackets or arms 4 on the pump cylinder casting, which rest upon parallel I-beams 5. Centrally below the pump cylinders and bolted thereto is a crank casing 6, in which is suitably mounted a two-throw crank shaft 7. The differential pistons 2 are of the trunk type, having each an explosion or power head 8 and an annular pump head 9. The pistons are directly connected with the crank shaft by connecting rods 10. In order to permit the connecting rods of each pair of opposite pistons to aline, one rod of each pair is provided with a bifurcated shaft end and the other rod is mounted within the same according to common construction.

Each explosion cylinder is provided with exhaust ports 11, air-admission ports 12 and fuel-admission ports 13. The exhaust ports are suitably proportioned and may extend partially around the cylinder, Fig. 4, at a point coinciding with the end of the power stroke or forward dead center, and they communicate with an exhaust chamber 14. The air-admission ports extend circumferentially between the ends of the set of exhaust ports, and these ports are arranged to uncover slightly after the exhaust ports begin to uncover, so as to permit the pressure of the explosive gases in the cylinder to first lower to atmospheric pressure. This enables the scavenging charge of air to be injected into the explosion chamber against a minimum pressure offered by the contents of the chamber. The fuel-admission ports are suitably remote from the exhaust ports toward the compression end of the explosion cylinder. The admission of fuel through these ports is controlled by suitable valve mechanisms hereinafter to be described, which serve to prevent the expanding gases of explosion from escaping therethrough after these ports are uncovered by the piston on its power stroke. Separate passages 15 and 16 are provided in the wall of each explosive cylinder, which communicate respectively with the air-admission ports 12 and fuel-admission ports 13. These passages incline at an angle to the axis of the cylinder for the purpose of directing the injected air charge and fuel charge against the head of the cylinder to thoroughly scavenge the explosion chamber in the first instance and to completely mix the vapor fuel with the air in the chamber in the latter instance. In order to facilitate the scavenging operation and the agitation of the fuel and air to produce the explosive mixture, a deflector 17 is provided on the power head 8 of the piston which positively deflects the charges in the direction of the cylinder head.

Each passage 15 forms a continuation of an independent air-carrying conduit 15′, Fig. 4, as set forth in my application above referred to. These conduits connect the air-chambers *a*, *b*, *c* and *d*, respectively with the explosion chambers B, C, D and A. The air chambers have each a single port 18, Fig. 4, through which the air charge is drawn into the chamber and through which it is also discharged. In each conduit a suction valve 19 is provided, which is automatic in action so as to open under the influence of the suction stroke of the pump piston to permit the intake of air and to close upon reversal of stroke to permit the delivery of air through the conduit and air-admission ports to the explosion chamber.

The inlet side of the suction valve is in communication with a suction chamber 20 Fig. 4. This chamber is formed in the pump cylinder casting centrally between the cylinders. The suction of atmospheric air into the chamber 20 takes place through an opening 21 at one end thereof, and by means of a rotary disk valve 22 the quantity of air drawn into the chamber may be regulated. This is an important function in connection with governing the speed of the engine, for the reason that according to the degree that the intake of air into the suction chamber is limited or varied relatively to the maximum, the scavenging charges of air correspondingly vary so that the scavenging of the explosion chamber of the burnt gases will be more or less complete, leaving a residue of the gases with which the fuel charges mix. The explosive mixture thus obtained will be below the normal explosive and caloric value and consequently the power impulses will be comparatively weaker. In this manner the power impulses may be controlled within certain limits so as to adapt the engine to different speed work. The valve 22 may be regulated automatically by a suitable governing mechanism, but in the present instance a manually-actuated valve is employed.

The air-carrying conduits are preferably cored out in the web 23 between the pump cylinders which comprises the top of the suction chamber, Fig. 4. These conduits are designed so as to provide within a limited area the particular system of connections between the various air chambers and explosion chambers. The suction valves 19 are of the poppet-cage type and are each removably secured in that portion of the web 23 between the suction chamber 20 and each air-carrying conduit. To permit of access to the valves, hand holes are provided in the web directly over the valves and these are closed by cover 24. Each cover is provided with an adjustable stop 25 which limits the extent to which the valve is capable of opening, and thereby relieves excessive tension upon the valve spring.

As shown in Fig. 4 the passages 16 which lead to the fuel-admission ports are by-passes communicating with the air-carrying conduits. A mechanically-operated valve mechanism is provided in each by-pass to control communication therethrough. This mechanism consists of a valve casing 27 and a by-pass puppet valve 28 having a stem guided in the casing, and is spring-actuated as usual. Each explosion cylinder is recessed at the outer end of its passage 16 to receive the casing which is removably bolted in place. The function of these by-passes or passages 16 is to provide means for utilizing a portion of each air-charge for contributing to inject the fuel charge into the explosion chamber. To accomplish this the fuel charge must be admitted into the passage during the time the by-passed portion of the air-charge is pumped through the passage. The fuel may be admitted in the form of vapor, or a liquid depending upon the degree of volatility thereof to vaporize while entraining with the air in passing to the explosion chamber. As to the manner of admitting the fuel charge, a fuel-inlet valve may be provided to open into each by-pass whereby the fuel can be admitted thereto simultaneously, or substantially so, with the opening of the by-pass valve 28, so that the fuel and by-passed air may issue together into the explosion chamber. In the preferred arrangement, however, the by-pass valve 28 possesses the additional function of admitting the fuel charge. For this purpose the valve seat is provided with a fuel port 29, Fig. 4, which connects with a suitable fuel supply system as will be hereinafter described. Thus, as the by-pass valve opens to permit air to pass, it also uncovers the fuel-admission port to permit the fuel charge to inject into the by-pass at the same time. These by-pass valves are actuated from a secondary shaft 30 by means of cams 31. The secondary shaft is suitably mounted in a cam casing 32 which is mounted on the air-suction chamber 20 in superimposed position and supported on brackets 33, Figs. 3 and 4. The secondary shaft may be driven from the crank shaft through an intermediate shaft 34 and intermeshing bevel gears 35 which may be provided at the ends thereof and on the crank shaft and secondary shaft Fig. 5.

The by-pass valves of each pair of cylinders are disposed opposite each other in symmetrical arrangement relatively to the secondary or cam shaft, Fig. 6. The cams 31 are disposed around the secondary shaft at 90 degrees. Intermediate the cams and stems of the by-pass valves are valve tappets 26 which extend through the walls of the cam casing and are mounted in bosses 36. One of the cams for each pair of valves alines with the respective valve stem, whereas the other cam is off-set relatively to its valve-stem and the tappet therefor is correspondingly off-set. Each off-set tappet is operatively related to its valve stem by means of a lever 37. This latter member is hinged on the cam casing and is supported in operative connection with its tappet and valve stem.

In connection with the present valve mechanism, variable cut-off regulation of the fuel supply to the explosion chamber is particularly desirable for maintaining the speed of the engine constant under varying load conditions. Such regulation may be either automatic, as by a speed governor, or manual, as by an operating lever, similar to launch or automobile work. To this end the cams are formed with their working portions diminishing in one direction and are carried on a sleeve 38 slidably keyed on the secondary shaft in the cam chamber. The front end of the cam sleeve extends through the casing in suitable bearings and connects with a fly-ball governor 39 secured on an extension of the secondary shaft. The sleeve revolves with the shaft and governor by means of its rigid connection with the sliding collar 40 of the governor. Upon variation in speed of the engine, the governor responds thereto and varies the position of the cams relatively to the tappets so that the period of lift of the by-pass or fuel-admission valves may be regulated according to the quantity of fuel needed to produce explosive charges that have the necessary energy to maintain steady speed.

Considering the cycle of operation of the engine as thus far described, reference is had to Fig. 4 of the drawing, in connection with the following explanation: According to the stage in the cycle as shown by the position of the pistons, the explosion chamber D has just been scavenged of the burnt gases and contains a charge of pure air, with the exhaust and air-admission ports covered by the piston which is on its return or compression stroke, and the fuel-admission or by-pass valve is held in open position by the cam-actuating means, as the fuel charge is injected into the chamber by the by-passed charge of air from the air chamber *a* which is discharging through the air-carrying conduit 15′, Fig. 4. In the explosion chamber C, the piston is approximately at dead center with the exhaust ports uncovered, and a scavenging charge of air being delivered into the chamber through the air-carrying conduit communicating therewith and uncovered air-admission ports for expelling the spent gases of explosion, the by-pass valve is as yet closed to prevent the fuel charge from injecting prematurely or before closure of the exhaust ports; the air chamber *c* has filled with air on the forward or suction stroke of the piston and is about to deliver its contents to the explosion chamber B through its connecting air-carrying conduit as the piston returns on its inward or compression stroke. As the piston in the explosion chamber B is 180 degrees displaced relatively to the piston of chamber D, the former is in a corresponding position to the latter but explosion has taken place and it is working on its power stroke; in this case the chamber *b* is taking in a charge of air through its connecting air-carrying conduit and its suction valve 19 from the suction chamber 20. Also, the piston in the explosion chamber A is approximately at its inner dead center, where compression of the explosive mixture in the chamber has ceased and ignition is about to occur, and the air chamber *a* is in the final stage of delivering air through the by-pass leading to the air chamber D. The sequence of the engine as to the occurrence of explosions, taking the pistons in the position shown, is in the following order: explosion of the mixture has just occurred in B, which is followed consecutively by A, D, C, B, A, etc.; and as to the air charges, the air chamber *a* delivers to the explosion chamber D, *d* to C, *c* to B, *b* to A, *a* to D, etc.

The air pumps are so proportioned that by their displacement each is capable of furnishing air in sufficient quantity to scavenge its respective explosion cylinder, and also to provide an excess of air for by-passing into the explosion chamber with the fuel charge. As the fuel admission ports of the explosion chambers are covered by the power pistons, it is necessary to have the pump pistons so related to the power pistons that the delivery of the by-passing portions of the air charges occurs slightly before on substantially at the time the power pistons begin to cover said ports. It will be noted that to carry out this scheme, each air chamber is connected with a definite explosion chamber of which the pistons hold such relation to each other that as the pump piston is delivering its charge the power piston is at or about passing through the forward dead center, or when the exhaust ports or fuel-admission and air-admission ports are uncovered.

A characteristic feature to be noted in connection with the engine operating on the present cycle is that of admitting the vapor fuel into the explosion chamber against a certain pressure which is due to the state of compression of the contents of the chamber incident to the initial part of the compression stroke of the piston. This is not the case in ordinary two-cycle practice wherein the fuel is admitted at substantially atmospheric pressure. In order to overcome this internal pressure of the explosion chamber the full charge must be admitted at a relatively higher pressure, and also for the further reason that the fuel-admission ports are uncovered for an appreciably less time than when they are arranged at or adjacent to the forward dead center, where the movement of the piston is relatively slower, the fuel charge must be injected at a higher speed in order that sufficient fuel can enter before the ports are covered, to produce the proper explosion mixture in the chamber. Therefore, the vaporizer best adapted to meet this condition is one that can furnish vapor at a comparatively high and substantially constant pressure. The vaporizer shown herewith is of the kind and consists of a flasher type of vapor generator capable of producing vapor in superheated state and at any desired pressure. It is especially designed for the vaporization of such of the heavy liquid fuels as kerosene. The supply of fuel to the vaporizer is maintained at a substantially constant rate in definite quantity relatively to the vapor generating capacity of the vaporizer for producing sufficient vapor to meet the maximum demand of the engine. The waste gases of explosion are utilized for heating the vaporizer and a heating system in this connection is provided in which complete control of the temperature is rendered possible. As the demand for vapor fuel varies from time to time according to load conditions the generating capacity of the vaporizer remains unaffected but means are provided to relieve vapor from the vaporizer as the vapor tends to rise above normal and thereby the vapor is maintained in normal condition. The relieved vapor is preferably by-passed back to its source and in transit it passes through a condensing device to change it to liquid state before delivering into the fuel tank.

Referring particularly to Figs. 4 and 5, the vaporizer comprises, in general terms, a heater 41, a vaporizing or flashing coil 42, a superheating chamber 43, vapor-fuel supply pipes 44 between the latter and by-pass valves 28, and a vapor-pressure-controlled by-pass or relief device 45 hereinafter to be explained.

The heater 42 is superimposed centrally between the cylinders of the engine. This is a hollow cylindrical body having removable heads 46 at its ends and is inclosed in a heat non-conducting jacket 47, as of asbestos. The ends of the heater are connected with the exhaust chambers of the cylinders by exhaust pipes 48. These pipes are also covered with asbestos and their upper ends open into the heads of the heater. The exhaust chambers of each pair of cylinders on opposite sides of the heater are in open communication with each other through a T-connection 49, and from each of these connections a relief exhaust pipe 50 leads into the atmosphere, Figs. 2 and 3, and each T-connection 49 contains a three-way valve 51, Figs. 4, 7 and 8, by manipulation of which the exhaust gases may be caused to pass either through the exhaust pipes 48 to the heater at both ends thereof or at one end only, with a portion of the gases passing through the exhaust pipes 50, or the entire gases may pass through the latter pipes and the heater be cut out of service, as for instance when the heat becomes excessively high therein. But in order to exhaust the entire gases directly to the atmosphere through the pipes 50 and thereby cut the heater out of service, the heater is provided with an outlet or discharge pipe 52 in which is provided a damper 53 by means of which latter the discharge of gases into and through the heater and the exhaust pipe 52 connected therewith, Fig. 5, is prevented. As shown in Figs. 7 and 8, the ports 54 in the plug 55 of the three-way valve are placed in the position whereby the exhaust gases can escape through the exhaust pipes 50. These valves may be hand-operated or mechanically operated, and for the latter purpose the stem of the valve is provided with a sprocket 56.

Within the heater the superheating chamber 43 is arranged, extending longitudinally and concentrically thereof, and is cast integral with the heater by means of connecting webs 57 located about centrally of the heater, Figs. 4 and 5. The vaporizing or flashing coil 44 hereinbefore mentioned is formed as a helix on the front half of the superheating chamber, and from the inner end of its helical portion the coil extends to the rear end of the chamber with which it communicates to discharge the kerosene vapor thereto for superheating. The superheating chamber is closed at its ends with heads 58 and the rear head is provided with an angular extension 59, having a passage 60 therethrough leading to the interior of the chamber and with which the rear end of the vaporizing coil connects. The connection between the extension and vaporizing coil is made by means of a differential nut 61 and access to the connection is had through a hand hole 62 in the wall of the heater, which is closed by a cover plate 63, Fig. 5. At the inner end of the passage 60 a spraying nozzle 64 is secured, and a needle or spindle 65 is provided whereby the quantity of fuel or vapor discharging into the superheating chamber may be regulated when desired. The spindle is mounted in the rear head of the heater and on its outer end carries a hand wheel 66, by manipulation of which the pointed end of the spindle is caused to vary the opening of the passage 60. The nozzle serves to spray the vapor upon the heated surface of the superheated chamber so as to effectually and rapidly raise the temperature of the vapor.

The front end of the vaporizing coil is suitably coupled through the wall of the superheating chamber with a liquid fuel supply pipe 67. The fuel supply system comprises a fuel tank 68 for kerosene, a force pump and the supply pipe 69. The effective discharge of the pump may be varied by adjusting the connection between the connecting rod 69^a and the crank 69^b, so that the quantity of fuel supplied to the vaporizer may be suitably proportioned to the vaporizing capacity determined upon for normal operation of the vaporizer. As the vaporizer is of the flasher type, the supply of fuel must bear a definite relation to its flashing capacity so as not to exceed that limit, otherwise there would result a flushing of the vaporizer with liquid fuel. By reason of the large effective heating area of the superheating chamber, and the temperature to which it is subjected, the vapor which discharges into the same from the vaporizing or flashing coil becomes superheated and raised to the desired pressure. The vapor-fuel in the superheating chamber is unmixed with air and is therefore non-explosive and the fuel charges depend upon subsequent mixing with air in the explosion chamber to be rendered explosive.

Between the superheating chamber and vapor fuel supply pipes 44, communication is established through passages 70 in the upper webs 57, between the wall of the heater and superheating chamber, Figs. 4 and 5, and the vapor fuel is supplied to the explosion chamber as the by-pass valves 28 are opened. The vapor pressure in the vaporizer must be sufficiently high so that in addition to the pressure of the by-passed air charge, the combined pressures will exceed the pressure that will have been attained in the explosion chambers while the pistons work on the compression stroke the distance between the exhaust ports and fuel-admission ports, which may be termed the initial stage of compression. At normal operation the pressure best adapted to this condition is approximately 10 pounds per square inch. In each vapor fuel supply pipe 44 a shut-off valve 71 is provided whereby any one or more explosive chambers may be cut out of service by shutting off the supply of vapor fuel thereto.

The vaporizer is adapted to generate vapor in such quantity as to amply supply the maximum demand that is likely to be made overload of the engine, whereas at normal load this quantity is in excess of the demand so that there exists a surplus of vapor under these conditions. As the generation of vapor is practically at a constant rate, this surplus would tend to store up in the vaporizer and raise the pressure therein. For this purpose the vaporizer is provided with a by-pass leading to the source of fuel and the excess of fuel is returned to the latter. This is controlled by a relief valve which is sensitive to pressure variation in the vaporizer, and according to any changes in the pressure the valve responds thereto, either closing or opening the by-pass as the case may demand, thus acting as a throttle in the by-pass. To this extent the by-pass valve is automatic in its regulation by vapor-pressure influences. At certain times, however, this is not sufficient responsive to effect close regulation of the engine, as would be required in special cases of work, as in electric lighting systems. There exists an appreciable lag in the action of the relief valve to follow the variation of the engine speed, as the vapor pressure does not change quickly enough. To overcome this the valve must be positively actuated, and quick to respond to every perceptible change of the engine speed. Thus, for instance, an overload on the engine tends to decrease the speed, the governor is immediately thrown into operation, prolonging the cut-off to admit larger fuel charges and simultaneously the governor is adapted to actuate the relief valve, immediately closing the same to prevent all or a portion of the excess of the vapor to by-pass, and utilizing this vapor to supply the extra demand of the engine. And, conversely, at underload the governor operates simultaneously the cut-off mechanism to reduce the quantity of vapor supplied for each charge, and the relief valve to cause it to open wider to permit a larger escape of the vapor from the vaporizer, thereby lowering the pressure in the latter. Accordingly, it will be noted that normally the pressure of the vapor is substantially constant, and under variation in load the pressure changes to meet these new conditions.

The following is a description of the mechanism for accomplishing the above method of regulation. The relief device 45 comprises a pressure-actuated valve situated in a by-pass connection or pipe 73 connecting with a passage 78 in the lower web 57 at the bottom of the superheating chamber and with the fuel tank 68, Figs. 4 and 5. The relief valve embodies a pressure chamber 74, a diaphragm 75, a stem or needle 76 carried thereby, and an adjustable spring 77 impinging upon the upper side of the diaphragm, Fig. 5. The lower part of the pressure chamber communicates with the interior of the superheating chamber through the passage 70 of one of the upper webs and a pipe connection 79, Figs. 1, 2 and 4. The diaphragm is thus subjected to the vapor tension of the superheating chamber, and the adjustable spring 77 is so set that the valve stem or needle 76 is balanced suitably above the seat to permit a definite excess of vapor to discharge through the by-pass. Should the pressure of the vapor tend to vary for any reason the valve will act automatically to correct the variation and maintain the pressure constant. The vapor that is relieved through the relief valve passes through a condenser 80 which is arranged in circuit with the by-pass connection 73, shown diagrammatically in Fig. 4, so as to deliver the excess kerosene vapor in liquid state to the fuel tank.

For the positive actuation of the relief valve a connection between the governor and the valve spring is provided so that tension of the spring varies according to the action of the governor. Bearing upon the spring 77 which impinges upon the diaphragm is a follower 81, suitably guided in the pressure chamber, Fig. 5, and connected with the follower, is a rod 82 which projects through the wall of the chamber to afford connection with the intermediate means attached to the governor. This means comprises hinged levers 83 and 84 fulcrumed on the engine at suitable points or respectively on the pressure chamber and heater of the vaporizer, as shown. The upper end of lever 83 is formed with an eye 85, through which passes the rod 82 held therein by means of adjustable nuts 86 on the rod which engage with the eye. This construction permits of the desired tension to be set on the spring by adjusting the nuts. The lower lever is bifurcated at its lower end and the extremities thereof engage in an annular groove 87 in the sliding collar 40 of the governor. By this arrangement any variation in the engine speed to which the governor responds is caused to be transmitted to the follower through the levers, and the follower in turn acts upon the spring to the end that greater or less tension is placed upon the diaphragm and the relief valve is correspondingly regulated.

In order to start the engine either of two methods may be employed. The first of these depends upon the vaporizer, that is the vaporizing coil and superheating chamber, being heated as by a torch to the proper temperature preparatory to supplying kerosene thereto and before the engine is started. In this manner the engine is in condition to start on kerosene vapor. In the second method the engine is started independently of the kerosene voporizer, as the vapor mixture is derived from a different source. An auxiliary gasolene vaporizer or carbureter is employed to supply the explosive mixture to the engine during this starting period and the exhaust gases of the explosion serve to heat the kerosene vaporizer of the engine so that a torch is not needed. After this preliminary heating to the proper temperature, kerosene is supplied to the vaporizer and the vapor thus generated is used for the explosive charges instead of the gasolene mixture which is at this stage cut off. To adapt the engine to these methods of starting the vapor generation, according to the first, one of the exhaust pipes 48 is provided with an opening adjacent to the front end of the heater through which the flame of a starting torch may be introduced to impinge upon the vaporizing coil and superheating chamber. As shown in Figs. 2 and 3, a removable cover 88 is adapted to be secured over this opening and prevents the escape of exhaust gases therefrom after starting. In carrying out the second method, connection may be provided with a gasolene supply and carbureting system (not shown) which supplies the explosive mixture to the air-suction chamber 20 of the engine in any desirable manner. According to this method the air system for the scavenging operation is for the time interrupted as the suction of mixture takes the place of the air supply. Under these conditions, the engine operates practically on the ordinary two-cycle principle, as to scavenging with the explosive charges. After the kerosene vapoizer has been sufficiently heated by the exhaust gases and vapor generation commenced, the gasolene mixture is cut off and the air system thus becomes restored and the engine takes up its cycle according to the principle herein described.

In accordance with the provisions of the patent statutes, I have described the principle of operation of my invention together with the apparatus which I now consider to be the best embodiment thereof; but I desire to have it understood that the apparatus is only illustrative and that the invention can be carried out by other means.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. The combination of a vaporizer, a source of liquid fuel supply, means for heating the vaporizer, a by-pass between the vaporizer and source of supply, a regulator for the by-pass for coarse regulation which is controlled by vapor pressure under certain conditions, and automatically actuated means for controlling the regulator under other conditions for fine regulation.

2. The combination of a vaporizer, a source of liquid fuel supply, controllable means for heating the vaporizer, a by-pass between the source of supply and vaporizer, a regulator for the by-pass controlled by vapor pressure, a motor supplied by the vaporizer, and a speed responsive device which controls the by-pass regulator.

3. The combination of a vaporizer, a source of liquid fuel supply, means for heating the vaporizer, means for by-passing a portion of the vapor from the vaporizer, a regulator for the by-pass controlled by the pressure on the vaporizer under certain conditions, a motor supplied by vapor, a speed responsive device therefor, and means between said device and by-pass regulator which controls the action of the latter.

4. The combination with an explosive engine, of a heater connected with the exhaust ports of the engine, a vaporizer in co-operative relation with the same, means controlling the exhaust gases for maintaining the temperature of the vaporizer substantially constant, means for supplying liquid fuel to the vaporizer, and means for controlling the pressure of the vaporizer to vary it directly as the supply of vapor to the engine varies.

5. The combination with an explosive engine, of a vaporizer adapted to generate superheated vapor fuel at a predetermined temperature and pressure, means for heating the vaporizer by the exhaust gases from the engine, means for controlling the heating of the vaporizer, means for supplying liquid fuel to the vaporizer in sufficient quantity to generate vapor equal to the maximum demand therefor and independently of variations in demand, and means sensitive to variations of vapor pressure and of the engine speed for by-passing a variable quantity of vapor from the vaporizer according to variations in demand therefor.

6. The combination with an explosive engine, of a vaporizer adapted to generate superheated vapor fuel, means supplying liquid fuel to the vaporizer at a constant predetermined quantity dependent upon the maximum vapor demand of the engine, means for heating the vaporizer to a predetermined temperature, and means whereby the pressure in the vaporizer remains substantially constant at normal demand and varies dur-

ing variation in demand in direct relation thereto.

7. The combination with an explosive engine, of a vaporizer for supplying vapor fuel to the engine, said vaporizer comprising means for gradually heating to the temperature of vaporization liquid fuel supplied thereto at substantially constant feed, means for supplying liquid fuel to the vaporizer in definite quantity, and means for maintaining the pressure in the vaporizer substantially constant during normal demand for vapor and for varying the pressure directly as the demand varies.

8. The combination with an explosive engine, of a vaporizer for supplying fuel vapor thereto, a heater adapted to maintain the vaporizer at substantially constant temperature, means supplying fuel to the vaporizer in definite quantitative relation to the vapor generating capacity of the vaporizer to generate sufficient vapor to meet the maximum demand therefor, means whereby a definite proportion of the vapor generated is permitted to escape from the vaporizer during normal demand, and automatic means cooperating with the last mentioned means for varying the quantity permitted to escape inversely as the demand for the vapor varies.

9. The combination with an explosive engine, of a vaporizer comprising means for gradually heating liquid fuel supplied to the vaporizer in definite quantity for generating vapor at a predetermined pressure, means responsive to the engine speed for varying the supply of vapor to the engine, and means responsive to the engine speed for normally by-passing a portion of the vapor at said predetermined pressure and varying the quantity by-passed as the demand for the vapor varies.

10. The combination with an explosive engine, of a vaporizer comprising means for gradually heating liquid fuel to the temperature of vaporization and means for superheating the vapor, means for supplying liquid fuel to the vaporizer in definite quantity for generating vapor at a predetermined pressure, and means responsive to the engine speed for by-passing a portion of the vapor at said predetermined pressure and capable automatically to vary the quantity bypassed in accordance with variation in demand for the vapor.

11. The combination with an explosive engine, of a vaporizer for supplying superheated vapor fuel to the engine, means for heating the vaporizer to substantially constant predetermined temperature, adjustable means supplying liquid fuel in definite quantitative relation to a predetermined temperature condition of the vaporizer, and means responsive to the vapor pressure and to the engine speed for by-passing vapor from the vaporizer in varying quantity as the vapor pressure tends to vary in accordance with variations in demand for vapor.

12. The combination with an explosive engine, of a vaporizer comprising means for gradually heating liquid fuel to the temperature of vaporization and means for superheating the vapor, means for supplying liquid fuel to the vaporizer in definite quantity sufficient to generate vapor equal to the maximum demand of the engine, and means responsive to speed changes for by-passing vapor from the vaporizer in varying quantity as the demand for vapor varies below the maximum.

13. The combination with an explosive engine, of a heater adapted to receive exhaust gases from the engine, a vaporizer inclosed in the heater, means for controlling the supply of exhaust gases to the heater for maintaining the temperature of the vaporizer substantially constant, a source of liquid fuel, means for supplying fuel therefrom to the vaporizer in definite quantity dependent upon the temperature of the vaporizer to generate vapor equal quantitatively to the maximum demands of the engine, an automatically-controlled by-pass leading from the vaporizer to the source of liquid fuel for permitting a definite portion of the vapor generated to by-pass at the normal demand for vapor, and a speed-responsive device for varying the portion by-passing inversely as the demand varies.

14. The combination with an explosive engine, of a vaporizer for supplying superheated vapor fuel to the engine at substantially constant pressure, means for maintaining the temperature of the vaporizer constant, a source of liquid fuel, means for supplying fuel therefrom to the vaporizer in definite quantitative relation to the temperature thereof for flashing into vapor at a predetermined pressure, a by-pass between the vaporizer and source of liquid fuel for delivering vapor fuel from the vaporizer, means dependent upon vapor pressure in the vaporizer for controlling the by-pass for permitting a definite proportion of the vapor generated to escape during the normal demand for vapor and dependent upon the speed of the engine for varying the proportion of the escaping vapor inversely as the demand varies, and a condenser in the by-pass for liquefying the vapor fuel delivered from the vaporizer.

15. The combination with an explosive engine, of a vaporizer adapted to be maintained at a constant temperature by a controlled supply of exhaust gases from the engine, said vaporizer comprising a vaporizing coil and a superheating chamber arranged in co-operative relation to each other for gradually heating liquid fuel supplied thereto successively to the temperature of vaporization and to a predetermined degree of superheat, a source of liquid fuel, means for supplying fuel to the

vaporizing coil, a by-pass connecting the superheating chamber and source of liquid fuel, a valve controlling the by-pass for permitting a definite quantity of vapor to by-pass at normal demand, and means for varying the movement of said valve in accordance with variation in demand for vapor fuel relatively to the normal demand at which the engine operates.

16. The combination with an explosive engine, of a vaporizer for supplying vapor fuel to the engine at a predetermined pressure, means for supplying liquid fuel thereto in definite quantity for generating vapor sufficient to supply the maximum demand of the engine, means for heating the vaporizer to substantially constant temperature, automatic relief means for by-passing vapor from the vaporizer to maintain the pressure substantially constant during normal demand for vapor fuel, and automatic means co-operating with the relief means for varying the quantity of vapor by-passed inversely as the demand for vapor varies relatively to the normal demand.

17. The combination with an explosive engine, of a vaporizer comprising a vaporizing coil and a superheating chamber arranged in co-operative relation to each other and providing a continuous passage whereby liquid fuel supplied thereto vaporizes and superheats to a predetermined pressure and temperature, a source of liquid fuel, means for supplying fuel to the vaporizer, means for maintaining the temperature of the vaporizer substantially constant, a by-pass between the superheating chamber and source of liquid fuel, a needle valve controlling the by-pass, a pressure regulator for varying the movement of the needle valve when the pressure of vapor in the superheating chamber tends to vary, and an automatic device sensitive to the load changes for varying the set of the regulator for fine regulation.

18. The combination with an explosive engine, of a vaporizer for supplying vapor fuel to the engine at a predetermined pressure and temperature, means supplying liquid fuel thereto in definite quantity to generate vapor sufficient to supply the maximum demand of the engine, means for maintaining the temperature of the vaporizer substantially constant, automatic relief means having a limited range of operation to maintain the vapor pressure in the vaporizer substantially constant at normal demand for vapor, and means responsive to variation of speed of the engine coöperating with the automatic relief means for varying the quantity of vapor relieved in inverse proportion to the variations in demand for vapor.

19. The combination with an explosive engine, of a vaporizer for supplying vapor fuel to the engine at a predetermined pressure, means supplying liquid fuel thereto in definite quantity for generating vapor sufficient to supply the maximum demand of the engine, means for heating the vaporizer, automatic relief means for maintaining the vapor pressure in the vaporizer substantially constant at normal demand for vapor fuel, and means normally in neutral operative relation to the automatic relief means adapted to coact therewith upon abnormal speed of the engine for varying the operation of the relief means.

20. The combination with an explosive engine, of a vaporizer for supplying vapor fuel to the engine at a predetermined pressure, means for varying the supply of vapor fuel to the engine directly as the working load thereon varies, and means for maintaining the vapor pressure in the vaporizer substantially constant during normal demand for vapor fuel and for varying the pressure directly as the demand varies.

21. The combination with an explosive engine, of a flash vaporizer for supplying vapor fuel in superheated state to the engine at a predetermined pressure, means for varying the effective supply of vapor fuel to the engine to maintain the speed thereof substantially constant during variations in load, and means for maintaining the vapor pressure in the vaporizer substantially constant during normal demand for vapor fuel and for varying the pressure directly as the demand varies.

22. The combination with an explosive engine, of a flash vaporizer for supplying vapor fuel in a superheated state to the engine, at a predetermined pressure and temperature, means governing the speed of the engine by regulating the effective supply of vapor fuel thereto according to variations in load, means supplying liquid fuel to the vaporizer in definite quantitative relation to the vapor generating capacity thereof, means sensitive to the variation in vapor pressure of the vaporizer for maintaining the pressure substantially constant at normal demand, and means co-operating with the latter means for varying the vapor pressure directly as the demand varies.

23. The combination with an explosive engine, of a flash vaporizer for supplying vapor fuel to the engine in a superheated state and at a predetermined pressure and temperature, automatic means responsive to speed variation for regulating the effective supply of vapor fuel to the engine, means separate from the said automatic means and co-operating therewith to maintain the vapor flashing capacity of the vaporizer substantially constant irrespective of variations in demand for vapor, automatic means for maintaining the pressure of the vaporizer substantially constant at normal demand for vapor, and means actuated by the speed responsive means and co-operating with said

latter automatic means for varying the pressure of vapor directly as the demand for vapor varies.

24. The combination with an explosive engine, of a vaporizer for supplying vapor fuel to the engine at a predetermined pressure, a speed responsive device, a variable cut-off mechanism operated thereby for controlling the supply of vapor fuel to the engine, automatic means for maintaining the pressure of the vaporizer substantially constant, means operatively connected with the speed responsive device for co-operating with said automatic means to vary the operative pressure of the vaporizer during abnormal speed of the engine.

25. The combination with an explosive engine, of a vaporizer for supplying vapor fuel to the engine at a predetermined pressure, a speed-responsive device, means operatively related thereto for varying the supply of vapor fuel to the engine, a source of fuel, a by-pass between the vaporizer and source of fuel, a needle-valve controlling the by-pass, a pressure chamber, a diaphragm therein carrying the needle-valve, a conduit connecting the vaporizer and pressure chamber, and means operatively related to the speed responsive device for varying the tension on the diaphragm simultaneously with the variation in supply of fuel vapor to the engine.

26. The combination with an explosive engine, of a vaporizer for supplying vapor fuel to the engine at a predetermined pressure, a speed-responsive device, means operatively related thereto for varying the supply of vapor fuel to the engine, a source of liquid fuel, a by-pass connecting the vaporizer with the source of liquid fuel, a needle-valve controlling the by-pass, a pressure chamber, a diaphragm therein carrying the needle-valve, a conduit connecting the vaporizer and pressure chamber to render the diaphragm sensitive to variation in pressure of vapor, and means operatively related to the speed-responsive device for varying the tension of the diaphragm to regulate the opening of the needle valve.

27. The combination with an explosive engine, of a vaporizer for supplying vapor fuel to the engine in a superheated state and at a predetermined pressure and temperature, said vaporizer comprising a vaporizing coil and superheating chamber, a source of liquid fuel, a by-pass connecting the superheating chamber and source of liquid fuel, a needle-valve controlling the by-pass, a pressure chamber, a diaphragm therein operating the needle valve, a conduit connecting the superheating chamber and pressure chamber for maintaining the needle-valve in partially open position by the vapor pressure of the vaporizer at a predetermined pressure and at normal demand for vapor, an adjustable spring impinging on the diaphragm, a speed-responsive device for varying the supply of vapor to the engine, and means operatively related to the speed-responsive device for varying the tension of the spring to control the action of the needle valve whereby the quantity of vapor by-passed varies inversely as the demand for vapor varies.

28. In an explosive engine, the combination of an explosive cylinder, a heating chamber, exhaust connections between the explosion cylinder and heating chamber, means in the exhaust connections controlling the discharge of exhaust gases into the heating chamber for regulating the temperature thereof a vaporizer within the heating chamber in co-operative connection with the explosion cylinder, means for supplying fuel to the vaporizer in definite quantitative relation to the vaporizing capacity thereof, means for by-passing vapor from the vaporizer during normal demand for vapor, and means controlled by the speed of the engine for varying the quantity of vapor by-passed inversely as the demand for vapor varies.

29. In an explosive engine, the combination of an explosion cylinder, a heating chamber, exhaust connections between the explosion cylinder and heating chamber, a kerosene superheating chamber within the heating chamber, a source of liquid fuel supply, a fuel heating coil surrounding and connected with the superheating chamber and with the source of fuel supply, means for supplying vapor to the explosion cylinder, a bypass between the superheating chamber and source of fuel supply, and means in the bypass actuated by vapor pressure for by-passing the vapor generated in excess of the normal demand of the engine.

30. In an explosive engine, the combination of an explosion cylinder, a heating chamber, exhaust connections between the explosion cylinder and heating chamber, a superheating chamber within the heating chamber which supplies vapor unmixed with air to the engine, a source of liquid fuel supply, a fuel heating coil connected with the superheating chamber and source of fuel, means supplying fuel in constant quantity sufficient to generate vapor equal to the maximum demand therefor, means regulated by the pressure of the vapor for by-passing the excess of vapor from the super-heating chamber during variation in demand, and variably controlled means supplying vapor from the said chamber to the explosion cylinder.

31. In an explosive engine, the combination of an explosion cylinder, a heating chamber, exhaust connections between the heating chamber and explosion cylinder, a vapor superheating chamber within the heating

chamber which delivers vapor unmixed with air to the cylinder, a fuel heating coil connected with the superheating chamber, means supplying fuel through the heating coil to the superheating chamber in predetermined quantity to generate vapor equal to the maximum demand therefor, means supplying the vapor from the chamber to the cylinder, and means controlled by the engine speed for by-passing the excess of vapor from the superheating chamber during variations in demand.

32. In an explosive engine, the combination of an explosion cylinder, a heating chamber, exhaust connections between the explosion cylinder and heating chamber, means in the exhaust connections controlling the discharge of exhaust gases into the heating chamber to vary the temperature thereof, a vaporizer within the heating chamber which delivers vapor unmixed with air to the engine, means supplying liquid fuel to the vaporizer in definite quantitative relation to the vaporizing capacity thereof independent of the demand for vapor, and means for by-passing the excess of vapor from the vaporizer upon variation in demand for vapor.

33. In an explosive engine, the combination of an explosion cylinder, an exhaust chamber, a vaporizer, a heating chamber inclosing the vaporizer, exhaust connections between the exhaust chamber and ends of the heating chamber, an outlet pipe for the escape of gas from the heating chamber, and a relief exhaust pipe connecting with the exhaust chamber and leading directly to the atmosphere.

34. In an explosive engine, the combination of an explosion cylinder, an exhaust chamber, a vaporizer, a heating chamber surrounding the vaporizer, exhaust pipes connecting the exhaust chamber with the ends of the heating chamber, a discharge pipe for the outlet of the exhaust gases from the heating chamber, a relief exhaust pipe leading to the atmosphere from the exhaust chamber, and a valve for regulating the discharge of the exhaust gases to the heating chamber and discharge pipe.

35. In an explosive engine, the combination of a plurality of cylinders, each having an exhaust chamber, a vaporizer, a heating chamber surrounding the vaporizer, exhaust pipes connecting the exhaust chambers with the ends of the heating chamber, a discharge pipe for the outlet of the exhaust gases from the heating chamber, relief exhaust pipes extending from the exhaust chambers to the atmosphere, a damper in the discharge pipe, and valves in the relief exhaust pipes co-operating with the damper to control the exhaust gases passing to the heater for varying the temperature of the vaporizer.

In witness whereof I have hereunto set my hand this tenth day of June, 1904.

HENRY O. WESTENDARP.

Witnesses:
DUGALD McK. McKILLOP,
JOHN J. WALKER.