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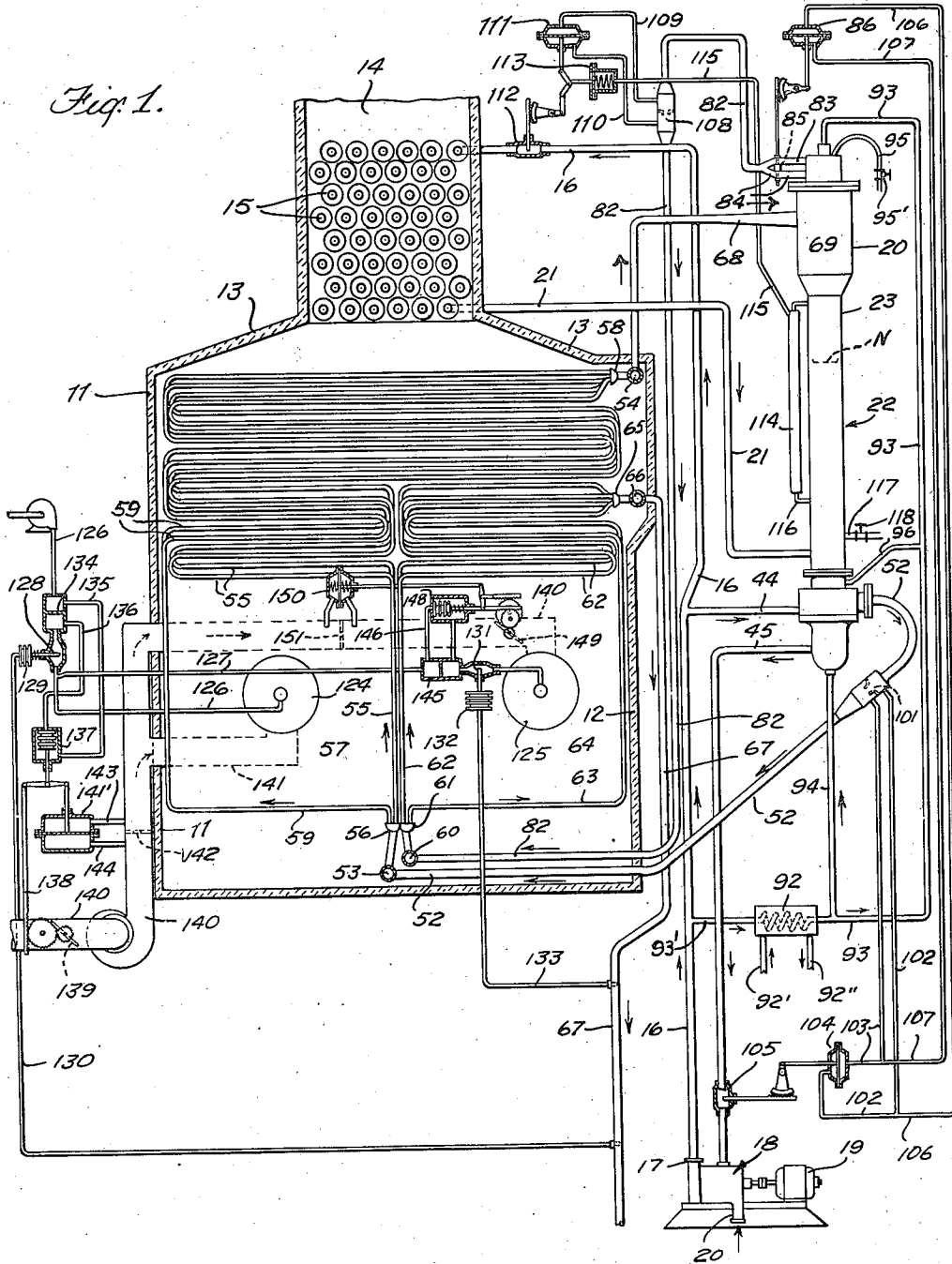
M. FRISCH

2,405,573

VAPOR GENERATOR

Filed Nov. 12, 1941

2 Sheets-Sheet 1



BY

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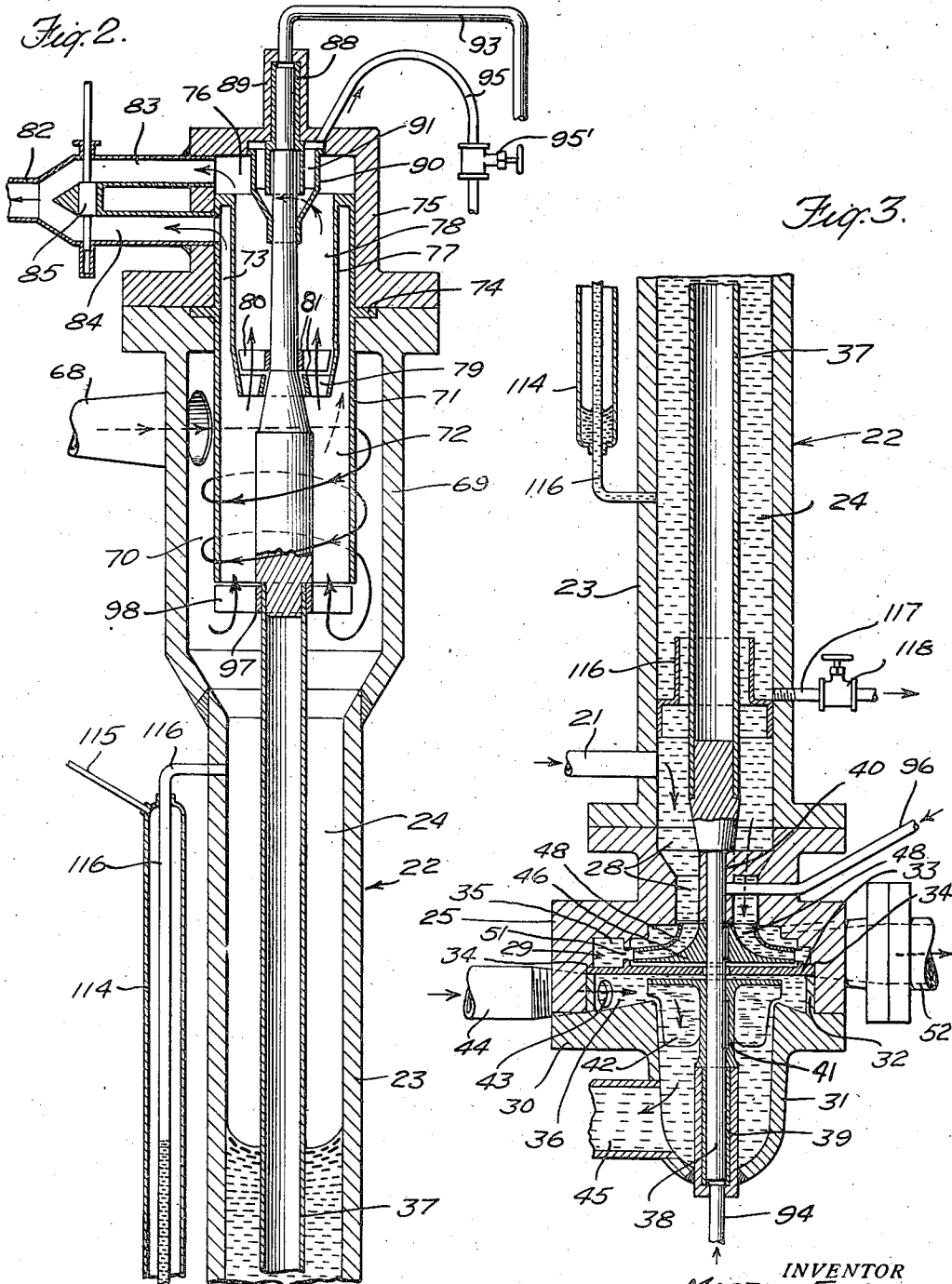
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2 Sheets-Sheet 2



*BY*

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## UNITED STATES PATENT OFFICE

2,405,573

## VAPOR GENERATOR

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43 Claims. (Cl. 122-448)

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This invention relates to vapor generators and more particularly pertains to vapor generators of the forced circulation type.

As applied to the generation of steam, the invention provides a forced circulation steam generator in which the amount of water storage is reduced to a minimum by dispensing with the drum or other usual type of vessel in which separation of the steam from the circulating water is effected, and replacing it with a separator of small volume in which the water and steam are separated mechanically by rapid rotation of the separating device which is operative with the circulating pump.

In the preferred arrangement, the circulating pump is driven, after the generator is started, by the steam flowing from the separator. To assure immediate and adequate circulation when the generator is started, an auxiliary water turbine is utilized to drive the circulating pump by feed water which is returned to the suction of the feed pump or to some intermediate stage thereof. Glands or external bearings are not required because cooled feed water at full feed pump pressure is employed to provide lubrication for the internal bearings of the pump and separator.

The generator may be controlled manually in the same manner as a natural circulation steam generator is controlled, or it may be controlled automatically. In the form of the invention disclosed, the generator is controlled automatically. One feature of this control is the regulation of the amount of water passed through the auxiliary water turbine and the amount of steam passed through the steam turbine so as to maintain a predetermined rate of circulation at all loads on the generator. A differential across a flow nozzle in the circulating water line actuates flow controllers which govern the flow of water to the auxiliary water turbine and the flow of steam to the steam turbine. The flow controllers are set so that as the load increases, the amount of water flowing through the water turbine is decreased progressively and the flow of steam through the steam turbine is increased progressively, so that at full generator load only sufficient water is passed through the water turbine to prevent boiling due to churning.

The tubes of the steam generating and the superheating sections are so arranged that there are a plurality of main paths of flow from the inlet to the outlet of each section, with the lengths of the flow paths in each section substantially equal and with the flow through each section and

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each path of each section generally concurrent to the flow of gases.

The invention will be understood from the following description when considered in connection with the accompanying drawings forming a part thereof, and in which:

Fig. 1 is a vertical sectional view, more or less diagrammatic, of a forced recirculation steam generator embodying the invention;

Fig. 2 is an enlarged vertical sectional view of the upper portion of the separating and circulating device shown in elevation in Fig. 1, and

Fig. 3 is a vertical sectional view of the lower portion of the separating and circulating device.

Like characters of reference refer to like parts throughout the several views.

Referring to Fig. 1, the setting of the generator shown, has opposite side walls 11 and 12, a roof 13, and a gas outlet 14. An economizer 15 in the outlet 14 is connected to a feed water conduit 16 leading from the discharge side 17 of a feed pump 18 which is driven by a motor 19 connected to a source of electricity, not shown. Feed water enters the pump 18 at the suction side 20 thereof, and is forced through conduit 16 and through the economizer 15 in a direction of flow counter-current to the direction of flow of the heating gases into an outlet conduit 21 which is connected to a separating and circulating device 22. As shown, the separating and circulating device comprises an elongated, vertically disposed, housing 23 having a fluid chamber 24 therein and a circulating pump casing 25 at the bottom of the housing.

The lower end of the chamber 24 is connected by a passage 28 with a chamber 29 in the casing. The lower end of the casing 25 is closed by a cap 30 having a hollow extension 31. Cap 30 has an annular flange 32 which projects into the chamber 29, and engages a partition 33 holding it tightly against an annular shoulder 34 to divide the chamber 29 into two separate chambers, a circulating pump chamber 35, and a water turbine chamber 36. A drive shaft 37 having a reduced lower end portion 38 rotatably mounted in a thrust bearing 39 is disposed in the closed end of the cap 31 in fluid-tight relationship thereto, and extends through the chambers 24, 35 and 36. The shaft 37 is hollow throughout the greater part of its length with solid end portions, but it may be solid throughout the entire length thereof, if desired.

A water turbine 41 having blades 42 which extend into the cap 31 is fixed to shaft 37 in chamber 36. Chamber 36 has an inlet port 43 in com-

munication with the discharge side 17 of the feed pump 18 through conduit 16 and a conduit 44, and an outlet conduit 45 conducts water from the chamber to the suction side of the feed pump 18.

A circulating pump impeller 46 is fixed to the shaft 37 above the water turbine and in the chamber 35. The impeller 46 has a plurality of blades 48 which are curved downwardly and outwardly from the passage 28 to the periphery of the impeller. Feed water flows into the impeller from the chamber 24 and is discharged into a feed conduit 52 which conducts circulating water to the steam generating section of the generator.

As shown, the tubes of the steam generating section are arranged to provide two main paths of flow in parallel, from the inlet header 53 to the outlet header 54. One main path comprises tubes 55 which are connected to a fitting 56 having communication with the inlet header 53, and which extend vertically upwardly in a single row at about the center of the setting and then extend horizontally toward the wall 11 to define one side and the top of a boiler furnace 57. Thereafter the tubes 55 extend in a plurality of superposed and horizontal rows over the boiler furnace and in a plurality of additional superposed and horizontal rows substantially entirely across the setting to the outlet fitting 58 which is connected to the outlet header 54. The other main path comprises tubes 59 which extend from the inlet fitting 56 horizontally along the bottom of the boiler furnace 57 in a single row and then vertically upwardly in a single row along the wall 11 to a point above the first two horizontal rows of the tubes 55, after which they extend in a plurality of superposed and horizontal rows above the boiler furnace and thereafter in like manner substantially entirely across the setting to the outlet fitting 58. The tubes in the horizontal rows above the boiler furnace are staggered, that is, with the tubes in alternate rows at a different elevation as compared with the elevation of the tubes in the other rows.

The tubes of the superheating section are arranged similarly to those of the steam generating section excepting that they do not extend entirely across the setting. The superheater inlet header 60 adjacent the inlet header 53 is connected to an inlet fitting 61 to which the superheater tubes of both main paths are connected. Tubes 62 extend vertically upward in a single row adjacent the tubes 55 to the elevation of the lowermost horizontal row of tubes 55, and then turn and extend horizontally to the wall 12 of the setting to define one side and the top of a superheater furnace 64. Thereafter, the tubes 62 extend in a plurality of superposed and horizontal rows to an outlet fitting 65 which is connected to a superheater outlet header 66 from which the superheated steam flows to the point of use through a conduit 67. Tubes 63 extend along the bottom and a side of the superheater furnace and in a plurality of superposed and horizontal rows to the outlet fitting 65. The horizontal rows of the superheater tubes are staggered in the same manner the tubes of the horizontal rows of the steam generating section are staggered.

The rear wall of both furnaces 57 and 64 are lined with water tubes, not shown, which are connected in the circulatory system so as to be supplied with water from header 53 and to deliver fluid to the outlet header 54.

With this arrangement of the tubes of the

steam generating and superheating sections, the paths of flow through the tubes 55 and 59 are substantially equal and the paths of flow through the tubes 62 and 63 are also substantially equal, with the flow through each of these groups of tubes generally in the direction of flow of the gases of combustion.

The boiler and superheater furnaces are separately fired, the gases produced in the boiler furnace 57 flowing through the furnace and over the horizontal rows of tubes 55 and 59 to the outlet 14 and over the economizer 15 therein. The gases produced in the superheater furnace 64 flow through the furnace and over the horizontal rows of the tubes 62 and 63 and then over the horizontal rows of tubes 55 and 59 of the steam generating section and to the outlet 14. The tubes 55 and 62 are arranged, with or without other wall or baffle means, to prevent the flow of gases from one furnace to the other.

The mixture of steam and water discharged from the steam generating section is conducted by a conduit 68 to the upper part 69 of the separating and circulating device 22, and is delivered tangentially into a separating chamber 70 therein which communicates at its lower end with the upper part of chamber 24 in the housing 23. A tubular member 71 of lesser diameter than the chamber 70 and having a passage 72 therein is disposed in the chamber 70, and as shown, is provided with a peripheral flange 74 which is received in a recess in part 69 to support the tubular member in position. A mechanical steam and water separator 97, Fig. 2, is provided as shown, by a plurality of radial blades 98, fixed to shaft 37 in chamber 70 closely adjacent the lower end of the tubular member 71 in the path of steam flowing from the separating chamber 70. Other forms of separators may be employed. The tubular member 71 projects upwardly into a hollow cap 75 which closes the upper end of part 69, to a point short of the upper end thereof, thereby forming a space 76 between the end of the tubular member and the cap. A cylindrical member 77 is secured at its upper end to the upper end of member 71 and extends downwardly in the member 71 in spaced relationship to the inner wall thereof to provide an annular steam by-pass passage 73. The interior of member 77 provides a main steam passage 78, which communicates with the space 76, for steam flowing from the passage 72. A plurality of spaced stationary turbine blades 79 disposed at the lower end of the member 77, and a plurality of rotatable blades 80 fixed to shaft 37 above the blades 79 provide a steam turbine 81 which is operated by steam flowing from passage 72 into passage 78. A steam conduit 82 which conducts steam from the separating device to the inlet header 60 of the superheater, is connected at its inlet end to the space 76 through a branch conduit 83 and to passage 72 through a by-pass conduit 84, the conduits 83 and 84 being controlled by a slide valve 85 which is actuated by a pressure responsive device 86, Fig. 1.

The upper end of drive shaft 37 extends through the passages 72 and 78 and is rotatably mounted in a thrust bearing 88 in a projection 89 on cap 75. A housing 90 forms a chamber 91 around the bearing 88 and the shaft 37. Bearing 88 is cooled by feed water from a heat exchanger 92, Fig. 1, which is conducted to the bearing through a conduit 93. Bearing 39 at the lower end of the shaft 37 is cooled also by feed water from heat exchanger 92 conducted to the bearing through conduits 93 and 94. Water is

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withdrawn from chamber 91 through a conduit 95 controlled by a valve 95'. Shaft 37 is also supported above the circulating pump 46 in a bearing 40 to which cooled feed water for lubrication is supplied by conduit 96. The feed water 5 supplied to the bearings 39 and 40 after lubricating these bearings, mixes with the water discharged from the auxiliary turbine and the water discharged by the circulating pump, respectively. Heat exchanger 92 is connected to feed water conduit 16 through a conduit 93' and a cooling medium is supplied thereto through a conduit 92' and is withdrawn therefrom through a conduit 92''.

A trap 116, Fig. 3, is secured in the lower portion of the chamber 24 above the point at which the economizer outlet conduit 21 is connected to the housing 23. The trap is shaped to provide a passage around the shaft 37 through which water will flow from chamber 24 into the passage 23 and the circulating pump 46. A blow-down conduit 117 connects with the bottom of the trap and is controlled by a valve 118.

The quantity of water delivered to the auxiliary water turbine and the quantity of steam flowing to the steam turbine is varied in response to variations in the quantity of water delivered to the steam generating section by the circulating pump. To this end, a flow nozzle 101, Fig. 1, is positioned in the feed water conduit 52 and pressure conduits 102 and 103 connect opposite sides of the nozzle 101 with opposite sides of the diaphragm of a pressure responsive device 104 which controls the flow of water in the outlet conduit 45 through a valve 105. Conduits 106 and 107 connect opposite sides of the diaphragm of pressure responsive device 86 with the conduits 102 and 103 respectively. The pressure responsive devices 104 and 86 are so arranged that an increase in the flow of circulating water through the conduit 52 will cause the device 104 to operate the valve 105 to decrease the flow of water through conduit 45 and to the auxiliary water turbine, and at the same time to cause the device 86 to operate the valve 85 to decrease the flow of vapor through the by-pass conduit 84 thereby increasing the flow through the branch conduit 83 and to the steam turbine. A decrease in the flow of circulating water through the conduit 52 will have the opposite effect.

The quantity of feed water is regulated in response to the rate of steaming. To accomplish this, a flow nozzle 108, Fig. 1, is positioned in the steam conduit 82 and opposite sides of this orifice are connected by conduits 109 and 110 to opposite sides of the diaphragm of a pressure responsive device 111 which operates a valve 112 in conduit 16 to control the flow of feed water to the economizer 15. An increase in the flow of steam through the conduit 82 will cause the device 111 to actuate valve 112 to permit an increase in the flow of water to the economizer, and vice versa, a decrease in the flow in the conduit 82 will cause a decrease in the flow of water to the economizer.

Valve 112 is also actuated independently of the pressure responsive device 111 to regulate the level of water to the chamber 24 of the separating and circulating device 22, irrespective of variations in the rate of steaming. This is accomplished by an auxiliary feed control pressure responsive device 113 which is in communication with a liquid level controller 114 through a tube 115. The level controller 114, which is of the vapor pressure type, has a control tube 116 there-

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in which communicates with the chamber 24 at points above and below the normal water level therein. As the water in chamber 24 rises to a predetermined level, the device 113 actuates the valve 112 to decrease the flow of water to the economizer 15 through conduit 16 and to the chamber 24, and when the water falls below the predetermined level, the valve is actuated to permit an increased flow of water to the economizer and the chamber 24.

The boiler furnace 57 is fired by a fuel burner 124 to which fuel is supplied through a fuel line 126, while the superheater furnace 64 is fired by a fuel burner 125 to which fuel is supplied through fuel lines 126 and 127. Positioned in the fuel line 126 between the source of fuel supply and the burners 124 and 125, is a control valve 128 actuated by a pressure responsive device 129 which operates in response to the pressure in the superheater steam outlet conduit 67 and is connected thereto through a tube 130. Valve 128 is actuated to permit an increased flow of fuel to the burners when the vapor pressure in the conduit 67 decreases and to decrease the flow of fuel to the burners when the vapor pressure in the conduit 67 increases. A control valve 131 similar to valve 128, controls the feed conduit 127. Valve 131 is operated by an actuating device 132 which is responsive to the temperature in the superheater vapor outlet 67 and is connected thereto through a line 133. Upon an increase in temperature in the conduit 67, the valve 131 is actuated to decrease the flow of fuel to the burner 125 and upon a decrease in temperature, the valve permits an increased flow of fuel to the burner.

An orifice 134 is disposed in the fuel line 126 between the valve 128 and the source of fuel supply. Opposite sides of the orifice are connected through lines 135 and 136 to a pressure responsive actuating device 137, which operates through a rack and pinion mechanism, a damper 139 in an air conduit 140 which conducts air to the burners 124 and 125. A branch conduit 141 connects the conduit 140 with the burner 124. The arrangement is such that an increase in the flow of fuel to the burners through line 126, will cause the pressure device 137 to actuate the damper 139 to permit an increased flow of air to the burners, while a decrease in the flow of fuel in line 126, will cause the damper 139 to be actuated to decrease the flow of air to the burners. An auxiliary pressure responsive device 141' is connected to opposite sides of an orifice 142 in air conduit 140 by tubes 143 and 144, and operates in conjunction with the device 137 to control the damper 139.

An orifice 145 in the fuel line 127 to the superheater burner 125, has its opposite sides connected to a pressure responsive device 143 which actuates through rack and pinion mechanism, a damper 149 in the air conduit 140 to increase and decrease the quantity of air flowing to the burner 125 in response to variations in the flow of fuel to the burner, an increase in the flow of fuel causing the damper to move to a more open position to permit a greater quantity of air to flow to the burner, while a decrease in the flow of fuel will cause the damper to move to a more closed position to decrease the quantity of air delivered to the burner. An auxiliary pressure responsive device 150 is connected across an orifice 151 in the conduit 140 and operates in conjunction with the device 143 to control the damper 149.

The means for controlling the supply of fuel

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and air to the burners 124 and 125 operates automatically to supply air and fuel to each burner in the proper amount to maintain the desired rate of steam generation. If the desired rate is exceeded, the control means will operate automatically to cause a decrease in the supply of fuel and air to the burners, whereas if the desired rate is not attained, the fuel and air supply to the burners will be increased. In addition to this control of both burners in response to the final pressure of the steam, the superheater burner 125 is controlled to obtain or to maintain the desired final temperature of the steam by increasing and decreasing the supply of fuel and air to the superheater burner as the steam temperature decreases and increases respectively. The amount of fuel and air supplied to the burners may be controlled manually, or by automatic means other than that disclosed, if desired.

In operation, feed water is forced through conduit 16 by feed pump 18 into and through the economizer 15 and conduit 21 into the lower part of chamber 24 of the separating and circulating device. Simultaneously, feed water is forced through conduit 44 and over the auxiliary water turbine 41 to rotate the shaft 37 and the circulating pump 46. Water discharged by the turbine 41 flows through conduit 45 and is returned to the pump 18 through fully open valve 105. Heated feed water delivered into the chamber 24 through conduit 21, flows downwardly to the circulating pump 46 which forces it through conduit 52 into and through the tubes 55 and 59 of the steam generating section of the generator.

The steam generated together with unvaporized water flows through conduit 68 into the chamber 70 of the separating and circulating device and flows in a spiral path through the chamber, causing the water and solids entrained in the steam to be separated from the steam. The separated water and solids flow down into the chamber 24 where the separated solids are deposited in the trap 116 and are removed through the blow-down valve 118. The water flows into the water in the lower part of chamber 24 and is recirculated through the tubes of the steam generating section by the pump 46 with the heated feed water from the economizer. The separated steam in chamber 70, flows over the rotating blades 98 which effects a further separation of water and entrained solids from the steam, and thereafter flows upwardly through passage 72. Depending upon the position of valve 85, the steam in passage 72 will flow through passage 73 and by-pass 84, or it will flow to the steam turbine and through passage 78 and passage 83, or through both these paths of flow. When the generator is started up, valve 85 is positioned to permit maximum flow of vapor through the by-pass 84 inasmuch as the circulating pump is being driven by the water turbine. Flow of steam from passage 72 into passage 78 drives turbine 80 and the shaft 37. The steam flowing through passage 83, by-pass 84, or both, flows through conduit 82 into and through the tubes of the superheater and through conduit 67 to the point of use.

Steam flowing into passage 78 will rotate the turbine 81 and the shaft 37 at a greater speed than that at which the shaft is driven by the water turbine 41, so that as soon as steam is produced in sufficient quantity to drive the shaft 37 by the turbine 81, the speed of shaft 37 will increase and the circulating pump 46 will be driven faster and circulating water will be forced into

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and through the conduit 52 and the steam generating section at a higher velocity than when the circulating pump is driven by the water turbine. This increase in the flow of water through the conduit 52 and the flow nozzle 101 therein causes the device 104 to move the valve 105 in line 45 toward closed position, thereby reducing the quantity of water delivered to the water turbine 41. Simultaneously, the pressure responsive device 86 actuates the valve 85 to decrease the flow of steam through the by-pass conduit 84 and to increase the flow of steam to the steam turbine 81, thereby increasing the speed of rotation of the shaft 37 and the circulating pump 46. Consequently, as the load and the rate of evaporation increases, the quantity of steam delivered to the steam turbine progressively increases and the quantity of water delivered to the water turbine progressively decreases, until at maximum load the quantity of water delivered to the water turbine is sufficient only to provide substantially the minimum circulation in the water turbine chamber 36 to prevent boiling due to the churning of the water therein resulting from the rotation of the water turbine.

As the angular velocity of the shaft 37 increases because of a greater flow of steam to the steam turbine, valve 112 in feed line 10 to the economizer is operated to increase the flow of water circulated by the circulating pump and, through the flow nozzle 101, pressure responsive device 104 and valve 105, to decrease the flow to the water turbine, and vice versa, with the result that in starting the generator, the water turbine drives the circulating pump and after starting, the separated saturated steam drives the circulating pump. Specifically, when the generator is started up, the valve 112 is in a position to permit the minimum required circulation of water through the steam generating section, but as the rate of steaming increases, pressure responsive device 111 operates to move valve 112 toward open position to increase the circulation, until at the maximum rate of evaporation, valve 112 is nearly fully open. Contrariwise, a drop in load will cause valve 112 to move toward closed position to decrease the circulation through the steam generating section. Valve 112 also functions in response to the device 113 to maintain the desired water level in the chamber 24 of the separating and circulating device 22. If the level drops, valve 112 will open to increase the circulation through the economizer and the quantity of water delivered to the lower part of chamber 24, while if the level is raised, valve 112 will move toward closed position to decrease the flow of water into the chamber 24.

With this arrangement and operation, it will be perceived that a separator of small volume having mechanical separating means is employed in lieu of the usual drum or equivalent device, with the advantage that the amount of water storage is reduced to a minimum. The unitary arrangement disclosed of the glandless circulating pump, mechanical separator, feed water turbine and steam turbine drive, is compact and efficient. The operating cycle and the control system are effective to control the operation at all loads on the generator so as to maintain a predetermined output at all loads. Adequate circulation is provided at all times including immediate circulation when the generator is started up, by utilizing part of the feed water to operate the circulating pump until the rate of steam generation is adequate to operate the pump by steam.

Although the invention is disclosed in connection with a forced recirculation steam generator, it is applicable also to other types including once through generators.

It will be understood that the form of the invention disclosed is a preferred form and that changes may be made in the form, location and relative arrangement of the several parts of the apparatus disclosed, as well as in the method steps and their sequence without departing from the principles of the invention. Accordingly, the invention is not to be limited excepting by the scope of the appended claims.

What is claimed is:

1. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid in said path for conversion of liquid to vapor, means for actuating said circulating means by vapor flowing from said path, fluid driven auxiliary actuating means for said circulating means, and fluid feeding means for supplying fluid under pressure to said auxiliary actuating means, the discharge of the driving means being unconnected directly with the inlet of the circulating means.

2. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, means for driving said circulating means by vapor flowing from said path, fluid actuated auxiliary driving means for said circulating means, fluid feeding means for supplying fluid under pressure to said auxiliary driving means, and control means to control the flow of fluid to said auxiliary driving means in response to the flow of fluid to said path.

3. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid into said path under pressure, means for heating the fluid for conversion of liquid to vapor, separating means in said path for separating moisture from vapor, vapor actuated driving means for driving said circulating means by vapor flowing from said separating means, fluid actuated auxiliary driving means for said circulating means, fluid feeding means for supplying fluid under pressure to said auxiliary driving means, and control means responsive to the flow of fluid from said circulating means for controlling the flow of fluid to said auxiliary driving means and the flow of vapor to said vapor actuated driving means to diminish the flow of fluid to said auxiliary driving means and to increase the flow of vapor to said vapor actuated driving means upon an increase in flow of fluid from said circulating means.

4. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, means for delivering fluid to the circulating means, driving means for the circulating means actuated by vapor discharged from said flow path, means for conducting vapor from said path to said driving means, means forming a discharge passage for vapor flowing from said driving means, means forming a by-pass for vapor around said driving means, valve means for controlling both said discharge passage and said by-pass to control the quantity of vapor delivered to said driving means, fluid actuated auxiliary driving means for said circulating means, fluid feeding means for supplying fluid under pressure to

said auxiliary driving means, and means for rendering said auxiliary actuating means inoperative and for moving said valve to control the by-pass when the circulating means is actuated by the vapor actuating means and for rendering the auxiliary driving means operative and for moving said valve to control the discharge passage when the circulating means is not actuated by said vapor actuated means.

5. A vapor generator comprising a vapor generating section, and separating and circulating means comprising a housing, a circulating pump in the housing, a vapor and liquid separator in the housing, a vapor actuated turbine in the housing for driving the circulating pump, a fluid actuated means in the housing constituting auxiliary means for driving the circulating pump, and control means for rendering the fluid actuated means inoperative when the circulating pump is actuated by the vapor actuated turbine and for rendering the fluid actuated means operative when the circulating pump is not actuated by said vapor actuated turbine.

6. A vapor generator comprising a vapor generating section, and separating and circulating means comprising a housing, a circulating pump in the housing, a vapor and liquid separator in the housing, a vapor actuated turbine in the housing for driving the circulating pump, movable separating means in the housing operable with the circulating pump, fluid actuated means in the housing constituting auxiliary means for driving the circulating pump, and control means for rendering the fluid actuated means inoperative when the circulating pump is actuated by the vapor actuated turbine and for rendering the fluid actuated means operative when the circulating pump is not actuated by said vapor actuated turbine.

7. A vapor generator comprising a vapor generating section, and separating and circulating means comprising a housing, a shaft rotatable about its axis in the housing, a centrifugal circulating pump on said shaft and rotatable therewith, a vapor and liquid separator in the housing, a vapor actuated turbine on said shaft operable by vapor flowing from said separator for driving the shaft, fluid actuated means on said shaft operable as auxiliary driving means for said shaft, and control means for rendering the fluid actuated means inoperative when the circulating pump is actuated by the vapor actuated turbine and for rendering the fluid actuated means operative when the circulating pump is not actuated by said vapor actuated turbine.

8. A vapor generator comprising a vapor generating section, a superheating section, means for firing the vapor generating and superheating sections, an economizer, a feed pump for delivering fluid to the economizer, a circulating pump, conduit means for conducting heated fluid from the economizer to the circulating pump, conduit means for conducting fluid under pressure from the circulating pump to the steam generating section, a separator, means for conducting vapor and fluid from the steam generating section to the separator, a vapor turbine in the path of vapor flowing from the separator and constituting main driving means for the circulating pump, a fluid actuated wheel constituting auxiliary driving means for the circulating pump, means for conducting fluid from the feed pump to the fluid actuated wheel, means for conducting fluid from said wheel to the suction of the feed pump, means for conducting vapor from the vapor turbine to

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the superheating section, means responsive to the flow of fluid from the circulating pump to the vapor generating section for controlling the flow of fluid from the feed pump to said fluid actuated wheel, means forming a by-pass for vapor around said vapor turbine, means responsive to the flow of fluid from the circulating pump to the vapor generating section for controlling said by-pass to control the flow of vapor to said vapor turbine, and means responsive to the flow of vapor from said vapor turbine to said superheating section for controlling the flow of fluid from the feed pump to the economizer.

9. A vapor generator comprising a vapor generating section, and separating and circulating means comprising a housing, a shaft rotatable about its axis in the housing, a centrifugal circulating pump on said shaft and rotatable therewith, a vapor and liquid separator in the housing, a vapor actuated turbine on said shaft operable by vapor flowing from said separator for driving the shaft, a fluid actuated wheel on said shaft operable as auxiliary driving means for said shaft, a feed pump for delivering fluid to the circulating pump to be delivered to the vapor generating section, bearings in said housing for said shaft, and means for conducting fluid from the feed pump to said bearings to lubricate the bearings.

10. A vapor generator comprising a vapor generating section, and separating and circulating means comprising a housing, a shaft rotatable about its axis in the housing, a centrifugal circulating pump on said shaft and rotatable therewith, a vapor and liquid separator in the housing, a vapor actuated turbine on said shaft operable by vapor flowing from said separator for driving the shaft, a fluid actuated wheel on said shaft operable as auxiliary driving means for said shaft, a feed pump for delivering fluid to the circulating pump to be delivered to the vapor generating section, bearings in said housing for said shaft, means for conducting fluid from the feed pump to said bearings to lubricate the bearings, and means for cooling the fluid delivered to said bearings.

11. The method of generating and superheating vapor which comprises passing fluid through a vapor generating zone, introducing vapor and liquid from said zone into a separating zone, separating vapor and liquid by passing the mixture thereof in contact with moving surfaces, utilizing vapor from the separating zone to operate a circulating pump to deliver fluid under pressure to said vapor generating zone, conducting vapor exhausted from said circulating pump to a superheating zone, controlling the quantity of vapor utilized to operate the circulating pump in response to the flow of fluid from the circulating pump to the vapor generating zone, controlling the heat supplied to the vapor generating zone in response to the pressure of vapor discharged from the superheating zone, and controlling the heat supplied to the superheating zone in response to the temperature of the vapor discharged from the superheating zone.

12. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for controlling the amount of fluid delivered to said path, means for heating the fluid for conversion of liquid to vapor, means for driving said circulating means by vapor flowing from said path, fluid actuated auxiliary driving means for said circulating means, fluid feeding means for supplying fluid under pressure to said auxiliary

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driving means, and control means responsive to the flow of fluid from said circulating means for controlling the flow of fluid to said auxiliary driving means and the flow of vapor to said vapor actuated driving means and operative to diminish the flow of fluid to said auxiliary driving means and to increase the flow of vapor to said vapor actuated driving means upon an increase in the flow of fluid from said circulating means.

13. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for controlling the amount of fluid delivered to said path, means for heating the fluid for conversion of liquid to vapor, means for driving said circulating means by vapor flowing from said path, fluid actuated auxiliary driving means for said circulating means, fluid feeding means for supplying fluid under pressure to said auxiliary driving means, and control means responsive to the flow of fluid from said circulating means and operative to increase the flow of fluid to the auxiliary driving means and to decrease the flow of vapor to the vapor actuated driving means upon a decrease in the flow of fluid from said circulating means thereby to actuate the circulating means by said auxiliary means and to increase the flow of vapor to said vapor actuated driving means and to decrease the flow of fluid to the auxiliary driving means upon an increase in the flow of fluid from the circulating means thereby to actuate the circulating means by the vapor actuated driving means.

14. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, means for driving said circulating means by vapor flowing from said path, fluid actuated auxiliary driving means for said circulating means, fluid feeding means for supplying fluid under pressure to said auxiliary driving means, means for controlling the delivery of fluid to the circulating means, and other control means for controlling the flow of fluid to the auxiliary driving means in response to the flow of fluid from the circulating means.

15. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, means for driving said circulating means by vapor flowing from said path, fluid actuated auxiliary driving means for said circulating means, fluid feeding means for supplying fluid under pressure to said auxiliary driving means, means for controlling the delivery of fluid to the circulating means in response to the flow of vapor from the path, and other control means for controlling the flow of fluid to the auxiliary driving means in response to the flow of fluid from the circulating means.

16. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, means for driving said circulating means by vapor flowing from said path, fluid actuated auxiliary driving means for said circulating means, fluid feeding means for supplying fluid under pressure to said auxiliary driving means, means for increasing the amount of fluid delivered to the fluid circulating means in response to an increase in the flow of vapor from the path, and other control means for decreasing the

flow of fluid to the auxiliary driving means in response to an increase in the flow of fluid from the circulating means.

17. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, driving means for the circulating means actuated by vapor discharged from said flow path, means for conducting vapor from said path to said driving means, means forming a discharge passage for vapor flowing from said driving means, means forming a by-pass for vapor around said driving means, valve means for controlling both said discharge passage and said by-pass to control the quantity of vapor delivered to said driving means, fluid actuated auxiliary driving means for said circulating means, fluid feeding means for supplying fluid under pressure to said auxiliary driving means, means for controlling the delivery of fluid to the circulating means in response to the flow of vapor from the path, and other control means for controlling the valve means to vary the quantity of vapor delivered to the driving means and also to vary the flow of fluid to the auxiliary driving means, said control means being responsive to the flow of fluid from the circulating means.

18. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, driving means for the circulating means actuated by vapor discharged from said flow path, means for conducting vapor from said path to said driving means, means forming a discharge passage for vapor flowing from said driving means, means forming a by-pass for vapor around said driving means, valve means for controlling both said discharge passage and said by-pass to control the quantity of vapor delivered to said driving means, fluid actuated auxiliary driving means for said circulating means, fluid feeding means for supplying fluid under pressure to said auxiliary driving means, means for increasing the amount of fluid delivered to the fluid circulating means in response to an increase in the flow of vapor from the path, and other control means adapted upon an increased flow of fluid from the circulating means to actuate said valve means to permit an increased flow of vapor through the discharge passage and thereby to increase the flow of vapor to the driving means and adapted upon an increased flow of fluid from the circulating means to decrease the flow of fluid to the auxiliary driving means.

19. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, means for delivering fluid to the circulating means, driving means for the circulating means actuated by vapor discharged from said flow path, means for conducting vapor from said path to said driving means, means forming a discharge passage for vapor flowing from said driving means, means forming a by-pass for vapor around said driving means, valve means for controlling both said discharge passage and said by-pass, fluid actuated auxiliary driving means for said circulating means, fluid feeding means for supplying fluid under pressure to said auxiliary driving means, and control means responsive to the flow of fluid from said circulating means for controlling the flow of fluid to said auxiliary driv-

ing means and for controlling the valve means to vary the flow of vapor through the discharge passage and through the by-pass thereby to control the quantity of vapor delivered to said driving means.

20. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, driving means for the circulating means actuated by vapor discharged from said flow path, means for conducting vapor from said path to said driving means, means forming a discharge passage for vapor flowing from said driving means, means forming a by-pass for vapor around said driving means, valve means for controlling both said discharge passage and said by-pass, fluid actuated auxiliary driving means for said circulating means, fluid feeding means for supplying fluid under pressure to said auxiliary driving means, flow controlling means for controlling the amount of fluid delivered to the fluid circulating means, and control means responsive to the flow of fluid from said circulating means for varying the flow of fluid to said auxiliary driving means and for operating the valve means to vary the flow of vapor delivered to the driving means, the arrangement being such that upon an increase in the flow of fluid from the circulating means the flow of fluid to said auxiliary driving means is diminished and the valve means is actuated to permit an increased flow of vapor through the discharge passage and a decreased flow of vapor through the by-pass thereby increasing the flow of vapor to the vapor actuated means.

21. A vapor generator comprising a vapor generating section, and separating and circulating means comprising a housing, a circulating pump in the housing, a vapor and liquid separator in the housing, a vapor actuated turbine in the housing for driving the circulating pump, means forming a discharge passage for vapor flowing from said turbine, means forming a by-pass for vapor around said turbine, valve means for controlling the amount of vapor flowing through the discharge passage and the by-pass, fluid actuated means in the housing constituting auxiliary means for driving the circulating pump, means for rendering said auxiliary actuating means inoperative and for moving said valve to control the by-pass when the circulating pump is actuated by the vapor turbine and for rendering the auxiliary driving means operative and moving said valve to control the discharge passage when the circulating pump is not actuated by said vapor turbine.

22. The method of generating vapor which comprises delivering fluid to a circulating zone, passing fluid from the circulating zone to a generating zone under pressure, controlling the delivery of fluid to the circulating zone by vapor generated in the generating zone, normally utilizing vapor from the generating zone to develop pressure in the circulating zone, controlling the quantity of vapor utilized to develop pressure in the circulating zone in response to the flow of fluid from the circulating zone, utilizing fluid under pressure to develop pressure in the circulating zone when the vapor from the generating zone is insufficient to develop pressure in the circulating zone, and controlling the quantity of fluid under pressure utilized to develop pressure in the circulating zone in response to the flow of fluid from the circulating zone.

23. The method of generating vapor which

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comprises passing fluid through a vapor generating zone, utilizing vapor generated in the generating zone to operate a circulating pump to deliver fluid under pressure to said vapor generating zone, controlling the amount of fluid delivered to the circulating zone, utilizing fluid under pressure to operate said circulating pump when the vapor from the vapor generating zone is insufficient to operate said circulating pump, and controlling both the quantity of vapor utilized and the amount of fluid under pressure utilized to operate the circulating pump in response to the flow of fluid from the circulating pump to the vapor generating zone.

24. The method of generating vapor which comprises passing fluid through a vapor generating zone, utilizing vapor generated in the generating zone to operate a circulating pump to deliver fluid under pressure to said vapor generating zone, controlling the amount of fluid delivered to the circulating pump in response to the vapor generated in the generating zone, utilizing fluid under pressure to operate said circulating pump when the vapor from the vapor generating zone is insufficient to operate said circulating pump, and controlling both the quantity of vapor utilized and the amount of fluid under pressure utilized to operate the circulating pump in response to the flow of fluid from the circulating pump to the vapor generating zone.

25. The method of generating vapor which comprises passing fluid through a vapor generating zone, introducing vapor and liquid from said zone into a separating zone, separating the vapor and liquid in the separating zone, utilizing vapor from the separating zone to operate a circulating pump to deliver fluid under pressure to said vapor generating zone, controlling the amount of fluid delivered to the circulating means in response to the vapor generated in the vapor generating zone, utilizing fluid under pressure to operate the circulating pump when the vapor from the vapor generating zone is insufficient to operate the circulating pump, and controlling both the quantity of vapor utilized and the amount of fluid under pressure utilized to operate the circulating pump in response to the flow of fluid from the circulating pump to the vapor generating zone.

26. The method of generating and superheating vapor which comprises passing fluid through a vapor generating zone, utilizing vapor generated in the generating zone to operate a circulating pump to deliver fluid under pressure to said vapor generating zone, conducting vapor exhausted from said circulating pump to a superheating zone, controlling the amount of fluid delivered to the circulating means in response to the flow of vapor from the circulating pump to the superheating zone, utilizing fluid under pressure to operate the circulating pump when the flow of vapor to the superheating zone is insufficient to operate the circulating pump, controlling both the quantity of vapor utilized and the amount of fluid under pressure utilized to operate the circulating pump in response to the flow of fluid from the circulating pump to the vapor generating zone, controlling the heat supplied to the vapor generating zone in response to the pressure of vapor discharged from the superheating zone, and controlling the heat supplied to the superheating zone in response to the temperature of the vapor discharged from the superheating zone.

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27. A vapor generator comprising tubular means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid in said path for conversion of liquid to vapor, a pump for delivering fluid to the circulating means, and driving means for the circulating means actuated by fluid discharged by said pump, the discharge of the driving means being connected to the intake of said pump.

28. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, means for actuating said circulating means by vapor flowing from said path, auxiliary actuating means for said circulating means, and control means responsive to the flow of fluid to said path for rendering the auxiliary driving means inoperative when the vapor actuating means is operative.

29. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, means for actuating said circulating means by vapor flowing from said path, auxiliary actuating means for said circulating means, and control means responsive to the flow of fluid to said path for rendering the auxiliary actuating means inoperative when the circulating means is actuated by the vapor actuating means and rendering the auxiliary actuating means operative when the circulating means is not actuated by said vapor actuated means.

30. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, means for driving said circulating means by vapor flowing from said path, auxiliary driving means for said circulating means, and control means to control the operation of said auxiliary driving means in response to the flow of fluid to said path.

31. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, means for actuating said circulating means by vapor flowing from said path, fluid driven auxiliary actuating means for said circulating means, and control means responsive to the flow of fluid to said path for rendering said fluid driven auxiliary actuating means inoperative when the vapor actuating means is operative.

32. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, means for actuating said circulating means by vapor flowing from said path, fluid driven auxiliary actuating means for said circulating means, and control means for rendering said fluid driven auxiliary actuating means inoperative when the circulating means is actuated by the vapor actuating means and for rendering said auxiliary actuating means operative when the circulating means is not actuated by the vapor actuating means, and fluid feeding means for supplying fluid under pressure to said auxiliary actuating means.

33. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for

heating the fluid for conversion of liquid to vapor, means for actuating said circulating means by vapor, fluid driven auxiliary actuating means for said circulating means, control means for rendering said fluid driven auxiliary actuating means inoperative when the circulating means is actuated by the vapor actuating means and for rendering said auxiliary actuating means operative when the circulating means is not actuated by the vapor actuating means, means for delivering vapor and liquid from said flow path to the means for actuating said circulating means by vapor, a separator in the path of flow of vapor from said flow path to the vapor actuated means, and movable vapor and liquid separating means in the path of the vapor flowing from said first-mentioned separator to the vapor actuated means.

34. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid to said path under pressure, means for heating the fluid for conversion of liquid to vapor, means for actuating said circulating means by vapor, fluid driven auxiliary actuating means for said circulating means, control means for rendering said fluid driven auxiliary actuating means inoperative when the circulating means is actuated by the vapor actuating means and for rendering said auxiliary actuating means operative when the circulating means is not actuated by the vapor actuating means, means for delivering vapor and liquid from said flow path to the means for actuating said circulating means by vapor, a separator in the path of flow of vapor from said flow path to the vapor actuated means, and movable vapor and liquid separating means in the path of the vapor flowing from said first-mentioned separator to the vapor actuated means, the movable separating means being operatively connected to said circulating means and actuated therewith.

35. A vapor generator comprising means forming a fluid flow path, circulating means for delivering fluid into said path under pressure, means for heating the fluid for conversion of liquid to vapor, vapor actuated driving means for driving said circulating means by vapor flowing from said flow path, fluid actuated auxiliary driving means for said circulating means, fluid feeding means for supplying fluid under pressure to said auxiliary driving means, and control means responsive to the flow of fluid from said circulating means for controlling the flow of fluid to said auxiliary driving means and the flow of vapor to said vapor actuated driving means to diminish the flow of fluid to said auxiliary driving means and to increase the flow of vapor to said vapor actuated driving means upon an increase in flow of fluid from said circulating means.

36. The method of generating vapor which comprises delivering fluid to a circulating zone, passing fluid from the circulating zone to a generating zone under pressure, controlling the delivery of fluid to the circulating zone by vapor generated in the generating zone, normally utilizing vapor from the generating zone to develop pressure in the circulating zone, utilizing fluid under pressure to develop pressure in the circulating zone when the vapor from the generating zone is insufficient to develop pressure in the circulating zone, and controlling the quantity of fluid under pressure utilized to develop pressure in the circulating zone in response to the flow of fluid from the circulating zone.

37. A vapor generator comprising a vapor generating section, a superheating section, means

for firing the vapor generating and superheating sections, circulating means, means for conducting fluid to the circulating means, conduit means for conducting fluid under pressure from the circulating means to the vapor generating section, vapor actuating means for actuating the circulating means, means for conducting vapor from the vapor generating section to the vapor actuating means, fluid actuated auxiliary driving means for said circulating means, means for conducting fluid under pressure to said auxiliary driving means, control means to control the flow of fluid to said auxiliary driving means in response to the flow of fluid to the vapor generating section, and conduit means for conducting vapor from the vapor actuated means to the superheating section.

38. A vapor generator comprising a vapor generating section, a superheating section, means for firing the vapor generating and superheating sections, circulating means, means for conducting fluid to the circulating means, conduit means for conducting fluid under pressure from the circulating means to the vapor generating section, vapor actuating means for actuating the circulating means, means for conducting vapor from the vapor generating section to the vapor actuating means, fluid actuated auxiliary driving means for said circulating means, means for conducting fluid under pressure to said auxiliary driving means, control means for rendering the auxiliary actuating means inoperative when the circulating means is actuated by the vapor actuating means and rendering the auxiliary actuating means operative when the circulating means is not actuated by said vapor actuated means, and conduit means for conducting vapor from the vapor actuating means to the superheating section.

39. A vapor generator comprising a vapor generating section, a superheating section, means for firing the vapor generating and superheating sections, separating and circulating means comprising a housing, a circulating pump in the housing, a vapor and liquid separator in the housing, a vapor actuated turbine in the housing for driving the circulating pump, fluid actuated means in the housing constituting auxiliary means for driving the circulating pump, control means for rendering the fluid actuated means inoperative when the circulating pump is actuated by the vapor actuated turbine and for rendering the fluid actuated means operative when the circulating pump is not actuated by said vapor actuated turbine, and means for conducting vapor from the vapor turbine to the superheating section.

40. A vapor generator comprising tubular means forming a fluid flow path, means for heating fluid in said path for conversion of the fluid to vapor, circulating means for delivering fluid to said path under pressure having an inlet and a discharge, means for delivering feed fluid to the inlet of the circulating means prior to introduction of the fluid into said flow path, means for delivering feed fluid from the discharge of the circulating means to said flow path, and driving means for the circulating means actuated by fluid discharged by the means for delivering feed fluid to the circulating means, the discharge of the driving means being unconnected directly with the inlet of the circulating means.

41. A vapor generator comprising tubular means forming a fluid flow path having an inlet through which feed fluid enters the path and an outlet through which vapor is discharged from

the path, circulating means for delivering fluid to said path under pressure having an inlet and discharge, conduit means connecting the inlet of said path and the discharge of the circulating means, means for heating the fluid in said path for conversion of liquid to vapor, means for discharging feed fluid under pressure, means for conducting part of the feed fluid discharged from said feed fluid discharging means to the inlet of the circulating means prior to the introduction of the feed fluid into the flow path, fluid actuated driving means for the circulating means, and means for conducting to the driving means another part of the fluid discharged from said feed fluid discharging means to actuate the driving means, the discharge of the driving means being unconnected directly with the inlet of the circulating means.

42. The method of generating vapor which comprises delivering fluid to a circulating zone, passing fluid from the circulating zone to a generating zone under pressure, controlling the delivery of fluid to the circulating zone, normally utilizing vapor from the generating zone to develop pressure in the circulating zone, controlling the quantity of vapor utilized to develop pressure in the circulating zone in response to the flow of fluid from the circulating zone, utilizing

fluid under pressure to develop pressure in the circulating zone when the vapor from the generating zone is insufficient to develop pressure in the circulating zone, and controlling the quantity of fluid under pressure utilized to develop pressure in the circulating zone in response to the flow of fluid from the circulating zone.

43. The method of generating vapor which comprises delivering fluid under pressure to a generating zone, normally controlling the delivery of fluid to the generating zone by the flow of vapor generated in said zone, initially controlling the delivery of fluid to the generating zone by the flow of other fluid under pressure, decreasing the flow of other fluid under pressure in response to an increased flow of the first-mentioned fluid to the vapor generating zone until the vapor generated in the vapor generating zone is sufficient to control the delivery of fluid to the generating zone, discharging said other fluid from direct flow to said generating zone after use of said other fluid for initially controlling delivery of the first-mentioned fluid, and thereafter normally controlling the delivery of said first-mentioned fluid to said vapor generating zone.

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