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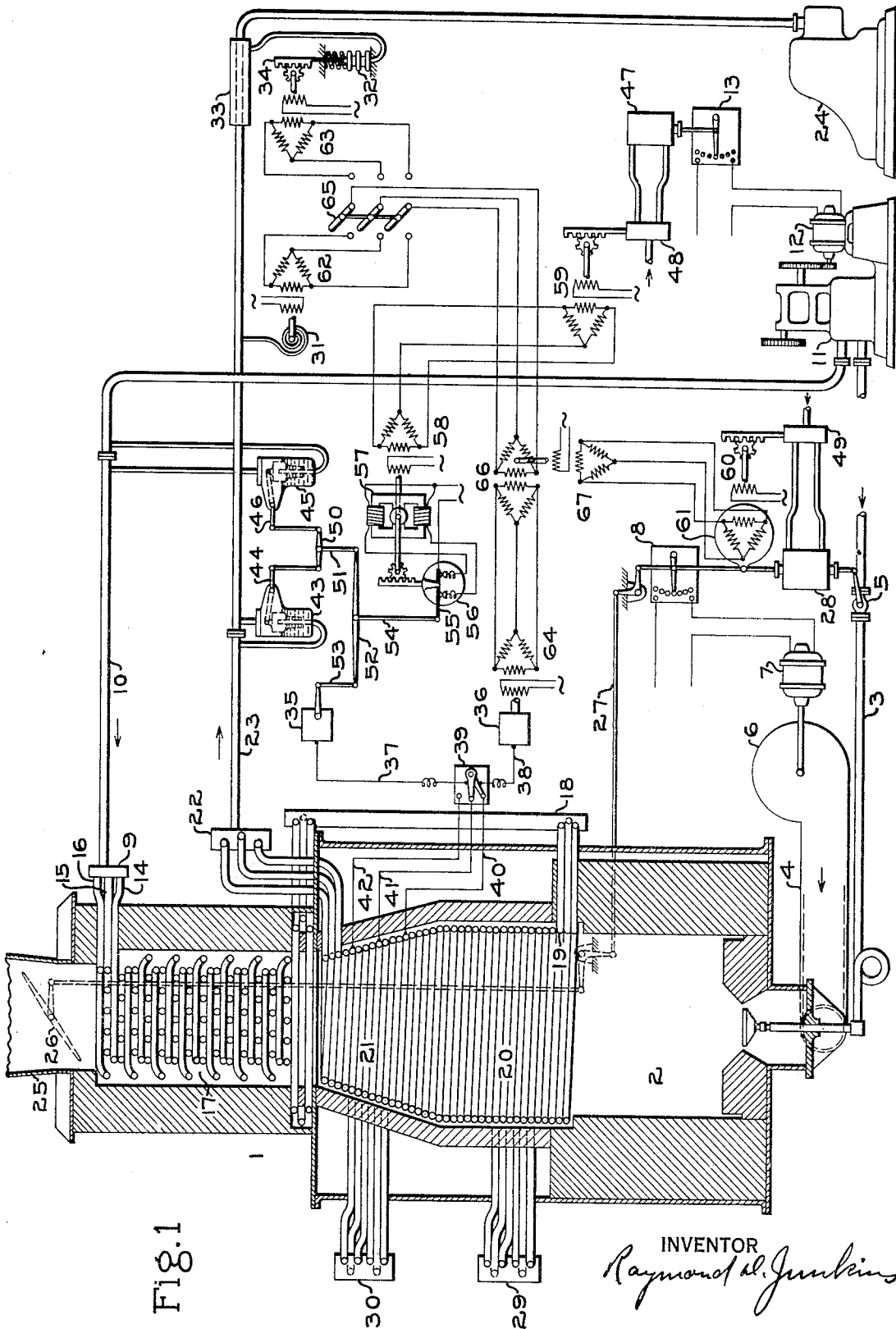
R. D. JUNKINS

1,975,104

CONTROL FOR VAPOR GENERATORS

Filed Dec. 12, 1931

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3 Sheets-Sheet 2

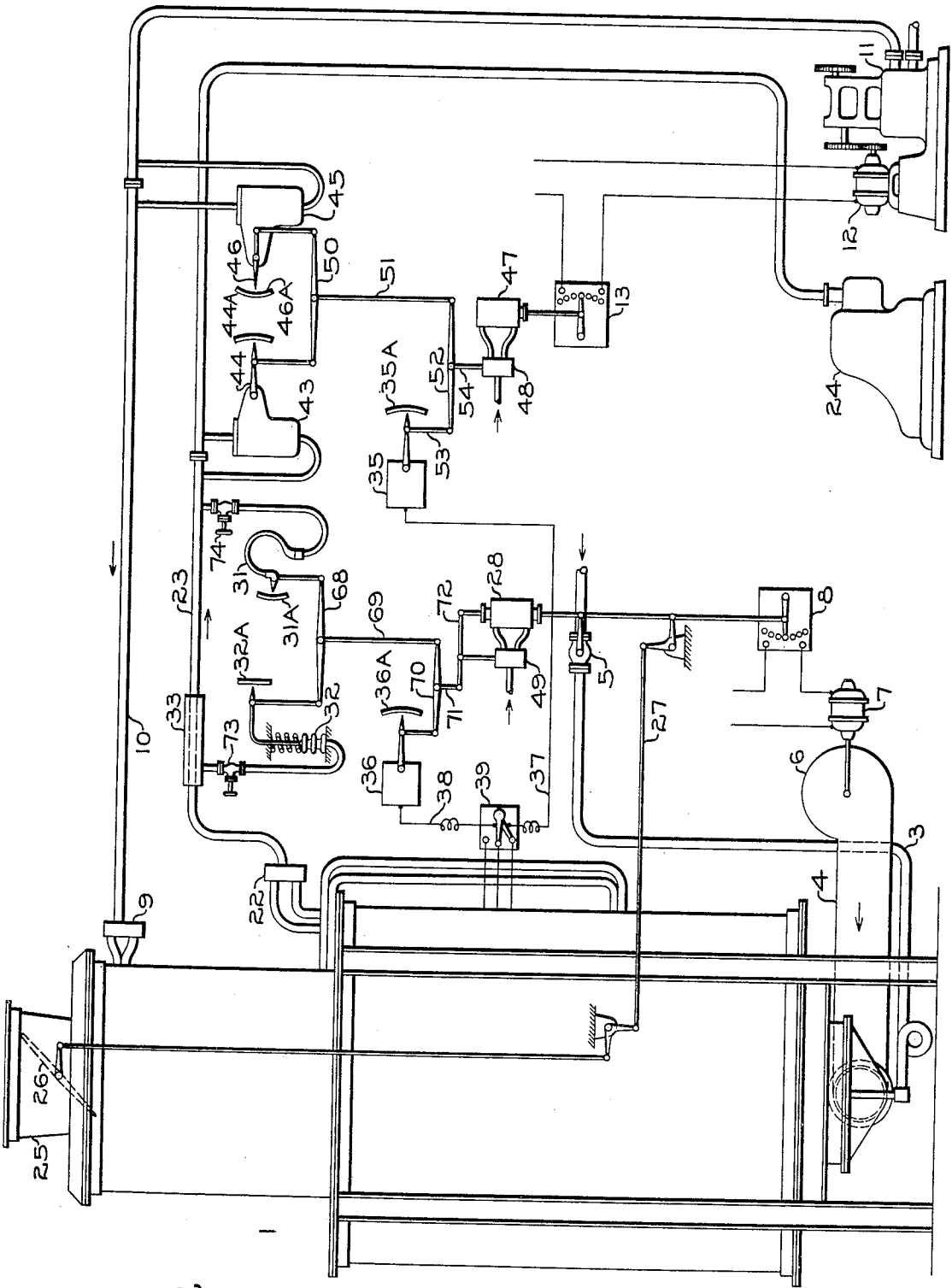


Fig. 2

INVENTOR
Raymond D. Junkins

Oct. 2, 1934.

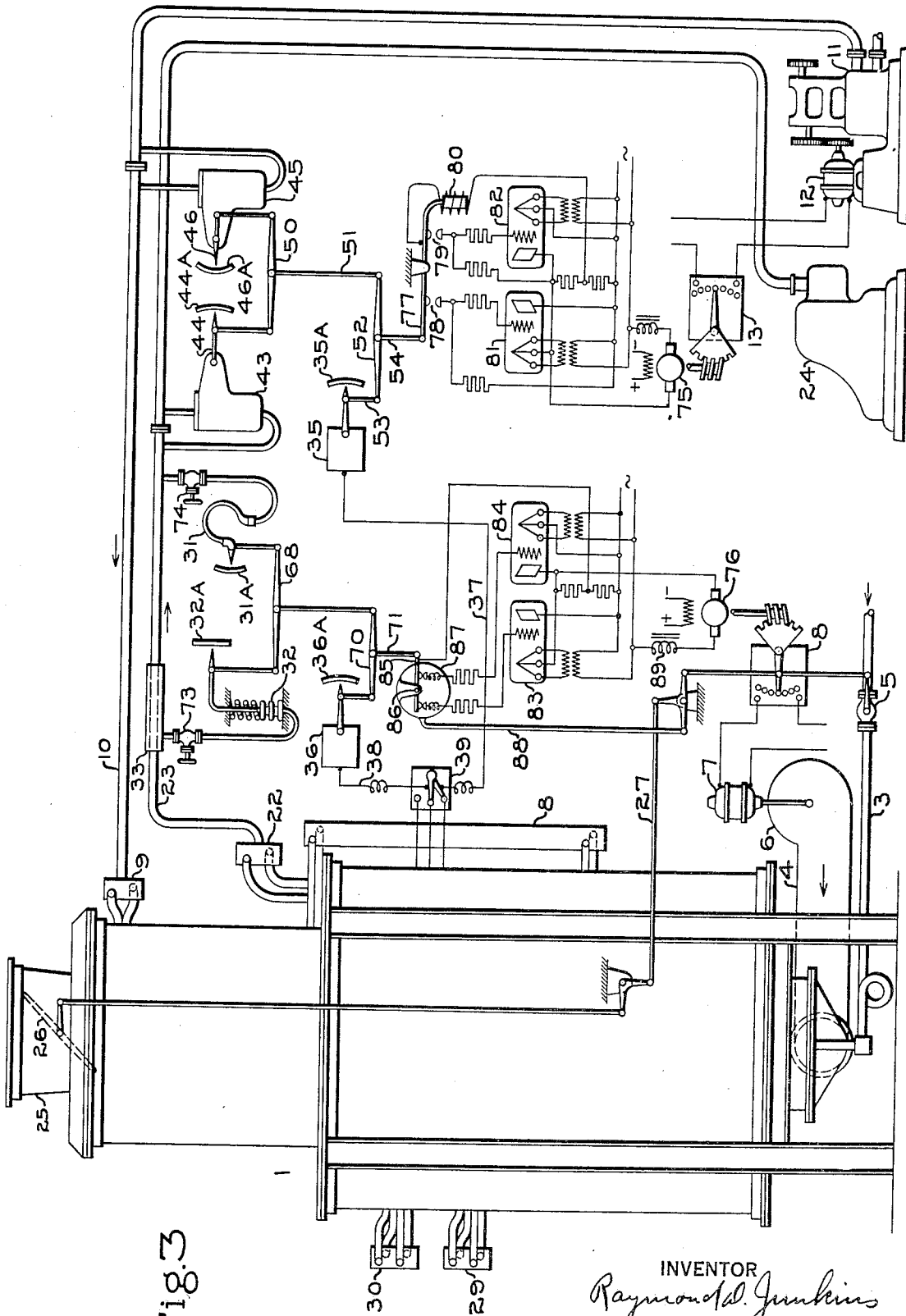
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3 Sheets-Sheet 3



UNITED STATES PATENT OFFICE

1,975,104

CONTROL FOR VAPOR GENERATORS

Raymond D. Junkins, Cleveland Heights, Ohio,
assignor to Bailey Meter Company, a corpora-
tion of Delaware

Application December 12, 1931, Serial No. 580,655

13 Claims. (Cl. 122-448)

This invention relates to a method and means for controlling the operation of vapor generators, and has particular reference to that type of drumless vapor generator having fluid flow paths in which the flow in each path is initiated by the entrance of liquid under pressure at one end of the path and characterized by the exit of vapor only at the other end of the path. Such boilers are disclosed in the co-pending application entitled "Method of operating a steam boiler", Serial No. 357,419, filed in the United States Patent Office April 23, 1929, by James Fletcher, and the application of Howard J. Kerr entitled "Steam boiler", Serial No. 450,348 filed in the United States Patent Office May 7, 1930; the present invention being in the nature of an improvement thereto as well as also being related and in the nature of an improvement to the co-pending application of Charles E. Lucke entitled "Method of operating a vapor generator", Serial No. 580,591, filed in the United States Patent Office of even date herewith. It is to be understood that throughout the specification, where I refer to boilers or vapor generators, I mean the same.

In vapor generators of the character mentioned having a once-through fluid flow path without circulation and wherein the liquid volume is always at a minimum, the liquid inflow must of necessity be continuous and at all times proportioned to the demand or generator load. Furthermore, this type of unit, having no substantial reserve liquid capacity and the fluid in motion in the conduit varying from liquid to vapor with intermediate percentages of vapor and liquid mixture, cannot be equipped with any liquid level indicating device such as the standard water glass to establish a safe operating condition. Vapor is generated in tubes as needed, and the liquid is fed to the tubes at such a rate that the desired proportion is held in a tube between liquid and vapor, so that vapor of the desired amount and quality may be obtained. A method and means for operating such a vapor generator in accordance with varying conditions must be provided. Such a method and means desirably providing for the supply of liquid in proportion to the demand upon the generator for vapor, and for supplying the elements of combustion to vaporize the liquid in proportion and amount to produce the vapor at desired conditions of outlet temperature and/or pressure. Such supply of liquid and elements of combustion desirably readjusted in accordance with other variables, such for instance as fluid temperature at a location in

the flow path, and preferably taken just beyond the saturation line.

I have found that constant predetermined quality or temperature of the vapor outflow may be insured regardless of the rate of outflow, through the maintaining substantially constant of the percentage of the fluid flow path within the boiler in which vapor alone exists. The point of conversion to complete vapor state, beyond which in the flow path fluid exists as vapor only, tends during operation to move along the flow path through several causes, such, for example, as variation in the rate of liquid inflow relative to the rate of vapor outflow, and through variation in the rate of supply of the elements of combustion for heating or causing change of state or temperature of the fluid.

One object of my invention in connection with a vapor generator of the drumless or once-through type is the control of liquid inflow there-to substantially equal to the vapor outflow therefrom. A further object is to control the liquid inflow so as to maintain substantially constant, regardless of the rate of vapor outflow, the percentage of fluid flow path within the boiler wherein exists the fluid as vapor only.

Another object is to control the liquid inflow proportionate to the vapor outflow, with readjustment or modifying control of the liquid inflow from a physical characteristic of the fluid, such for example as temperature indication at a location along the fluid flow path.

Still another object is to control the supply of one or more of the elements of combustion in accordance with the departure from predetermined value of one or more of the physical characteristics of the fluid outflow and to readjust such supply from a physical characteristic of the fluid flow within the generator, such, for example, as temperature indication along the fluid flow path.

Still another object is to so coordinate the control of liquid inflow and the supply of the elements of combustion as to most efficiently provide a vapor outflow from the boiler of desired quantity and quality.

In the illustrative embodiments of my invention I show herewith:

Fig. 1 is a sectional elevation of a vapor generator according to the present invention combined with the requisite apparatus to control the functioning thereof, and such apparatus shown in partially diagrammatic fashion.

Fig. 2 is a side elevation of a vapor generator similar to that shown in Fig. 1, having diagrammatically shown in connection therewith, control

equipment comprising a second embodiment of the invention.

Fig. 3 is similar to Fig. 2, illustrating a third embodiment of my invention.

5 In the various drawings, identical parts bear the same reference numerals.

Referring now in particular to Fig. 1, I have illustrated a steam generating boiler 1, having a furnace 2 for heating fluid passed through a multiplicity of conduits in heating relation with the combustion and the products of combustion. Elements of combustion such as fuel and air, for example, are fed to the furnace 2, in regulated amounts through the conduits 3 and 4 respectively. The conduit 3 is adapted, in the present embodiment, to supply oil for combustion to the furnace 2, such supply being regulated through the positioning in the conduit of a regulating valve 5. The conduit 4 for supplying air for combustion to the furnace 2 is supplied with air under pressure from a fan 6, driven by a motor 7 at a speed dependent upon the controlled position of a rheostat 8 in the electric circuit of the motor.

10 Liquid to be converted to vapor under pressure is fed to a header 9 through a conduit 10 by a pump 11 driven by a motor 12 at a speed dependent upon the controlled position of a rheostat 13 inserted in the electric circuit of the motor.

From the header 9 originate three parallel conduits 14, 15 and 16, each of series type and which are of small diameter and great length, being formed sinuously in layers by suitable bending, in a water heating or economizer section 17 of the flow path, the lower portions of which having much greater length than the upper portions and which extend outwardly into the walls of the flue passage for support. From the economizer section 17, the parallel conduits lead to a header 18, and from the header 18 enter the furnace at 19, whereafter they are coiled upwardly surrounding a secondary combustion space of the furnace. A certain portion of the surrounding conduit wall comprises a steam generating portion 20, while the uppermost portion of the surrounding conduits comprise a superheating section 21, from which the parallel conduits lead to a header 22, from which there passes a conduit 23 to a turbine or other utilizing apparatus 24. The products of combustion pass from the furnace 2 in series heating contact with the steam generating portion 20, the superheating portion 21 and the economizer portion 17 to a stack 25, whose draft is controlled by the positioning therein of a damper 26 through the medium of linkage 27 controlled in parallel with the rheostat 8 and the fuel controlling valve 5 through the agency of a hydraulic piston 28.

It will be observed that the grouping of the parallel conduits is definitely segregated into three sections; namely, an economizer section 17, a generating section 20 and a superheating section 21, wherein the fluid flowing through the conduit is continuously in heating relation with the products of combustion passing from the furnace. Equalizing headers 18, 29 and 30 are shown in the flow path to bring the fluid of the several conduits into mixing relation to commingle and for equalization of the temperature and distribution, whereafter they again separate into the respective flow paths.

70 It will likewise be seen that the grouping of the respective portions of the conduit is such that each represents a continuous, sinuous fluid path of great length and small diameter from liquid entrance to superheated vapor outlet, with some portion thereof having a fluid flow countercurrent

to the hot gases passing thereover, while other portions thereof have fluid flow with the gases passing thereover concurrently.

The grouping of the conduit sections and their arrangement with respect to the furnace, secondary combustion chamber and flue, is such that insofar as arrangement is considered, the heat absorbed by any one conduit is substantially equal to the heat absorbed by any other conduit, with the result that heat input to each conduit for a given combustion condition is approximately constant and the furnace and flue are constructed so that the heat stored therein is at a minimum.

In the operation of such a vapor generator, certain variables are indicated and utilized as the basis for automatically controlling the supply of fluid thereto, and the supply of the elements of combustion to the heating furnace.

I indicate at 31 a pressure responsive device such as a Bourdon tube connected to the conduit 23 wherein is the vapor outflow. At 32 is indicated an expandable metallic bellows, spring loaded, forming the movable portion of a gas-filled pressure system of which the bulb 33 is located adjacent the conduit 23, sensitive to the temperature of the vapor outflow therein, to the end that a rack 34, moved by the bellows 32, is positioned responsive to temperature of the vapor outflow.

At 35 and 36 are indicated devices positioned each responsive to temperature such, for example, as electric instruments of known type connected respectively by conductors 37 and 38 through a switch 39 selectively with thermocouple wires 40, 41 or 42 adapted respectively to contact with separate portions of the conduit and sensitive to temperature of the fluid at selected points in its flow path within the boiler. Preferably the thermocouple 40 is located to be sensitive to temperature in the generating section, namely temperature of a mixture of liquid and vapor corresponding to the pressure, while the thermocouple 42 is located to be sensitive to temperature of the fluid in the superheater portion, namely being beyond, in the direction of fluid flow, the location in the flow path of conversion to complete vapor state, and wherein the vapor may be slightly superheated.

The temperature responsive apparatus 35, 36 may be of any known commercial type so long as the movable member of each is positioned to advise the instantaneous value of the temperature in the fluid flow path at a selected location. The switch is indicated in general at 39 as having two movable arms insulated from each other, and each adapted to contact selectively with one of the three thermocouple leads. The arrangement is such that the two arms may complete circuit to the same or different thermocouple contacts so that the temperature responsive devices 35, 36 may be positioned responsive to the same or different location temperatures in the fluid flow path.

As an indicator of generator output or load upon the generator I provide a rate of flow meter 43 adapted to position an arm 44 for advising the instantaneous value of the rate of vapor outflow from the generator.

As an indicator of liquid inflow to the generator I provide in connection with the conduit 10 a rate of flow meter 45 adapted to position an arm 46 for advising the instantaneous value of the rate of liquid inflow through the conduit 10 to the header 9.

The rate of flow meters indicated at 43 and 45 are similar and of known type such as is disclosed

in the patent to Ledoux No. 1,064,748 granted June 17, 1913. Such a meter is a differential pressure responsive device adapted to correct for non-linear relation between differential pressure and rate of flow, to the end that angular positioning of the respective arms is in each case by increments directly proportional to increments of rate of flow. I illustrate by dotted lines within each of the flow meters the outline of its internal construction wherein is a liquid sealed bell having walls of material thickness and shaped as described and claimed in the above mentioned Ledoux patent.

I show as an operating or positioning power means for the rheostat 13 a hydraulic power piston 47 controlled by a pilot 48 and in connection with the hydraulic piston 28 a pilot 49.

I preferably primarily control the liquid inflow to the boiler by means of the rheostat 13 directly proportional to the relation between liquid inflow and vapor outflow, or to the departure of such relation from desired relation wherein the liquid inflow is always equal to the vapor outflow. I modify such control, however, from an indication of a physical characteristic of the fluid within the boiler, as for example, (through the agency of the temperature responsive device 35) as the instantaneous value of the temperature at a location in the fluid flow path.

The arm 44 of the vapor outflow meter 43 is positioned in a clockwise direction for an increase in rate of flow, while the arm 46 of the liquid inflow meter 45 is positioned in a counterclockwise direction for an increase in flow.

Pivotally suspended from the two arms 44, 46 respectively are rods joined pivotally at the opposite end of each to a freely floating beam 50. Intermediate the ends of the beam 50 is pivotally suspended a rod 51 which is pivotally connected at its other end to one end of a freely floating beam 52. The other end of the beam 52 is pivotally connected through a rod 53 to the positionable arm of the temperature responsive device 35.

The arrangement is such that the freely floating beam 50 is positioned, relative to the point of connection of the rod 51, jointly by rate of liquid inflow and rate of vapor outflow, so that when the two rates of flow are equal or in desired proportion the rod 51 is in predetermined position regardless of the rate of generator output. The beam 52 is positioned at one end by such relation and at the other end by an indication of temperature at a location in the fluid path, so that a rod 54 pivotally depending from the beam 52 is positioned vertically jointly by the relation between liquid inflow and vapor outflow, and the indication of temperature mentioned.

The freely depending rod 54 is pivotally connected at its lower end to a contactor beam 55 pivoted intermediate its ends to a contactor case 56 and having a pair of normally close-circuited contacts in operative relation between the beam 55 and case 56.

The contactor 56, in combination with a double field synchronous motor 57 forms a torque amplifier, certain features of which are disclosed and claimed in a co-pending application Serial No. 589,009 filed January 26, 1932 by Walter E. Dueringer.

The operation is such that when through departure from desirable position the rod 54 moves vertically, for example, downward, then the contact bar 55 pivoting around its center in the

case 56 causes an open-circuiting of the right-hand (in the drawings) contact, to the end that the upper (in the drawings) field of the motor 57 is open-circuited, allowing the motor to rotate in a direction as driven by the lowermost shown field. Correspondingly, if the rod 54 is positioned upwardly, then the lefthand contact is open-circuited, allowing rotation in the opposite direction of the motor 57. The arrangement is such that normally the two fields of the motor 57 are energized, whereby the equal opposing torques prevent rotation. Rotation of the armature of the motor which carries a gear meshing with a rack in turn carried by the contactor case 56, causes a repositioning of the case 56 to again close-circuit the two contacts mentioned, whereby further rotation of the armature is stopped. Thus a vertical positioning of the rod 54 causes an operation of the motor 57 in desired direction of rotation until such motion causes a movement of the contactor case 56 to close-circuit the contacts and stop the rotation. The change in position of the armature shaft, through proper inherent gearing, is utilized as an indication in amplified power form of the positioning of the rod 54 relative to a predetermined position.

For remotely controlling the pilot 48 upon a positioning of the rod 54 from predetermined position I utilize a system comprising self-synchronous or selsyn motors indicated in general at 58 and 59. The rotor of a transmitting generator 58 is positioned by the motor 57 resulting in a positioning of the rotor of a receiving motor 59, which rotor is connected by gear and rack, as shown, to position the pilot 48 for a control, through the power piston 47, of the rheostat 13.

For the control of the elements of combustion I position the induced draft damper 26, the forced draft fan motor rheostat 8 and the fuel control valve 5 together, by the hydraulic piston 28 controlled through the pilot 49 which is positioned through the rack and pinion shown, by the rotor of a self-synchronous receiving motor 60, the stator 61 of which is adapted to be positioned relative to the rotor by movement of the power piston 28. The arrangement comprising the hydraulic piston 28, the controlling pilot 49 and the self-synchronous motor 60 has certain features disclosed and claimed in the co-pending application entitled "Power amplifying positioning devices" of Paul S. Dickey, Serial No. 551,215 filed in the United States Patent Office July 16, 1931.

I desirably control the supply of the elements of combustion in accordance with vapor outflow temperature, vapor outflow pressure, and/or an indication of temperature at a location in the fluid flow path. The Bourdon tube 31 positioned sensitive to vapor outflow pressure, positions the rotor of a self-synchronous transmitting generator 62, while the temperature responsive device 32 is adapted to position the rotor of a self-synchronous transmitting generator 63, and the temperature responsive device 36 is adapted to position the rotor of a self-synchronous transmitting generator 64.

I provide at 65 a switch for selectively connecting the temperature responsive device 32 or the pressure responsive device 31 to a differential type of self-synchronous motor indicated at 66, to which is also connected electrically the stator of the generator 64. One element of the differential device 66 comprises a stator, and the other a rotor which is adapted to position the rotor

of a transmitting generator 67 connected in turn to position remotely the rotor of the receiving motor 60.

The arrangement then is such that should vapor outlet temperature or pressure depart from predetermined value, and depending upon the selective position of the switch 65, such departure will cause a positioning of the corresponding transmitting generator rotor from predetermined position, resulting in an angular movement, through the differential motor 66, of the rotor of 67, and of the rotor of 60, to the end that the pilot 49 will be moved out of shut-off position, causing a flow of hydraulic fluid to the piston 28, which in turn positions the fuel valve 5, the air control rheostat 8, and damper 26, as well as moving the stator 61 to cause a repositioning of the rotor 60 whereby the pilot 49 will be returned to shut-off position.

Likewise a departure of temperature, as indicated at 36, from predetermined value will result in a positioning of the pilot 49 in desired direction and amount.

In the remote positioning of pilots as described, 58, 62, 63, 64 and 67 are known as transmitting generators, while 59 and 60 I term receiving motors, and 66 a differential motor. The transmitting generator in each case is operated at a suitable angular rotation of the order of 30 degrees maximum through angular positioning of the rotor or single phase field winding. The stator or armature is in each case provided with a three-phase winding. The field winding of each transmitting generator is energized from a suitable source of alternating current supply. The rotor of each transmitting generator is positioned as previously described by a factor or relation of factors. The receiving motors have three-phase stator windings and single-phase field rotor windings similar to the transmitting generators.

The operation of systems of this general character for the transmission of angular movement is well known in the art. Voltages are induced in the three-phase stator windings of the interconnected generator and motor by the single-phase field windings. When the rotor of the transmitting generator is moved from a predetermined position with respect to its stator, a change is effected in induced voltage in the armature windings and the rotor of the receiving motor connected thereto assumes a position of equilibrium relative to the transmitting generator, wherein the induced voltages in the three phase windings are equal and opposite, and consequently no current is set up in the armature windings. If the rotor of the transmitting generator is turned and held in a new position, the voltage is no longer counterbalanced, whereby equalizing currents are caused to flow in the armature windings. The equalizing currents exert a torque on the rotor of the receiving motor, causing it to take up a position corresponding to that of the rotor of the transmitting generator. Angular movement imparted mechanically to the rotor of the transmitting generator results in proportional angular positioning of the rotor of the connected receiving motor.

The differential motor 66 comprises two three-phase armature windings, one a stator and the other a rotor. The one is connected with the armature of the transmitting generator 64, while the other is connected selectively with the armature of the transmitting generator 62 or 63. It is immaterial which of the three-phase windings of the differential motor 66 is connected to the

transmitting generator 64, so long as one of them comprises a rotor and such rotor will take up a position relative to its stator as a differential of the positioning effect of the rotor 64 and the rotor 62 or 63 to which it is selectively connected. The position of the rotor 66 will mechanically position the rotor 67 comprising a transmitting generator of which 60 is the receiving motor.

The arrangement wherein the stator 61 is also positioned mechanically relative to the rotor 60 provides what I term a positioning control wherein for each position of the rotor 67 from predetermined position there is a corresponding position of the power piston 28. When the rotor 67 is moved, for example 5 degrees of rotation from a starting point, the rotor 60 is correspondingly moved, say 5 degrees from its starting point, throwing the pilot 49 a certain amount out of shut-off position. Passage of hydraulic fluid to the power piston 28 causes a positioning of the stator 61 in proper direction 5 degrees counter to the previous movement of the rotor 60, whereby the rotor 60 is dragged backwards 5 degrees to return the pilot 49 to shut-off position but retaining the angular difference of 5 degrees between the rotor and stator windings.

In operation, it will be seen that the disclosure provides a method and means for the control of liquid input to the generator substantially equal to vapor outflow, but capable of modification through the agency of an indication of temperature at a location in the fluid flow path, preferably at a location beyond the saturation line in the direction of fluid flow, wherein there exists vapor only, slightly superheated above the temperature corresponding to the pressure. I provide further a control of the supply of the elements of combustion to maintain a desirable vapor outlet temperature and/or pressure, but with the possibility of modification through the agency of an indication of temperature at a location in the fluid flow path.

I have found that primarily in the control of a boiler such as is described, it is essential in maintaining the vapor outflow in desired quantity and quality, that I maintain a fixed percentage of the flow path or conduit to have vapor only being superheated, and it will be seen that the best way to so maintain the predetermined portion of the flow path as desired, is to proportion the inflow of liquid to the outflow of vapor as I have explained, and readjust the inflow from an indication of temperature at a location in the flow path, which temperature will vary responsive to a change in the amount of the flow path which I desire to have remain constant.

For example, if the thermocouple 42 is sensitive to temperature just beyond the point of complete conversion to vapor state, then it will be sensitive to a temperature which is equal to the temperature corresponding to pressure plus whatever superheat is present in the vapor. Such a location has preference over a thermocouple located exactly at the point of complete conversion to vapor state, for until the vapor begins to be superheated there is no temperature change between that of the liquid and that of the vapor, so that it is not practical to attempt to determine exactly the location in the flow path of complete conversion to vapor state. I provide, however, the thermocouples 40, 41 which I may use as a checking control upon the supply of liquid input to the generator through the selectivity of the switch 39 if desired.

In Fig. 2 I illustrate an embodiment of my

invention somewhat similar to that of Fig. 1, except that herein I show an interconnection of mechanical linkage between the various related factors for the positioning of pilot valves to control hydraulic power pistons. The vapor generator illustrated in general at 1 is shown in side elevation rather than in sectional elevation. The internal construction is the same as in Fig. 1, except that I have dispensed with the equalizing or mixing boxes 18, 29 and 30. I supply liquid to the boiler through the conduit 10, and vapor passes from the boiler through a conduit 23. I further illustrate only two parallel conduits comprising the generator, as compared to the three shown in Fig. 1. Fuel is supplied to the furnace through a conduit 3, and air for combustion through a conduit 4, as in Fig. 1.

The arrangement and inter-relation of factors for the control of liquid inflow and the supply of the elements of combustion to the furnace for heating the generator are as described in connection with Fig. 1. The liquid inflow to the generator is primarily controlled in accordance with the relation between liquid inflow and vapor outflow, with the possibility of modification from an indication of temperature at a location in the fluid flow path. The vapor outflow meter 43 for positioning one end of the floating beam 50, indicates the rate of vapor outflow upon an index 44A. The liquid inflow meter 45 for positioning the other end of the floating beam 50, indicates the rate of liquid inflow upon an index 46A. The temperature responsive device 35 indicates the instantaneous value of such temperature upon an index 35A.

In Fig. 2 the depending rod 54 positioned vertically by the relation between liquid inflow and vapor outflow, and an indication of temperature at a location in the flow path, positions directly and mechanically the pilot valve 48 for control of the power piston 47.

In the control of the supply of the elements of combustion I employ the vapor outflow pressure indicated by a Bourdon tube 31 upon an index 31A, and/or the vapor outflow temperature indicated by a metallic bellows 32 upon an index 32A, along with an indication of temperature at a location in the fluid flow path through the device 36 as indicated upon an index 36A; to directly control the pilot 49.

A beam 68 has one end positioned responsive to vapor outflow pressure and the other responsive to vapor outflow temperature, while from intermediate its ends depends a rod 69 pivotally connected to one end of a floating beam 70 which is positioned at the other end by the temperature device 36. Intermediate the ends of the beam 70 is a depending rod 71 for positioning one end of a beam 72, the other end of which is connected to the power piston 28, and from intermediate the ends of which is connected the pilot 49.

The arrangement is such that by means of the shut-off valves 73, 74 I may selectively utilize vapor outlet temperature and/or vapor outlet pressure to cooperate with temperature at a location in the fluid flow path for positioning the pilot 49. As soon as the pilot 49 is moved from predetermined position, the passage of hydraulic fluid to one side or the other of the power piston 28 causes a movement thereof, and of the beam 72 for repositioning the pilot 49 to shut-off position.

In Fig. 3 I illustrate a similar embodiment to those of Fig. 1 and Fig. 2, differing therefrom in

that herein I employ a combination of the mechanical linkage of Fig. 2, with electric means comprising motors 75, 76 for the liquid inflow control and the supply of elements of combustion respectively.

Considering first the control of the rheostat 13 regulating the liquid inflow, the rheostat is primarily controlled through actuation of the motor 75, energized for rotation in one direction or the other upon a departure from predetermined desirable relation between liquid inflow and vapor outflow as modified by an indication of temperature at a location in the fluid flow path. The depending rod 54 similar to that of Fig. 1 and Fig. 2, is pivotally connected to one end of a contactor bar 77 which is adapted to be oscillated or positioned about a pivot point intermediate the ends, relative to a pair of contacts 78, 79 normally open-circuited. Moved with the contactor bar 77 is a solenoid core 80 whose function will be explained shortly. Closing of the circuit of either of the contacts 78, 79 results in an energization, through thermionic valves 81 or 82, of the motor 75 to position the rheostat 13 in the proper direction.

The circuit of the pilot motor 75 and its contactor 77 is similar to the one disclosed and claimed in the co-pending application Serial No. 561,006 by John D. Ryder entitled "Motor control circuits", filed in the United States Patent Office September 3, 1931, and embodies the use of thermionic valves connected in an alternating-current circuit and arranged each to pass a pulsating direct-current comprising one-half of the alternating-current wave. The field of the pilot motor 75 is energized across a source of direct-current, while the armature is in an alternating-current circuit including the thermionic valves 81 and 82 whose grid circuits are respectively controlled by the contacts 78 and 79, normally open-circuited, to the end that when one or the other of the contacts 78, 79 is close-circuited, a pulsating direct-current in one direction or the other will be applied to the armature 75 for causing rotation thereof in desired direction. The variable reactance 80 in the motor circuit is for varying the speed thereof in either direction of rotation, as disclosed and claimed in the referred to Ryder application.

Similarly, the pilot motor 76 is in an electric circuit including thermionic valves 83, 84 controlled through a pair of contacts actuated by a contactor bar 85 which is adapted to be oscillated or positioned about a pivot point 86 fixed in a contactor case 87. The contactor case 87 itself carries a pair of contacts mating with those carried by the beam 85 and may be raised or lowered, that is, positioned as a whole vertically through a link 88, positioned by the motor 76 which in itself is connected in the circuit comprising the said contacts. The motor 76 is adapted then to position not only the fuel valve 5, the forced draft fan motor rheostat 8, the induced draft damper 26, but also the contactor case 87.

The circuit of the pilot motor 76 and the contactor 87 is similar to the one disclosed and claimed in the co-pending application Serial No. 561,005 filed September 3, 1931 by John D. Ryder, entitled, "Motor control circuits", and embodies the use of thermionic valves connected in an alternating-current circuit and arranged each to pass a pulsating direct-current comprising one-half of the alternating-current wave. The field of the motor 76 is energized across a source of direct-current, while the armature is in an al-

ternating-current circuit including thermionic valves 83, 84, whose grid circuits are respectively controlled by the contacts of the contactor 87 normally close-circuited, to the end that the armature of the motor 76 is normally energized in the alternating-current circuit. The opposing equal torques of the alternating-current half-waves prohibit rotation of the armature, and thermal damage to the motor is prevented through the use of a reactor 89. When the grid control circuit to either of the valves 83 or 84 is open-circuited, as by the contactor 87, that valve ceases to pass current, and the torque on the motor armature from the pulsating direct-current passing through the other valve causes rotation of the said armature in desired direction.

The arrangement is such that when the rod 71 is moved downwardly, then (on the drawings) the lefthand contact is open-circuited and the motor 76 is caused to rotate in a direction wherein the contactor case 87 is moved downwardly until the lefthand contact is again close-circuited, whereupon a substantially instantaneous application to the armature 76 of opposing equal torques of the full-wave alternating-current causes substantially instantaneous plugging or stoppage of rotation thereof. Simultaneously the motor has caused a positioning of the fuel and air supplying devices in desired amount.

In operation it will be seen that the three drawings and the disclosure provides a method and means for the control of liquid input to the boiler from a relation between liquid inflow and vapor outflow, with such control modified by an indication of temperature at a location along the fluid flow path. Furthermore, the supply of the elements of combustion, both air and fuel, to the furnace for heating the vapor generator, is controlled from an indication of vapor outlet pressure and/or vapor outlet temperature, with a possibility of such control being modified from an indication of temperature at a location in the fluid flow path.

Effective upon the rate of supply of liquid to the generator as well as the rate of supply of the elements of combustion to the furnace, are respectively the devices 35 and 36 responsive to selected temperatures at locations in the conduit or fluid flow path. Preferably I employ in the control of liquid inflow, temperature at a location along the flow path beyond the point of complete conversion to vapor state, as indicated for example, by the location of the thermocouple 42 just within the superheater section of the conduit.

In general, in the operation and control of such a vapor generator and furnace, I contemplate a method and means for controlling the liquid inflow and the supply of the elements of combustion in the most efficient manner for insuring a vapor outflow of desired quantity and quality. The control of such a drumless vapor generator as I have described presents a problem differing considerably from the ordinary storage type of vapor generator, and it is necessary to appreciate in connection therewith the fact that in each conduit comprising a fluid flow path through the generator, there will be at all times a location which I term the "vaporization line", at the inlet side of which is the water heating section and at the outlet side, a combination of vapor and liquid. There is further in the series flow path a location which I designate as the "saturation line" or "point of conversion to complete vapor state", beyond which exists vapor only. A

water heating or economizing portion of the fluid flow path is first in the series flow before the vaporization line is reached as may also be part of the vapor generator or heating surface. Between the vaporization line and the saturation line exists a mixture of vapor and liquid, and beyond the saturation line, in what I term the superheater section, is vapor only in varying degree of superheat.

One of the main features of my invention is the discovery that by maintaining substantially constant the percentage of the fluid flow path comprising the superheater section beyond the location in the fluid flow path of complete conversion to vapor state, regardless of rate of output of the boiler, I will maintain substantially constant the quality of the vapor output. The temperature of the vapor at the saturation line will be the same as the temperature just preceding the line for it will be the temperature corresponding to pressure, regardless of whether at that point exists liquid or vapor. Beyond the saturation line, however, where vapor only exists and is still subjected to the heating effect of the furnace and products of combustion, the vapor may have a temperature superheated or substantially higher than that at the point of complete conversion to vapor state, and usually progressively higher from the saturation line to the point of outflow from the generator. Thus by taking a temperature measurement in the flow path just beyond the saturation line, I obtain a temperature which is indicative of complete vapor state with a slight amount of superheat, and by utilizing this temperature as the readjusting control in regulating the supply of liquid inflow to the fluid flow path, wherein the primary control of liquid inflow is in accordance with the relation between liquid inflow and vapor outflow, I accomplish my desirable feature of maintaining substantially constant the portion of the fluid flow path wherein exists vapor only.

I have illustrated and described the use of a selective switch 39 whereby I may utilize as a corrective influence a temperature selective between a multiplicity of locations in the fluid flow path, and I have such possible selection for the purpose of basically changing the amount or portion of the fluid flow path wherein exists vapor only, through the control selectively from one of the said temperatures and for the purpose of selecting between desired quality of the outflowing vapor. Thus, for example, should I desire the vapor outflow to have a temperature of 750 degrees Fahrenheit, representing a certain amount of superheat, I may control to maintain a certain portion of the flow path to have vapor only therein, such, for example, as that portion slightly greater in length than from the location of the thermocouple 42 to the exit from the boiler. If, however, I desire to control for a slightly different temperature of the vapor leaving the boiler, I may utilize the thermocouple 41, thereby increasing the percentage of the fluid flow path wherein exists vapor only.

Similarly, I use an indication of temperature within the fluid flow path as a modifying or readjusting control of the supply of the elements of combustion through the agency of a second temperature responsive device 36 connected to one of the arms of the selective switch 39. The arrangement as illustrated is such that either of the selective arms of the switch 39 may contact for completing a circuit to either of the thermocouples 40, 41 or 42, and the two arms may be

simultaneously connected to any one of the three thermocouples, in which event both the devices 35 and 36 would be sensitive to temperature at the same location in the fluid flow path.

I show in Fig. 1, three parallel conduits comprising three similar fluid flow paths through the boiler, with the utilization of equalizing or mixing boxes at various points along the path. In Fig. 2 and Fig. 3 I show two parallel conduits, and in Fig. 2 they are carried completely through the boiler as separate flow paths having no equalizing boxes. It will be apparent that I am not limited in my invention to two or three flow paths or to the use of equalizing boxes, but I contemplate broadly the utilization of one or more conduits comprising a continuous fluid flow path wherein liquid under pressure enters at one end and vapor of desired quantity and quality is discharged from the other end without appreciable storage or circulation.

Having thus described my invention and preferred embodiments thereof, I desire it to be distinctly understood that I am not to be limited thereby except as to the claims in view of prior art.

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

1. Apparatus for automatically controlling the operation of a vapor generator having a once-through fluid passage receiving liquid under pressure at one end and delivering superheated vapor only at the other end and heated by elements of combustion, comprising in combination, liquid inflow regulating apparatus, supply means for the elements of combustion, control means actuated by electron discharge devices for said regulating apparatus and responsive to relation between liquid inflow and vapor outflow, and control means actuated by electron discharge devices for controlling the supply of the elements of combustion and responsive to conditions of the vapor outflow, both of said control means further responsive to an indication of temperature in the fluid flow path beyond the saturation line.
2. Apparatus for automatically controlling the operation of a vapor generator having a once-through fluid passage receiving liquid under pressure at one end and delivering superheated vapor only at the other end and heated by elements of combustion, comprising in combination, a vapor outflow meter, a liquid inflow meter, a thermostat sensitive to temperature at a location in the passage wherein is superheated vapor, a second thermostat sensitive to temperature at a location in the passage, a pressure indicator of vapor outlet pressure, a temperature indicator of vapor outlet temperature; hydraulically actuated regulating means of the rate of liquid inflow to the generator, control means for said hydraulically actuated means positioned by said meters and by said first-named thermostat, hydraulically actuated regulating means of the rate of supply of the elements of combustion to the furnace, and control means for said last-named hydraulically actuated means positioned by said pressure indicator, said temperature indicator and said second-named thermostat.
3. Apparatus for automatically controlling the operation of a vapor generator having a once-through fluid passage receiving liquid under pressure at one end and delivering superheated vapor only at the other end and heated by elements of combustion, comprising in combination, a vapor outflow meter, a liquid inflow meter, a thermostat sensitive to temperature at a location in the pas-

sage wherein is superheated vapor, a second thermostat sensitive to temperature at a location in the passage, a pressure indicator of vapor outflow pressure, a temperature indicator of vapor outflow temperature; hydraulic control means for regulating the liquid inflow, electrical means for remotely actuating said hydraulic control means and responsive to said meters and to said first-named thermostat, hydraulically actuated control means for varying the rate of supply of the elements of combustion, and electrical means for remotely actuating said second-named hydraulically actuated control means and responsive to said temperature indicator, said pressure indicator and said second-named thermostat.

4. Apparatus for automatically controlling the operation of a vapor generator having a once-through fluid passage receiving liquid at one end and delivering superheated vapor at the other end and heated by elements of combustion, comprising in combination, a regulator for controlling the heating, means responsive to one or more physical characteristics of the fluid, and control means for positioning said regulator, said control means actuated by electron discharge devices responsive to said first named means.

5. Apparatus for automatically controlling the operation of a vapor-generator having small liquid storage with a high rate of evaporation and heated by elements of combustion, comprising in combination, a regulator for controlling the heating, means separately positioned responsive to a plurality of physical characteristics of the fluid, and control means conjointly positioned by said several means for positioning the regulator.

6. Apparatus for automatically controlling the operation of a vapor-generator having a once-through fluid passage receiving liquid at one end and delivering superheated vapor at the other end and heated by elements of combustion, comprising in combination, a regulator for controlling the rate of supply of elements of combustion, means responsive to a plurality of physical characteristics of the fluid, and control means for positioning said regulator, said control means actuated by electron discharge devices responsive to said first-named means.

7. Apparatus for automatically controlling the operation of a vapor generator having small liquid storage with a high rate of evaporation and heated by elements of combustion, comprising in combination, liquid inflow regulating apparatus, supply means for the elements of combustion, control means for said regulating apparatus, said control means actuated by electron discharge devices responsive to relation between liquid inflow and vapor outflow, and control means for said supply means, said last-named control means actuated by electron discharge devices responsive to a plurality of conditions of the vapor outflow.

8. Apparatus for automatically controlling the operation of a vapor-generator having small liquid storage with a high rate of evaporation and heated by elements of combustion, comprising in combination, a regulator for controlling the heating, means responsive to one or more physical characteristics of the fluid, and control means for positioning said regulator, said control means actuated by electron discharge devices responsive to said first-named means.

9. Apparatus for automatically controlling the operation of a vapor-generator having small liquid storage with a high rate of evaporation and heated by elements of combustion, compris-

ing in combination, a regulator for controlling the rate of supply of elements of combustion, means responsive to a plurality of physical characteristics of the fluid, and control means for positioning said regulator, said control means actuated by electron discharge devices responsive to said first-named means.

10. In combination, a vapor-generator and a furnace therefor, said vapor-generator having a once-through fluid passage receiving a forced flow of liquid at one end and delivering superheated vapor at the other, liquid supplying means to said passage, fuel supplying means to said furnace, apparatus for maintaining liquid inflow substantially equal to vapor outflow, means also controlling the liquid inflow and responsive to an indication of temperature at a location in the fluid flow path just beyond the saturation line, and apparatus solely responsive to a plurality of conditions of the vapor outflow for controlling the rate of supply of fuel to the furnace.

11. In combination, a vapor-generator and a furnace therefor, said vapor-generator having a once-through fluid passage receiving a forced flow of liquid at one end and delivering superheated vapor at the other, liquid supplying means to said passage, fuel supplying means to said furnace, apparatus for maintaining liquid inflow substantially equal to vapor outflow, and ap-

paratus solely responsive to a plurality of conditions of the vapor outflow for controlling the rate of supply of fuel to the furnace.

12. Apparatus for automatically controlling the operation of a vapor generator having a once-through fluid passage receiving liquid at one end under pressure and delivering superheated vapor at the other end and heated by the elements of combustion, comprising, in combination, apparatus for maintaining liquid inflow substantially equal to vapor outflow, means also controlling the liquid inflow and responsive to an indication of temperature at a location in the fluid flow path just beyond the saturation line, and apparatus solely responsive to a plurality of conditions of the vapor outflow for controlling the rate of supply of at least one of the elements of combustion.

13. Apparatus for controlling the operation of a vapor generator having small liquid storage with a high rate of evaporation and heated by the elements of combustion, comprising in combination, a regulator of liquid inflow, means measuring vapor outflow and for positioning said regulator, and apparatus solely responsive to a plurality of conditions of the vapor outflow for controlling the rate of supply of at least one of the elements of combustion.

RAYMOND D. JUNKINS.

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