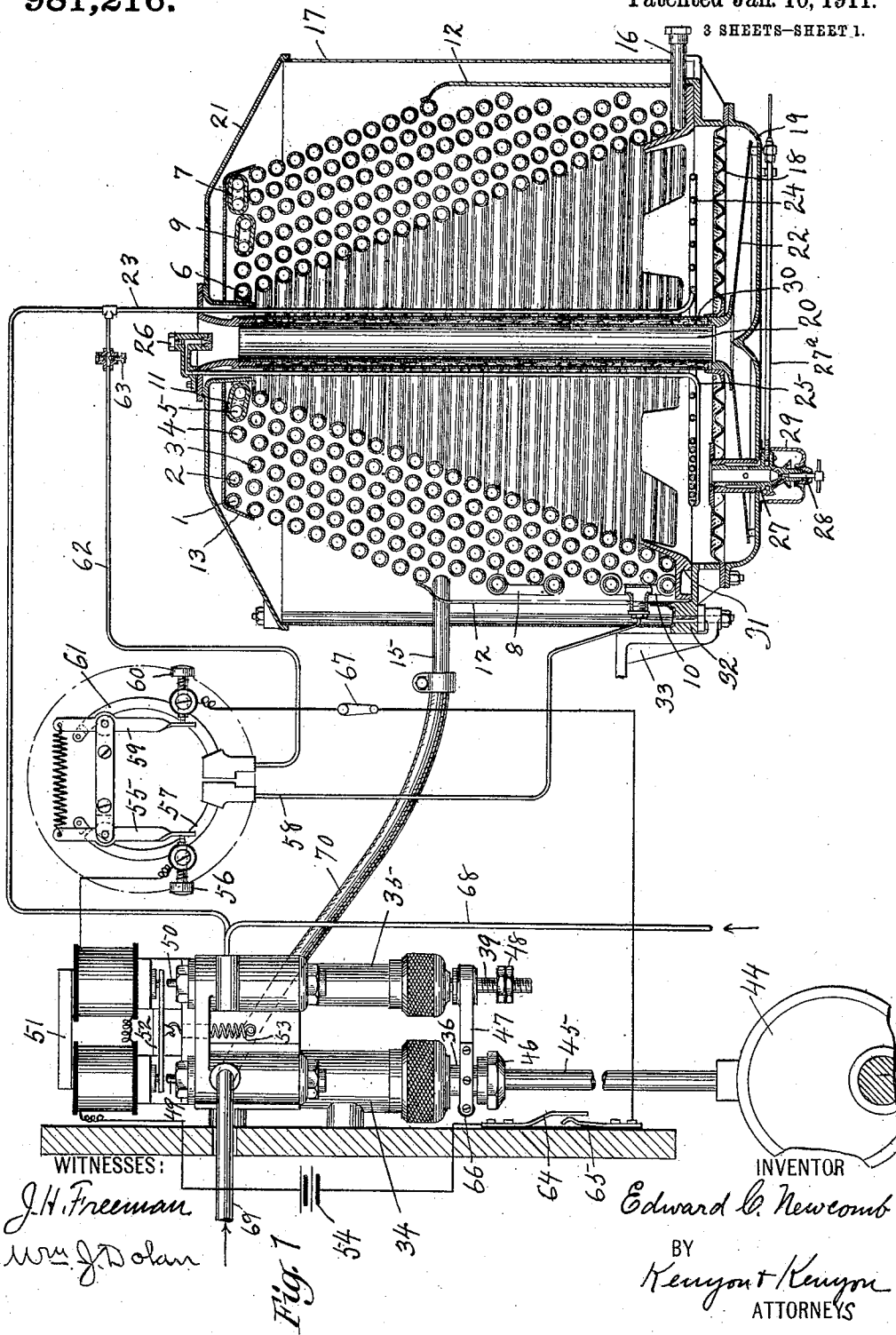


E. C. NEWCOMB.
 APPARATUS FOR GENERATING STEAM OR OTHER VAPOR.
 APPLICATION FILED JAN. 27, 1906.

981,216.

Patented Jan. 10, 1911.

3 SHEETS-SHEET 1.

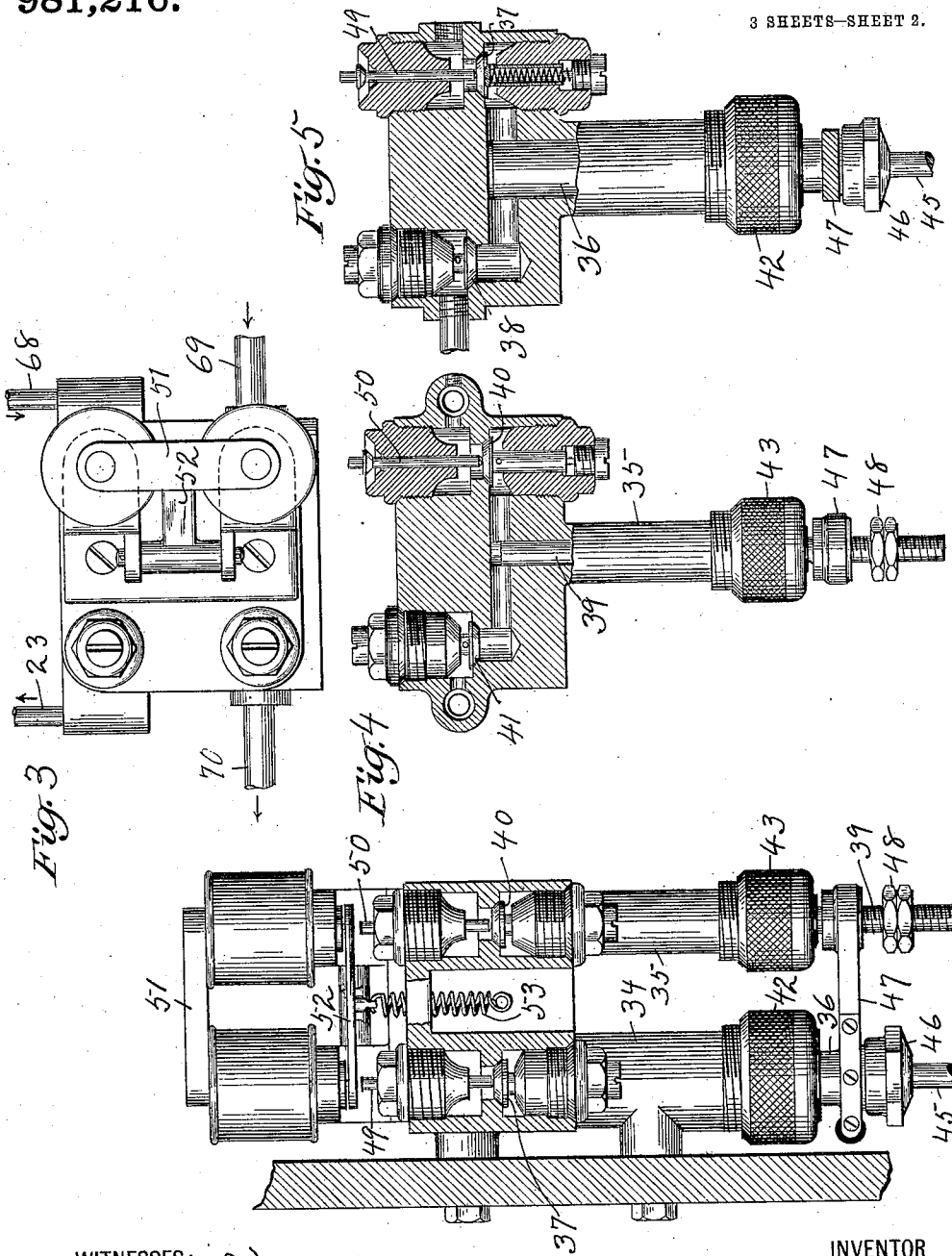


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3 SHEETS-SHEET 2.



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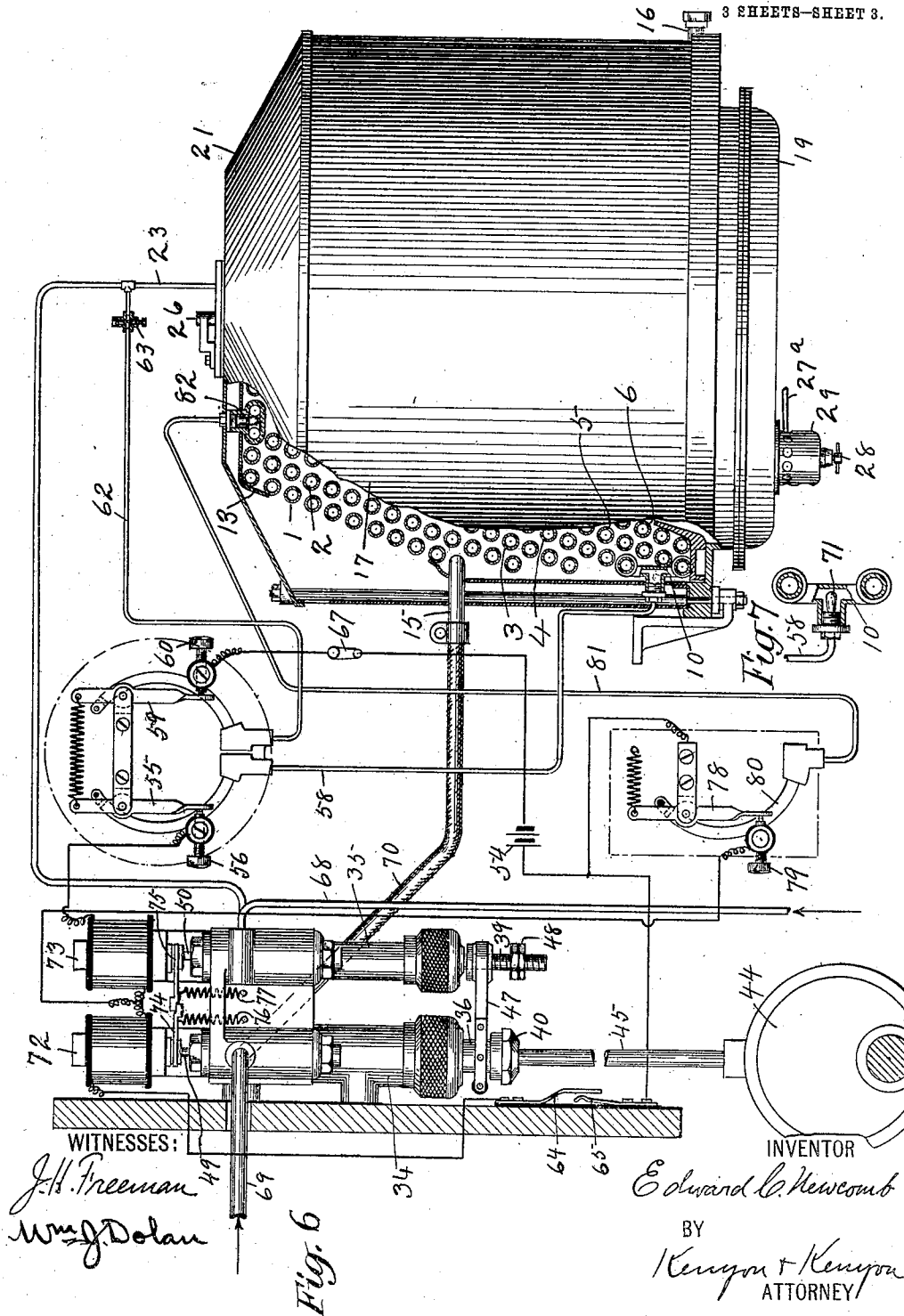
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3 SHEETS-SHEET 3.



UNITED STATES PATENT OFFICE.

EDWARD C. NEWCOMB, OF BOSTON, MASSACHUSETTS, ASSIGNOR TO THE NEWCOMB MOTOR COMPANY, A CORPORATION OF NEW YORK.

APPARATUS FOR GENERATING STEAM OR OTHER VAPORS.

981,216.

Specification of Letters Patent.

Patented Jan. 10, 1911.

Application filed January 27, 1905. Serial No. 242,824.

To all whom it may concern:

Be it known that I, EDWARD C. NEWCOMB, a citizen of the United States, and a resident of Boston, county of Suffolk, and State of Massachusetts, have invented certain new and useful Improvements in Apparatus for Generating Steam or other Vapors, of which the following is a specification.

My invention relates to the generation of steam or other vapor, and more particularly to certain forms or species of the generic inventions set forth in United States Letters Patent No. 704,907, and No. 704,908, both dated July 15th, 1902.

In accordance with the various embodiments of my invention, including those set forth in the patents referred to, the generation of the thermal energy is varied in substantial unison with the variations in demand for thermal energy and in substantially the same degree with said variations of demand, so that little reserve energy is required in the apparatus. This is accomplished by varying the supplies of a fluid to be heated and an agent for heating the same in substantial unison with the variations of demand for the thermal energy contained in the heated fluid and each according to a definite quantitative relation to said variations of demand, as more fully set forth in the patents referred to.

As illustrated and specifically described in the patents referred to, the invention is applied to apparatus for generating steam or other vapor, and the supplies of the liquid to be heated and vaporized and the fuel for heating and vaporizing the liquid are automatically varied by variations in the condition of the fluid being heated.

An object of my present improvements is to provide a method and means whereby my invention may be more perfectly carried into effect and the apparatus rendered simpler and more practical. These and other objects will more fully appear from the following description.

As applied to an apparatus for generating steam or other vapor, my present improvements will be embodied in an apparatus comprising means forming a combustion chamber, a generator having a continuous passage so arranged with relation to the combustion chamber that the water is gradually heated to the temperature of vaporization and is then gradually vaporized, means

for supplying fuel to the combustion chamber, means for supplying a liquid to the generator, and means rendered operative by variations in the condition of the fluid at a predetermined point in said passage for varying the supplies of both the fuel and the liquid in substantial unison with the variations of demand for the thermal energy of the steam or other vapor delivered by the apparatus and according to substantially definite quantitative relations to said variations of demand.

In accordance with one embodiment of the present improvements, the generator may be constructed of coiled pipe forming a single continuous passage, the liquid being supplied to the end of the passage most remote from the combustion chamber and the vapor delivered from the end of the passage nearest the combustion chamber.

In practice, a fluid fuel or a fuel which can be controlled like a fluid should be used in order that the quantity of the heat developed may be accurately regulated and quickly varied to correspond to the variations of demand for the thermal energy of the steam or vapor. Water or any suitable liquid substance which will not decompose under the conditions to which it is subjected in the apparatus may be used in the generator.

In accordance with a preferred construction, the means for supplying the fuel and the liquid are preferably capacitated to supply the same at a greater rate than the demand, and the means for varying the supplies operate intermittently to establish and cut off the supplies, the mean supplies of the fluids being varied by the variations of the frequency or duration of the operations of the supply-controlling means or by variations of both the frequency and the duration of said operations.

In accordance with a preferred embodiment of the present improvements, also, the supply-controlling means may be rendered operative by variations in the condition of the fluid in the generator at or near the point of the passage where the liquid is first brought to the temperature of vaporization, and the condition either as to pressure or as to temperature may be selected as the controlling condition. The supply-controlling means, also, may act directly to vary the supply of liquid to the generator in the

manner described and the supply of fuel may be varied indirectly by means tending to maintain a predetermined relation between the supplies of the fuel and the liquid.

5 In accordance with a preferred embodiment of the present improvements, also, means are provided whereby the predetermined relation between the supplies of the liquid and the fuel may be varied in such
10 manner as to deliver the vapor at the desired predetermined temperature; and if desired, means may be provided for automatically varying the relation between the supplies of the fuel and the liquid so as to compensate for any variations in the efficiency of
15 the apparatus at different loads or demands for thermal energy. And according to a preferred embodiment of this feature of the present improvements, the variations in the condition as to temperature of the liquid
20 at a predetermined point in the passage of the generator may be utilized for automatically varying the relation between the supplies of the fuel and the liquid.

25 In accordance with a preferred embodiment of the present improvements, also, the supply-controlling means and the ratio-controlling means, also, where the latter means are employed, may include electromagnetic connections whereby the supplies
30 of the fuel and the liquid may be varied through their maximum range for a minimum range in the variations of the controlling condition selected.

35 For the sake of clearness and brevity, I have herein referred to the variations of the thermal energy of the vapor delivered by the apparatus as variations of demand for vapor energy.

40 It is not to be understood by the term "substantial unison" as used herein that the relative variations between demands for and the supplies of the fluids are strictly simultaneous. The essential in this regard
45 is that the variations be produced promptly enough to maintain the apparatus in a practically predetermined condition.

The expressions "substantially in definite quantitative relation" and "substantially in
50 predetermined quantitative relation," as used herein, are not to be understood as necessarily referring to unchanging relations between the supplies or flows of the fluids and the demand for thermal energy, for
55 such relations may be made to vary. It is intended that these expressions shall comprehend such relations between the supplies of the fluids and the demand as will produce practically uniform results and maintain the apparatus in a practically predetermined
60 condition. Where, for example, the efficiency of the apparatus varies materially with different demands for vapor energy, the definite or predetermined relations between the supply of the fluid to be heated

and the heating agent may be so changed as to compensate for variations in the efficiency of the apparatus and to deliver the heated fluid at the desired temperature at all times.

70 My present invention consists in the novel improvements, combinations, and constructions herein described and shown.

The accompanying drawings, which are referred to herein and form a part hereof,
75 illustrate one embodiment of my invention together with certain additional features, the same serving in connection with the description herein to explain the principles of the invention.

80 Of the drawings, Figure 1 is a view partly in section, partly in elevation and partly diagrammatic illustrating an apparatus constructed in accordance with certain features of the present improvements; Fig. 2 is a side
85 elevation partly in section of the devices for supplying liquid to the generator and fuel to the combustion chamber, and also part of the means for controlling said supplies; Fig. 3 is a plan view of the same; Fig. 4 is a
90 view partly in elevation and partly in section of a fuel pump; Fig. 5 is a similar view of a liquid pump; Fig. 6 is a view similar to Fig. 1 illustrating another feature of the improvements; and Fig. 7 illustrates a fea-
95 ture which may be substituted for the corresponding feature of the apparatus illustrated in Fig. 6.

Like reference numerals refer to like parts.

100 While some of the advantages of my invention may be realized by the use of various forms of generators, the best results can only be obtained in connection with the main features of my present improvements, as will hereinafter more fully appear, by
105 the use of a generator in which the liquid is gradually heated from its point of entrance until it is brought to the temperature of vaporization and is then gradually vaporized, only a small quantity of the liquid in the
110 generator being maintained at the temperature of vaporization corresponding to the pressure at which the apparatus is operated.

In accordance with the particular embodiment of the invention illustrated, the generator is constructed of coiled pipe forming
115 a single continuous passage adapted to receive the liquid to be vaporized at one end and to deliver the vapor, preferably in a superheated condition, at the other end, said
120 passage having a liquid-heating portion in which the liquid is gradually heated to the temperature of vaporization, a vaporizing portion in which the liquid is gradually vaporized, and a superheating portion forming
125 a continuation of the vaporizing portion.

As shown, the generator consists of six frusto-conical pipe coils numbered 1, 2, 3, 4, 5, and 6, said coils being nested one within another and all being of substantially the
130

same diameter at the larger end and being made successively longer from the outer coil to the inner coil so as to form an approximately cylindrical mass of heating surfaces.

5 The coils are connected together in series, preferably by suitable connections 7, 8, 9, 10, and 11. The coils surround the combustion chamber and the convolutions of the coils are suitably separated from each other so as to provide passages for the flow of the products of combustion throughout the entire mass of heating surfaces from the inner coil to the outer coil, suitable shields 12 and 13 being provided so as to cause all the products of combustion to pass between the convolutions of each of the coils successively from the innermost coil to the outermost coil. The outermost coil is connected at its lower end to the liquid supply pipe 15, and the innermost coil is connected at its lower end to the steam delivery pipe 16, so that the fluid is caused to flow from the outermost coil to the innermost coil in a direction opposite to that in which the flow of the products of combustion takes place so that the heat of the products of combustion is efficiently absorbed and the fluid is gradually heated from the point of entrance to the point of delivery. The heat absorbing efficiency of the generator is materially increased by reason of the fact that the total area of the passages for the products of combustion between the convolutions of each coil is successively decreased from the innermost coil to the outermost coil substantially in proportion to the decrease in the volume of the products of combustion due to the gradual decrease in the temperature thereof. By reason of the construction shown and described, also, the products of combustion are caused to flow in substantially the same path at all times, and the distribution of the heat in the generator remains practically uniform for all loads or demands upon the apparatus. The connections between the several coils are also located outside of the combustion chamber so that they are not subjected to the hottest products of combustion. The generator is preferably inclosed in a substantially cylindrical casing 17 between the lower part of which and the shield 12 is formed an annular discharge flue for the waste products of combustion.

So far as some of the features of my invention are concerned, any suitable means may be provided for the combustion of the fuel by which the heat generated may be accurately controlled and quickly varied to correspond with variations in the demand for steam. As shown, a burner adapted for the consumption of liquid fuel is provided, the same consisting of a perforated plate 18 between which and a plate 19 is provided a chamber adapted to receive a suitable mixture of fuel and air from a central mixing

tube 20 and evenly distribute the same throughout the area of the perforated plate 18. Preferably and as shown, the mixing tube 20 is vertically arranged and extended upwardly through the center of the space inclosed by the generator coils to the center of the top plate 21 of the generator-inclosing case. For the purpose of more evenly distributing the mixture of fuel and air throughout the area of the perforated plate 18, a conical distributing plate 22 is preferably arranged between the plates 18 and 19, said plate 22 being connected to the lower end of the mixing tube 20 and separated a suitable distance from the lower plate 19 at its outer edge, substantially as shown. The chamber formed between the plate 22 and the lower plate 19 also serves to separate any unvaporized particles of the fuel which may be carried through the vaporizer or formed by condensation of the vapor, and prevent the same from entering the combustion chamber until they are properly vaporized by the current of heated fuel and air mixture. This is a valuable feature of the burner, especially when a heavy hydrocarbon such as kerosene or fuel oil is used.

In accordance with the construction shown, the liquid fuel is supplied through the pipe 23 to a fuel-vaporizing coil 24 arranged in the combustion chamber above the perforated plate 18, the vaporized fuel being led by a pipe 25 to a nozzle 26 arranged in the mouth of the mixing tube 20. For the purpose of heating the fuel vaporizer to start the burner, a suitable pilot burner is provided, the same consisting of a hollow part 27 having a vaporizing passage in its lower end to which a suitable liquid fuel is supplied by a pipe 27^a and from which the vaporized fuel is led through a nozzle regulated by a needle valve 28, to the combustion chamber formed by said part 27. The air necessary to support the combustion is supplied through suitable perforations in the part 27, as shown.

The pilot burner is protected from external drafts by a suitable perforated casing 29, said casing having a cup-shaped lower end adapted to receive a small quantity of alcohol or gasoline to start the pilot burner. The pilot burner is designed to operate continuously to form an igniter for the main burner, so that the latter is permitted to become extinguished when there is no demand for steam or vapor from the generator. The vaporizer 24 of the main burner is preferably formed of small tubing having ample heating surface and a small quantity of reserve energy so that the heat developed in the burner will vary in substantial unison with the variations in the supply of fuel to the vaporizer. The mixing tube 20 is preferably shielded from the heat of the combustion

tion chamber, as by means of a shield tube 30 between which and the tube 20 a packing of refractory material such as asbestos is provided. The nested coils of the generator 5 are preferably separated from each other and the convolutions thereof kept in a suitably separated position by means of suitable separators (not shown), the whole being supported by a casting 31, which in turn 10 rests upon a supporting base ring 32 which may be carried by suitable supporting brackets, one of which is illustrated at 33.

So far as some of the features of my invention are concerned, any suitable means 15 may be provided for supplying liquid to the generator and fuel to the combustion chamber which are adapted to have the supplies accurately controlled or regulated in substantial unison with the variations of demand for vapor energy and in definite quantitative relation to said variations of demand. In accordance with a preferred embodiment of the invention, the means for 20 supplying the liquid and the fuel are capacitated to supply each of said fluids at a rate greater than the demand at any given time, and means are provided for intermittently establishing and cutting off said supplies so that the mean effective supply of each fluid 25 is varied in the manner described.

As shown, a pump 34 is provided for supplying the liquid and a pump 35 is provided for supplying the fuel, the liquid pump having a reciprocating plunger 36 and 35 suitable suction and delivery valves 37 and 38, respectively, as clearly shown in Fig. 5, and the fuel pump is provided with a reciprocating plunger 39 and suction and delivery valves 40 and 41, respectively. The 40 plungers of the water and fuel pumps are provided with suitable stuffing boxes 42 and 43, respectively, and the plungers 36 and 39 are caused to reciprocate through normally fixed lengths of stroke in unison by means 45 of a suitably driven eccentric 44 and a connecting rod 45, the rod 45 preferably being connected by a ball and socket pivot joint 46 to the lower end of the plunger 36, which is connected with the plunger 39 by an arm 50 47. A suitable amount of lost motion or back lash is preferably provided between the fuel plunger and the cross-arm 47, and in order that the effective displacement of the fuel plunger may be varied with relation 55 to the displacement of the liquid plunger means are provided whereby the back lash between the fuel plunger and the crossarm may be varied, said means as shown consisting of a pair of lock nuts 48 60 threaded to the lower end of the plunger 39.

The capacities of the two pumps are preferably so proportioned that they will slightly exceed the maximum demand that may be made upon the generator, and while 65 the pumps may be driven from any suitable

source of power they are preferably driven from the engine to which the steam or vapor from the generator is supplied so that their speed will be varied with the speed of the engine and consequently in a general way 70 with the variations in the demand for steam from the generator. It is to be observed that the pumps, as shown in Fig. 1, are too large in proportion to the generator.

So far as some of the features of my invention are concerned, any suitable means 75 may be provided for varying the effective deliveries of the pumps, said means being rendered operative by variations in the condition of the fluid in the generator so as to 80 vary the supplies of the liquid and fuel in the manner described. In accordance with the embodiment of the invention illustrated, means are provided for controlling the deliveries of the pumps in such manner that 85 the pumps will be caused either to discharge all of the liquids drawn into them on the suction strokes back to the supplies or to deliver all of said liquids to the generator and the combustion chamber, respectively. 90 In accordance with the construction shown, the control of the deliveries of the pumps is effected by controlling the suction valves of the pumps. To this end a valve-controlling device is arranged in coöperative relation 95 with each of the suction valves 37 and 40, said controlling means being in the form of a pair of pins 49 and 50, each passing freely through perforated plugs arranged in the pump casing in axial alinement with 100 the respective suction valve.

So far as some of the features of my invention are concerned, any suitable means rendered operative by variations in the condition of the fluid at a predetermined point 105 in the generator passage may be provided for operating the pins 49 and 50. In accordance with the construction shown, a bipolar electromagnet 51 is mounted on the pump casing above the pins 49 and 50, and 110 an armature 52 is pivotally mounted on the pump frame so as to play between the poles of the magnet and the pins 49 and 50. The armature 52 is normally pulled downwardly against the pins 49 and 50 so as to cause 115 the latter to unseat the suction valves 37 and 40 by a suitable spring 53. The magnet 51 may be energized and deenergized by any suitable means rendered operative by variations in the condition of the fluid at a predetermined point in the generator. 120

In accordance with the construction shown, the magnet 51 is arranged in an electric circuit energized by any suitable means as by a battery 54 having a circuit-breaker consisting of a spring-held lever 55 125 arranged to normally make contact with an adjustable pole 56. The lever 55 is arranged in coöperative relation with the free end of a Bourdon tube 57 connected by a suitable 130

pipe 58 to a suitable point in the generator, as will hereinafter be more fully explained, the relation between the Bourdon tube and the lever 55 being such that when the pressure of the fluid at the point of the generator to which the Bourdon tube is connected reaches a predetermined degree, the electric circuit will be broken and the magnet deenergized so as to permit the spring 53 to hold the suction valves open and prevent any delivery of liquid to the generator or fuel to the combustion chamber.

In order that the suction valves may not be released and the pumps brought into action at an intermediate point of their delivery strokes, means are preferably provided whereby the electromagnet 51 may be energized only at or near the beginning of the delivery strokes of the pumps. As shown, this means consists of a circuit breaker in the form of a pair of spring contacts 64 and 65 located in the path of a part arranged to move in unison with the pumps. As shown, the contacts are so arranged that the spring 64 is pressed into contact with the contact 65, when the pumps are at or near the ends of their suction strokes, by an insulated part 66 carried by the cross arm 47.

By reason of the construction described, the pumps can only be brought into action near the beginning of their delivery strokes, and when once brought into action they will necessarily deliver their full displacements of liquid to the generator and fuel to the burner, the suction valve of the liquid pump being firmly held to its seat during the entire delivery stroke of the pump by the pressure developed therein and acting through the pin 49 to hold the armature 52 raised against the tension of the spring 53, thus leaving the suction valve of the fuel pump free to be seated by the pressure developed in the fuel pump or by the pressure of the spring in the suction valve in the event of there being insufficient pressure in the pump for this purpose. To make certain that the suction valve of the fuel pump shall be free to seat itself when the suction valve of the water pump is seated, the pin 49 is preferably made somewhat longer than the pin 50, as indicated in Fig. 2 of the drawings, so that when the armature 52 is resting on the pin 49 it cannot touch the pin 50.

So far as some features of the invention are concerned the supplies of liquid and fuel may be controlled independently of each other, as by causing the magnets to act independently on the suction valves; but by reason of the construction described, the action of the fuel pump is made to depend on the action of the water pump so that the maintenance of a predetermined relation between the supplies of the liquid and the fuel

is rendered more certain. This is rendered still more certain by the fact that the part of the stroke of the liquid pump during which the spring 64 is held in contact with the spring 65 is less than the back lash between the arm 47 and the fuel plunger. It follows that the fuel pump can not be brought into action unless sufficient pressure is developed in the liquid pump to hold its suction valve closed against the force of the spring 53. If the liquid pump fails to operate, therefore, the fuel pump will also fail to operate. For example, if the supply of liquid should be exhausted, or if for any reason the liquid pump should not be properly filled with liquid on its suction stroke, sufficient pressure would not be developed in the pump at the beginning of its stroke to hold the suction valve to its seat. Then, when the magnet is deenergized, the spring 53 will open the suction valves of both pumps and thus render them inoperative. A further advantage of this combination is that fuel can not be supplied to the combustion chamber without the proper proportion of liquid being supplied to the generator, so that the apparatus can not be injured by overheating. The intermittently operated circuit breaker 64, 65 also serves to economize the energy of the battery 54 in that the electric circuit is normally open and at the most is only closed for a short interval during each stroke of the pump. In order that the energy of the battery may not be dissipated, should the apparatus happen to be stopped with the pump at the lower end of its stroke, a hand switch 67 is preferably provided in the electric circuit so that the circuit may be broken.

A suction pipe for the fuel pump is indicated at 68, and a suction pipe for the liquid pump is indicated at 69. These pipes may communicate with any suitable source of supply for the respective liquids, it being understood that the liquids are not under sufficient pressure to establish a flow through the pumps independently of the operation of the plungers thereof. To avoid undue strain on the pump mechanism, which might result from the intermittent starting and stopping of the long column of liquid in the generator, especially when the pumps are operated at high speed, a suitable cushioning device is arranged between the delivery of the liquid pump and the feed pipe 15 of the generator. The cushioning device shown consists of a section of elastic tubing 70. In practice, a heavy rubber hose capable of withstanding the pressures in the generator and the added pressure required to repeatedly accelerate the column of liquid is employed.

In accordance with the preferred embodiments of my invention shown and described in my prior patents, the means for controlling the supplies of fuel and liquid are ren-

dered operative by variations in the pressure at the liquid-receiving end of the generator, a cushioning device in the form of an air chamber of ample dimensions being provided to absorb the effect of the intermittent operation of the liquid-feeding means and render the mean pressure at the liquid-receiving end of the generator substantially the same as that in the generator.

10 In accordance with one feature of my present invention, the means for varying the supplies of liquid and fuel are rendered operative by variations in the condition of the fluid at some point in the generator where the condition selected as the controlling condition varies inversely and in substantial unison with the variations in the demand for steam or vapor energy, and preferably at such a point that the controlling condition at that point may be kept substantially uniform without involving a material change in the condition of the generator either as to the quantity of heat therein or as to the distribution of the heat therein. I have found that variations in the condition as to the temperature or the pressure of the fluid in the vaporizing portion of the generator are effective for the purpose specified, and that the variations in the condition as to the pressure or the temperature of the fluid in a portion of the generator, which for all variations of demand for vapor energy constitutes a vaporizing portion of the generator, are more effective than those at any other portion of the generator. The reasons for this will be apparent upon considering the physical changes which take place in the fluid in the generator. The liquid supplied to the generator is gradually heated from the temperature at which it is supplied to the temperature of vaporization so that only a small portion of the liquid, to-wit, the extreme inner end of the liquid column is maintained at the temperature of vaporization. It follows from this that when a flow of vapor is created or when an existing flow is increased, the pressure in the generator immediately begins to fall and the liquid which is at the temperature of vaporization corresponding to the higher pressure immediately begins to vaporize and also to fall in temperature corresponding to the temperature of vaporization of the liquid at the reduced pressure. The vapor which is developed in the small portion of liquid which was at the higher temperature greatly increases the volume of that liquid and projects it in the form of a spray toward the delivery end of the generator, thereby increasing the vaporizing surface of the generator, the tendency being to render effective a sufficient area of heating surface to supply the increased demand for vapor.

65 When a decrease in the demand for vapor

occurs, the spray which has been projected along the vaporizing portion of the generator and is suspended in the vapor contained therein will be more rapidly precipitated upon the hotter metal and cause a prompt rise in temperature and consequently in pressure, and as the end of the liquid column is at the lower temperature the vapor in contact therewith will be condensed and the spray driven back so as to slightly increase the length of the liquid column and bring the temperature thereof up to the temperature of vaporization corresponding to the increased pressure. It will be seen therefore that the condition both as to the temperature and as to the pressure of the fluid at or near the end of the liquid column in the generator vary inversely with the variations of demand for vapor and that these variations take place promptly or in substantial unison with the variations of demand. It will also be seen that, if the length of the liquid column and the condition as to the temperature and as to the pressure of its inner end be maintained substantially uniform irrespective of variations in demand, the quantity of heat in the generator and the distribution of the heat must remain substantially uniform. With a liquid-fuel supply and supplying-controlling means which act to maintain the condition of the fluid as to the temperature or as to the pressure thereof at the point in the generator to which the supply-controlling means is connected substantially uniform, such for example as the liquid and fuel supply and supply-controlling means herein shown and described, connected to the generator at or near the end of the liquid column or to a point of the generator at which the liquid is first brought to the temperature of vaporization and under all conditions constitutes a vaporizing portion of the generator, the quantity of heat in the generator and the distribution of the heat in the generator must remain substantially uniform irrespective of variations in demand, and the effective supplies of liquid and fuel must be varied in substantial unison with the variations in demand for vapor energy and substantially in the same degree with said variations in demand.

It may be here observed that the water in the vaporizing portion of the generator being always in the form of a spray is small in quantity, and the variations in the quantity or in the distribution of the spray do not involve a material variation or distribution of heat in the generator for the reason that the variations in the quantity of heat absorbed by the spray are met by corresponding variations in the heat supply, the temperature of the metal at all points remaining substantially uniform. In fact, the variations in the quantity of spray and con-

sequently in the length of the vaporizing and superheating portions of the generator are instrumental in causing the apparatus to deliver the superheated vapor at the uniform temperature irrespective of variations in the demand and consequently in preventing a change in the quantity or distribution of the heat in the generator. This is due to the fact that the heating efficiency of a superheater of a given temperature varies directly with the rate of flow of the vapor through the superheater. The greater the rate of flow of a vapor through a superheating pipe of a given temperature, the less the length of pipe required to give the vapor the desired degree of superheat. With a generator properly proportioned, as shown for example in the drawings, the superheating portion will be decreased in length on an increase in demand for or rate of flow of the vapor, and will be increased on a decrease of the demand for and rate of flow of the vapor, so that the vapor will be delivered at substantially the same temperature at all times and so that the heat will be absorbed from the superheater at a rate corresponding to that at which it is supplied, the temperature of the superheating portion of the generator remaining substantially uniform irrespective of variations in the demand. It may be further remarked that it is desirable to employ the variations in the condition of the fluid in the generator at a point near that at which the liquid is first brought to the temperature of vaporization rather than at any other point for the reasons, among others, that the variations of the condition as to pressure of the fluid at any other point are more or less affected by disturbing influences such as the inertia effects of the fluid flowing through the generator, the pressure at all points in the generator being derived from the vapor tension at the end of the liquid column and more or less modified by the friction, changes of velocity, etc., of the fluid in the generator; and that the condition as to temperature of the fluid at any other point in the generator either does not vary inversely with variations in the demand for vapor energy or is, like the pressure, more or less affected by disturbing influences.

While the condition either as to the temperature or as to the pressure of the fluid in the vaporizing portion of the generator may be employed as the controlling condition, the supply-controlling means of the particular embodiment of the present improvements illustrated in Fig. 1 are represented as being rendered operative by the variations in the pressure. To this end the pipe 58 by which pressure is communicated to the circuit controlling Bourdon tube 57 is placed in communication with the contents of the generator near the lower end of the coil 5,

said pipe being, as shown, tapped into the connection 10 between the lower ends of the coils 4 and 5, this point being found by experiment with a generator, constructed substantially as illustrated in the drawings, to be near the point at which the liquid in the generator is first brought to the temperature of vaporization when the supplies of liquid and fuel are so proportioned as to deliver the steam at the desired temperature.

While any suitable means may be employed for utilizing the temperature of the fluid in the vaporizing portion of the generator as the supply-controlling condition, such condition may be employed in the particular embodiment of the invention illustrated by connecting the pipe 58 with a suitable thermostat, such as a saturated-vapor-tension thermostat, which is subjected to the temperature changes of the fluid at the desired point in the generator, as indicated in Fig. 7, the thermostat being designated by number 71. Although the employment of a thermostat tends to make the apparatus complicated, it has the advantage of an added safety device to prevent overheating of the generator, if for any reason the supply of fuel should be continued without a proper proportion of liquid. A saturated-vapor-tension thermostat has the further advantage of affording means for magnifying the variations in the controlling condition of the fluid in the generator. By employing in the thermostat a liquid having a lower temperature of vaporization than that used in the generator, the pressure in the supply-controlling means will vary through a greater range for a given change in the condition of the fluid in the generator than if the supply-controlling means were rendered operative directly by the pressure in the generator.

With the object in view of reducing the effect of the slight periods of time which occur between the instant when the supply devices are rendered operative and the instant when the supplies become effective, as for instance the time required to vaporize the liquid fuel and deliver the vapor mixed with air to the combustion chamber, means may be provided for cutting off the supplies of both the liquid and the fuel when the rate of supply of fuel to the burner reaches a predetermined amount. As regards some of the features of my invention, any suitable means may be provided for this purpose. In accordance with the construction shown, a second make and break device is arranged in the circuit of the electromagnet 51, the same consisting of a spring-held lever 59 arranged to normally make contact with an adjustable pole piece 60. For the purpose of operating said lever to break the circuit, when the rate of supply of fuel to the burner reaches a predetermined amount,

a Bourdon tube 61 is arranged in coöperative relation with the lever 59, said tube being connected by a suitable pipe 62 at some point in the fuel passage between the fuel pump and the nozzle 26. To reduce the effect of pulsations of pressure in the fuel passage an adjustable choking valve 63 is preferably arranged in the pipe 62. The effect of this construction is not to vary the time or quantitative relation between the variations in the demand for vapor energy and the variations in the supplies of the liquid and the fuel but rather to reduce the duration and increase the frequency of the intermittent operation of the liquid and the fuel supply devices so as to make the variations in the supplies conform in their time relations more nearly to the variations in the demand for vapor energy.

In accordance with one feature of the invention, means may be provided for varying the ratio between the supplies of the liquid and the fuel automatically so as to compensate for variations in the efficiency of the apparatus under different conditions. Where it is found, for example, in a particular case, that the combined efficiency of the generator and the burner vary materially for different rates of delivery of vapor energy so that, while the vapor may be delivered at the desired temperature when the demand is small, the vapor is not delivered at the desired temperature, when the demand is great, or vice versa, means may be provided for changing the mean effective ratio which is maintained between the supplies of the liquid and the fuel so that the vapor will be delivered at the desired temperature at all times. So far as some of the features of my invention are concerned, any suitable means may be provided for this purpose. One embodiment of this feature of the invention is illustrated in Fig. 6 of the drawings. In accordance with this construction, the generator and the burner and the means for supplying the fluids thereto are substantially the same as the corresponding parts previously described, and except as to certain changes to be presently pointed out the supply-controlling means are substantially the same as those previously described. In accordance with the embodiment of this feature of the invention illustrated, the effective deliveries of the two pumps are rendered independent of each other to the extent that the fuel pump may under certain conditions be operated independently of the liquid pump, the effective displacements of the two pumps being so adjusted that the pumps tend to supply the liquid slightly in excess of a proper proportion to the fuel, except possibly under the conditions when the combined efficiency of the burner and generator are at their maximum. To this end, the suction valves of the pumps are con-

trolled by independent single pole magnets 72 and 73 having independent armatures 74 and 75 adapted to play between their respective magnets and their corresponding valve operating pins 49 and 50, each armature being moved in the direction to unseat the valves by independent springs 76 and 77. The two magnets 72 and 73 are arranged in series in the circuit controlled by the contact levers 55 and 59, and the circuit breaker 64, 65 as in the previous form of the device. The armatures 74 and 75 are preferably also so arranged that whenever the liquid pump is operative, the fuel pump is also rendered operative. For the purpose of rendering the fuel pump operative independently of the liquid pump, a shunt circuit is arranged so as to cut out the liquid pump controlling magnet 72 and preferably also the make and break device 64 and 65, said shunt circuit including a make and break device rendered operative by the condition of some portion of the generator or of the fluid therein which varies with the variations in the efficiency of the apparatus. As shown, the make and break device consists of a spring-controlled contact lever 78 and an adjustable pole piece 79. Any suitable means may be provided for operating the lever 78 to close the shunt circuit when the vapor is delivered at a lower temperature than that desired. As shown, a Bourdon tube 80 is arranged in such relation to the lever 78 that an increase in pressure therein beyond a predetermined point will break the shunt circuit. This Bourdon tube is connected by a pipe 81 to a saturated-vapor-tension thermostat 82 located at a suitable part of the generator.

In accordance with the preferred construction thermostat 82 is located in the liquid-heating portion of the generator, preferably at a point as close as convenient to the end of the liquid column. It follows from this construction that when the generator is started, the shunt circuit will be closed as will also the main circuit, so that the fuel supply will be maintained at its maximum until the pressure or other controlling condition in the generator reaches the predetermined point fixed by the adjustment of the circuit breaker formed by the lever 55 and adjustable pole piece 56. If the part of the liquid column in the generator in which the thermostat 82 is located has not been brought to the temperature predetermined by the adjustment of the circuit breaker consisting of the lever 78 and the adjustable pole piece 79, at this time, the fuel pump will continue to operate intermittently as permitted by the operation of the contact levers 55, 59 until the liquid-heating portion of the generator is brought to the desired temperature, whereupon the shunt circuit will be broken and the liquid pump thus

rendered operative. Thereafter the liquid pump will be rendered inoperative from time to time as required to bring the mean effective supply of fuel up to the required amount with relation to the mean effective supply of the liquid.

The circuit breaker 64, 65 is preferably cut out by the shunt circuit for the reason that after a brief period of idleness there will be no pressure in the fuel vaporizer, and consequently in the fuel pump, at least not sufficient pressure therein to hold the suction valve of the fuel pump to its seat against the tension of the spring 77. When the shunt circuit is closed, therefore, the electromagnet 73 will be energized for a sufficient length of time to render the fuel pump operative notwithstanding the lack of sufficient pressure therein to hold the suction valve to its seat against the force of the spring 77.

It will be understood that the relative proportions between the parts as illustrated in the drawings are not such as would be employed in practice, certain parts, as for example the pumps and pump-controlling means, being exaggerated to illustrate more clearly the construction thereof. It may be stated that the proportion of the generator and burner illustrated is substantially correct for a generator in which the coils are formed of $\frac{3}{4}$ inch steel tubing, the steel of which is as thin as can readily be employed where the coils are made in the form shown. The pumps as illustrated in Figs. 2, 3, 4, and 5 are substantially of the proper proportions, it being understood that when driven from the engine, the capacity of the water pump should be sufficient to fill the cylinder or cylinders of the engine with steam at the desired pressure and temperature at the maximum length of cut off. The suction pipes of the pumps should be of such proportions as will insure the complete filling of the pumps on their suction strokes at the maximum speed at which it is desired to drive the pumps. It will be further understood that certain features of the apparatus shown, as for example, the circuit breaker controlled by variations of pressure in the fuel vaporizer may be omitted, if desired. It is to be clearly understood furthermore that my invention in its broader aspects is not to be limited to the particular construction or constructions shown and described nor to any particular construction by which it has been or may be carried into effect, as the construction of the apparatus may be greatly varied without departing from the main principles of the invention and without sacrificing its chief advantages.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. An apparatus for generating vapor in-

cluding in combination, means forming a combustion chamber, a generator having a continuous passage constructed to receive the liquid to be vaporized at one end and to deliver the vapor at the other end, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, and means rendered operative by variations in the pressure of the fluid at a predetermined point in said passage for varying the supplies of both the fuel and the liquid in substantial unison with the variations of demand for vapor energy and in definite quantitative relations to said variations of demand.

2. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator having a continuous passage constructed to receive the liquid to be vaporized at one end and to deliver the vapor at the other end, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, and means rendered operative by variations in the pressure of the fluid at a predetermined point in the generator for varying the supplies of both the fuel and the liquid in substantial unison with the variations of demand for vapor energy and substantially in the same degree with the said variations of demand.

3. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator having a continuous passage constructed to receive the liquid to be vaporized at one end and to deliver the vapor at the other end, means for supplying liquid to the generator, means rendered operative by variations in the pressure at a predetermined point in the generator for automatically varying the supply of the liquid in substantial unison with the variations of demand for vapor energy and substantially in a definite quantitative relation to said variations of demand, means for supplying fuel to the combustion chamber, and means for maintaining a substantially predetermined quantitative relation between the supplies of liquid and fuel.

4. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator having a continuous passage constructed to receive the liquid to be vaporized at one end and to deliver the vapor at the other end, means for supplying liquid to the generator, means rendered operative by variations in the pressure of the fluid at a predetermined point in said passage for automatically varying the supply of the liquid in substantial unison with the variations of demand for vapor energy and substantially in the same degree with said variations of demand, means for supplying fuel to the combustion

chamber, and means for maintaining a predetermined quantitative relation between the supplies of the liquid and the fuel.

5 5. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator having a plurality of pipe coils connected together in series and located one within another around the combustion chamber, means for supplying
10 fuel to the combustion chamber, means for supplying liquid to an outer coil of the generator, and means rendered operative by variations in the pressure of the fluid in an inner coil of the generator for automatically
15 varying the supplies of both the fuel and the liquid in substantial unison with the variations of demand for vapor energy and substantially in definite quantitative relations to said variations of demand.

20 6. An apparatus for generating vapor and delivering the same in substantially an unvarying condition as to the temperature thereof, including in combination, means forming a combustion chamber, a generator
25 consisting of a plurality of pipe coils connected together in series and located one within another around the combustion chamber, means for supplying fuel to the combustion chamber, means for supplying
30 liquid to an outer coil of the generator, and means rendered operative by variations in the pressure of the fluid in an inner coil for automatically varying the supplies of both the liquid and the fuel in substantial unison
35 with the variations of demand for vapor energy and substantially in the same degree with said variations of demand.

7. An apparatus for generating vapor including in combination, means forming a
40 combustion chamber, a generator consisting of a plurality of pipe coils connected together in series and located one within another around the combustion chamber, means for supplying liquid to an outer coil,
45 means rendered operative by variations in the pressure of the fluid in an inner coil for automatically varying the supply of the liquid in substantial unison with the variations of demand for vapor energy and
50 substantially in a definite quantitative relation to said variations of demand, means for supplying fuel to the combustion chamber, and means for maintaining a substantially predetermined quantitative relation
55 between the supplies of the liquid and the fuel.

8. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator having a
60 vaporizing portion constructed to receive a small quantity of liquid and vaporize it gradually, means for supplying liquid to the generator, means rendered operative by variations in the condition of the fluid in the
65 vaporizing portion of the generator for

automatically varying the supply of liquid in substantial unison with the variations of demand for vapor energy and substantially in definite quantitative relation with said variations of demand, means for supplying
70 fuel to the combustion chamber, and means for maintaining a predetermined quantitative relation between the supplies of the liquid and the fuel.

9. An apparatus for generating vapor in- 75 cluding in combination, means forming a combustion chamber, a generator having a vaporizing portion constructed to receive a small quantity of liquid and vaporize it gradually, means for supplying fuel to the
80 combustion chamber, means for supplying liquid to the generator, and means rendered operative by variations of the pressure of the fluid in the vaporizing portion of the generator for automatically varying
85 the supplies of both the fuel and the liquid in substantial unison with the variations of demand for vapor energy and substantially in definite quantitative relations to said variations of demand. 90

10. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator having a vaporizing portion constructed to receive a small quantity of liquid and vaporize it
95 gradually, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, and means rendered operative by variations in the pressure of the fluid in the vaporizing portion of the
100 generator for automatically varying the supplies of both the fuel and the liquid in substantial unison with the variations of demand for vapor energy and substantially in the same degree with said varia- 105 tions of demand.

11. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator having a vaporizing portion constructed to receive
110 a small quantity of liquid and vaporize it gradually, means for supplying liquid to the generator, means rendered operative by variations in the pressure of the fluid in the vaporizing portion of the generator for
115 automatically varying the supply of liquid in substantial unison with the variations of demand for vapor energy and substantially in definite quantitative relation with said variations of demand, means for supplying
120 fuel to the combustion chamber, and means for maintaining a predetermined quantitative relation between the supplies of the liquid and the fuel.

12. An apparatus for generating vapor 125 including in combination, means forming a combustion chamber, a generator having a vaporizing portion constructed to receive a small quantity of liquid and vaporize it gradually, means for supplying liquid to 130

the generator, means rendered operative by variations in the pressure of the fluid in the vaporizing portion of the generator for automatically varying the supply of liquid in substantial unison with the variations of demand for vapor energy and substantially in the same degree with said variations of demand, means for supplying fuel to the combustion chamber, and means for maintaining a predetermined quantitative relation between the supplies of the liquid and the fuel.

13. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator having a liquid-heating portion in which the liquid is gradually heated to the temperature of vaporization, a vaporizing portion constructed to receive a small quantity of the liquid and vaporize it gradually, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, and means rendered operative by variations in the pressure of the fluid in the vaporizing portion of the generator for automatically varying the supplies of the fuel and the liquid in substantial unison with the variations of demand for vapor energy and substantially in the same degree with said variations of demand.

14. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator having a liquid-heating portion in which the liquid is gradually heated to the temperature of vaporization, a vaporizing portion constructed to receive a small quantity of the liquid and to vaporize it gradually, means for supplying liquid to the generator, means rendered operative by variations in the pressure of the fluid in the vaporizing portion of the generator for automatically varying the supply of liquid in substantial unison with the variations of demand for vapor energy and substantially in the same degree with said variations of demand, means for supplying fuel to the combustion chamber, and means for maintaining a definite quantitative relation between the supplies of fuel and liquid.

15. An apparatus for generating superheated vapor including in combination, means forming a combustion chamber, a generator having a liquid-heating portion in which the liquid is gradually heated to the temperature of vaporization, a vaporizing portion constructed to receive a small quantity of the liquid and vaporize it gradually and a superheating portion directly connected to and forming an extension of said vaporizing portion, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, and means rendered operative by variations in the pressure of the fluid in the vaporizing

portion of the generator for automatically varying the supplies of the fuel and the liquid in substantial unison with the variations of demand for vapor energy and substantially in definite quantitative relations to said variations of demand.

16. An apparatus for generating superheated vapor including in combination, means forming a combustion chamber, a generator having a liquid-heating portion so arranged with relation to the combustion chamber that the liquid is gradually heated to the temperature of vaporization, a vaporizing portion so arranged with relation to the combustion chamber as to receive a small quantity of liquid and to vaporize it gradually and a superheating portion directly connected to and forming an extension of the vaporizing portion, means for supplying liquid to the generator, means rendered operative by variations in the pressure of the fluid in the vaporizing portion of the generator for automatically varying the supply of liquid in substantial unison with the variations of demand for superheated vapor energy and substantially in the same degree with said variations of demand, means for supplying fuel to the combustion chamber, and means for maintaining a definite quantitative relation between the supplies of the fuel and the liquid.

17. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid supplied to one end of the coil is gradually heated to the temperature of vaporization and then gradually vaporized, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, and means rendered operative by variations in the condition of the fluid near that point in said passage where the vaporization of the liquid begins for varying the supplies of the fuel and the liquid in substantial unison with the variations of demand for vapor energy and substantially in a predetermined quantitative relation to said variations of demand.

18. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and then gradually vaporized, means for supplying liquid to the generator, means rendered operative by variations in the condition of the fluid near that point in the passage where the vaporization of the liquid begins for automatically varying the supply of liquid in substantial unison with

the variations of demand for vapor energy and substantially in the same degree with said variations of demand, means for supplying fuel to the combustion chamber, and means for maintaining a substantially pre-

5 determined quantitative relation between the supplies of the liquid and the fuel.

19. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid supplied to one end of the coil is gradually heated to the temperature of vaporization and then gradually vaporized, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, and means rendered operative by variations in the pressure of the fluid near that point in said passage where the vaporization of the liquid begins for varying the supplies of the fuel and the liquid in substantial unison with the variations of demand for vapor energy and substantially in a predetermined quantitative relation to said variations of demand.

20. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and then gradually vaporized, means for supplying liquid to the generator, means rendered operative by variations in the pressure of the fluid near that point in the passage where the vaporization of the liquid begins for automatically varying the supply of liquid in substantial unison with the variations of demand for vapor energy and substantially in the same degree with said variations of demand, means for supplying fuel to the combustion chamber, and means for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

21. An apparatus for generating superheated vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid supplied to one end of the coil is gradually heated to the temperature of vaporization then gradually vaporized and then gradually superheated, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, and means rendered operative by variations in the condition of the fluid near that point in said passage where the vaporization of the liquid begins for varying the supplies of the fuel and the liquid in substantial

unison with the variations of demand for superheated vapor energy and substantially in a predetermined quantitative relation to said variations of demand.

22. An apparatus for generating superheated vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization then gradually vaporized and then gradually superheated, means for supplying liquid to the generator, means rendered operative by variations in the condition of the fluid near that point in the passage where the vaporization of the liquid begins for automatically varying the supply of liquid in substantial unison with the variations of demand for superheated vapor energy and substantially in the same degree with said variations of demand, means for supplying fuel to the combustion chamber, and means for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

23. An apparatus for generating superheated vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid supplied to one end of the coil is gradually heated to the temperature of vaporization then gradually vaporized and then gradually superheated, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, and means rendered operative by variations in the pressure of the fluid near that point in said passage where the vaporization of the liquid begins for varying the supplies of the fuel and the liquid in substantial unison with the variations of demand for superheated vapor energy and substantially in a predetermined quantitative relation to said variations of demand.

24. An apparatus for generating superheated vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization then gradually vaporized and then gradually superheated, means for supplying liquid to the generator, means rendered operative by variations in the pressure of the fluid near that point in the passage where the vaporization of the liquid begins for automatically varying the supply of liquid in substantial unison with the variations of demand for superheated vapor energy and substantially in

the same degree with said variations of demand, means for supplying fuel to the combustion chamber, and means for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

25. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and then gradually vaporized, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, and means rendered operative by variations in the condition of the fluid near that point of the passage in which the vaporization of the liquid begins for regulating the supplies of the fuel and the liquid.

26. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and then gradually vaporized, means for supplying liquid to the generator, means rendered operative by variations in the condition of the fluid near that point in said passage where the vaporization of the liquid begins for regulating the supply of the liquid, means for supplying fuel to the combustion chamber, and means for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

27. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and then gradually vaporized, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, and means rendered operative by variations in the pressure of the fluid near that point of the passage in which the vaporization of the liquid begins for regulating the supplies of the fuel and the liquid.

28. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and then gradually vaporized, means for supplying liquid to the generator, means rendered operative by variations in

the pressure of the fluid near that point in said passage where the vaporization of the liquid begins for regulating the supply of the liquid, means for supplying fuel to the combustion chamber, and means for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

29. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator so constructed and arranged with relation to the combustion chamber that different portions of the generator are heated to different temperatures, means for supplying fuel to the combustion chamber, means for supplying liquid to a cooler portion of the generator, means rendered operative by variations in the pressure of the fluid at a hotter part of the generator and tending to maintain a predetermined quantitative relation between the supplies of the liquid and the fuel, and means rendered operative by variations in the temperature of a cooler portion of the generator for automatically varying the relation between the supplies of the fuel and the liquid.

30. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and is then gradually vaporized, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, means rendered operative by variations in the condition of the fluid near that point of the passage at which the vaporization of the liquid begins and tending to maintain a predetermined quantitative relation between the supplies of the liquid and the fuel, and means for varying the relation between the supplies of the liquid and the fuel.

31. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and is then gradually vaporized, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, means rendered operative by variations in the condition of the fluid near that point of the passage at which the vaporization of the liquid begins and tending to maintain a predetermined quantitative relation between the supplies of the liquid and the fuel, and means rendered operative by variations in the temperature of the liquid

at a predetermined point in said passage for automatically varying the relation between the supplies of the fuel and the liquid.

32. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and is then gradually vaporized, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, means rendered operative by variations in the condition of the fluid near that point of the passage at which the vaporization of the liquid begins and tending to maintain a predetermined quantitative relation between the supplies of the liquid and the fuel, and means including a saturated-vapor-tension thermostat rendered operative by variations in the temperature of the passage for automatically varying the relation liquid at a predetermined point in said passage between the said supplies.

33. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and is then gradually vaporized, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, means rendered operative by variations in the pressure of the fluid near that point of the passage at which the vaporization of the liquid begins and tending to maintain a predetermined quantitative relation between the supplies of the liquid and the fuel, and means for varying the relation between the supplies of the liquid and the fuel.

34. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and is then gradually vaporized, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, means rendered operative by variations in the pressure of the fluid near that point of the passage at which the vaporization of the liquid begins and tending to maintain a predetermined quantitative relation between the supplies of the liquid and the fuel, and means rendered operative by variations in the temperature of the liquid at a predetermined point in said passage for automatically varying the relation between the supplies of the fuel and the liquid.

35. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and is then gradually vaporized, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, means rendered operative by variations in the pressure of the fluid near that point of the passage at which the vaporization of the liquid begins and tending to maintain a predetermined quantitative relation between the supplies of the liquid and the fuel, and means including a saturated-vapor-tension thermostat rendered operative by variations in the temperature of the liquid at a predetermined point in said passage for automatically varying the relation between the said supplies.

36. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and is then gradually vaporized, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, means rendered operative by the condition of the fluid in said passage near the point at which the vaporization of the liquid begins for varying the supplies of the fuel and the liquid in substantial unison with the variations of demand for vapor energy and substantially in the same degree with said variations of demand, and means rendered operative by variations in the temperature of the liquid at a predetermined point in said passage for varying the relation between the supplies of the fuel and the liquid.

37. An apparatus for generating vapor including in combination, means forming a combustion chamber, a suitable generator arranged in coöperative relation therewith, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, said means being capacitated to supply the fuel and the liquid at a rate greater than the demand, means for intermittently establishing and cutting off the supplies of both the fuel and the liquid in such manner as to vary both of said supplies in substantial unison with the variations of demand for vapor energy and in definite quantitative relations to said variations of demand, and means whereby one of said supply means is rendered operative at intervals independently of the other for varying the mean effective relation between said supplies.

38. An apparatus for generating vapor in-

cluding in combination, means forming a combustion chamber, a suitable generator arranged in coöperative relation therewith, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, said means being capacitated to supply the fuel and the liquid at a rate greater than the demand, means for intermittently establishing and cutting off the supplies of both the fuel and the liquid in such manner as to vary both of said supplies in substantial unison with the variations of demand for vapor energy and in definite quantitative relations to said variations of demand, and means rendered operative by variations in the condition of the fluid at a predetermined point in the generator whereby one of said supplies is rendered operative at intervals independently of the other to automatically vary the mean effective relation between said supplies.

39. An apparatus for generating vapor including in combination, means forming a combustion chamber, a suitable generator arranged in coöperative relation therewith, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, and means including an electromagnet for varying said supplies in substantial unison with the variations of demand for vapor energy and in definite quantitative relations to said variations of demand.

40. An apparatus for generating vapor including in combination, means forming a combustion chamber, a suitable generator arranged in coöperative relation therewith, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, means including an electromagnet rendered operative by variations in the condition of the fluid in the generator for varying the supplies of both the fuel and the liquid in substantial unison with the variations of demand for vapor energy and in definite quantitative relations to said variations of demand.

41. An apparatus for generating vapor including in combination, means forming a combustion chamber, a suitable generator arranged in coöperative relation therewith, a reciprocating pump for supplying fuel to the combustion chamber, a reciprocating pump for supplying liquid to the generator, and means including electromagnets for controlling the effective deliveries of said pumps in such manner as to vary the supplies of both the fuel and the liquid in substantial unison with the variations of demand for vapor energy and in definite quantitative relations to said variations of demand.

42. An apparatus for generating vapor including in combination, means forming a combustion chamber, a suitable generator ar-

ranged in coöperative relation therewith, a reciprocating pump for supplying fuel to the combustion chamber, a reciprocating pump for supplying liquid to the generator, means for reciprocating said pumps in unison, means for varying the effective deliveries of said pumps in unison, and means for varying the effective delivery of one pump independently of that of the other pump at intervals to vary the relation between the mean effective supplies of the liquid and the fuel.

43. An apparatus for generating vapor including in combination, a suitable generator, a burner for heating the same, means for supplying fuel to the burner, means for supplying liquid to the generator, and means rendered operative by variations in the condition of the fluid in the generator and of the fuel supplied to the burner for varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for vapor energy and in definite quantitative relations to said variations of demand.

44. An apparatus for generating vapor including in combination, a suitable generator, a burner for heating the same, means for supplying liquid to the generator, means for supplying fuel to the burner, and means including electromagnets rendered operative by variations in the condition of the fluid in the generator and of the fuel supplied to the burner for varying the effective supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in definite quantitative relations to said variations of demand.

45. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator having a continuous passage constructed to receive the liquid to be vaporized at one end and to deliver the vapor at the other end, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, means rendered operative by variations in the condition of the fluid at a predetermined point in said generator passage for rendering the fuel and liquid supplying means operative, and means rendered operative by the condition of the fuel supplied to the combustion chamber for rendering said fuel and liquid supplying means inoperative.

46. An apparatus for generating vapor including in combination, means forming a combustion chamber, a generator having a continuous passage constructed to receive the liquid to be vaporized at one end and to deliver vapor at the other end, means for supplying fuel to the combustion chamber, means for supplying liquid to the generator, means rendered operative by variations in

the condition of the fluid at one point in the said passage for rendering the fuel and liquid supplying means operative, and means rendered operative by the condition of the fuel supplied to the combustion chamber for rendering said fuel and liquid supplying means inoperative, and means rendered operative by the condition of the fluid at another point in said passage for controlling the operation of one of said supplying means independently of the other.

47. An apparatus for generating vapor including in combination, a suitable generator, a burner for heating the same, a pump for supplying fuel to the burner, a pump for supplying liquid to the generator, means including an electromagnet for rendering said pumps operative when the pressure in the generator falls below a predetermined point, and means for rendering the pumps inoperative when the pressure in the burner rises above a predetermined point.

48. An apparatus for generating vapor including in combination, a burner, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and then gradually vaporized and superheated, a pump for supplying fuel to the burner, a pump for supplying liquid to the generator, means rendered operative by variations in the pressure of the fluid near that point in the pas-

sage where the vaporization of the liquid begins for rendering the pumps operative, and means rendered operative by variations in the pressure of the fuel supplied to the burner for rendering said pumps inoperative.

49. An apparatus for generating vapor including in combination, a burner, a generator consisting of coiled pipe so arranged with relation to the combustion chamber as to form a single continuous passage in which the liquid is gradually heated to the temperature of vaporization and then gradually vaporized and superheated, a pump for supplying fuel to the generator, a pump for supplying liquid to the generator, means rendered operative by variations in the pressure of the fluid near that point in the passage where the vaporization of the liquid begins for rendering the pumps operative, means rendered operative by variations in the pressure of the fuel supplied to the burner for rendering said pumps inoperative, and means rendered operative by the temperature of the water at a cooler point in the generator for controlling the operation of one of said pumps independently of the other.

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

EDWARD C. NEWCOMB.

Witnesses:

WM. J. DOLAN,
EDWIN SEGER.