Dec. 16, 1952 M. FRISCH 2,621,637

VAPOR GENERATOR

Filed Aug. 20, 1946 2 SHEETS—SHEET 1

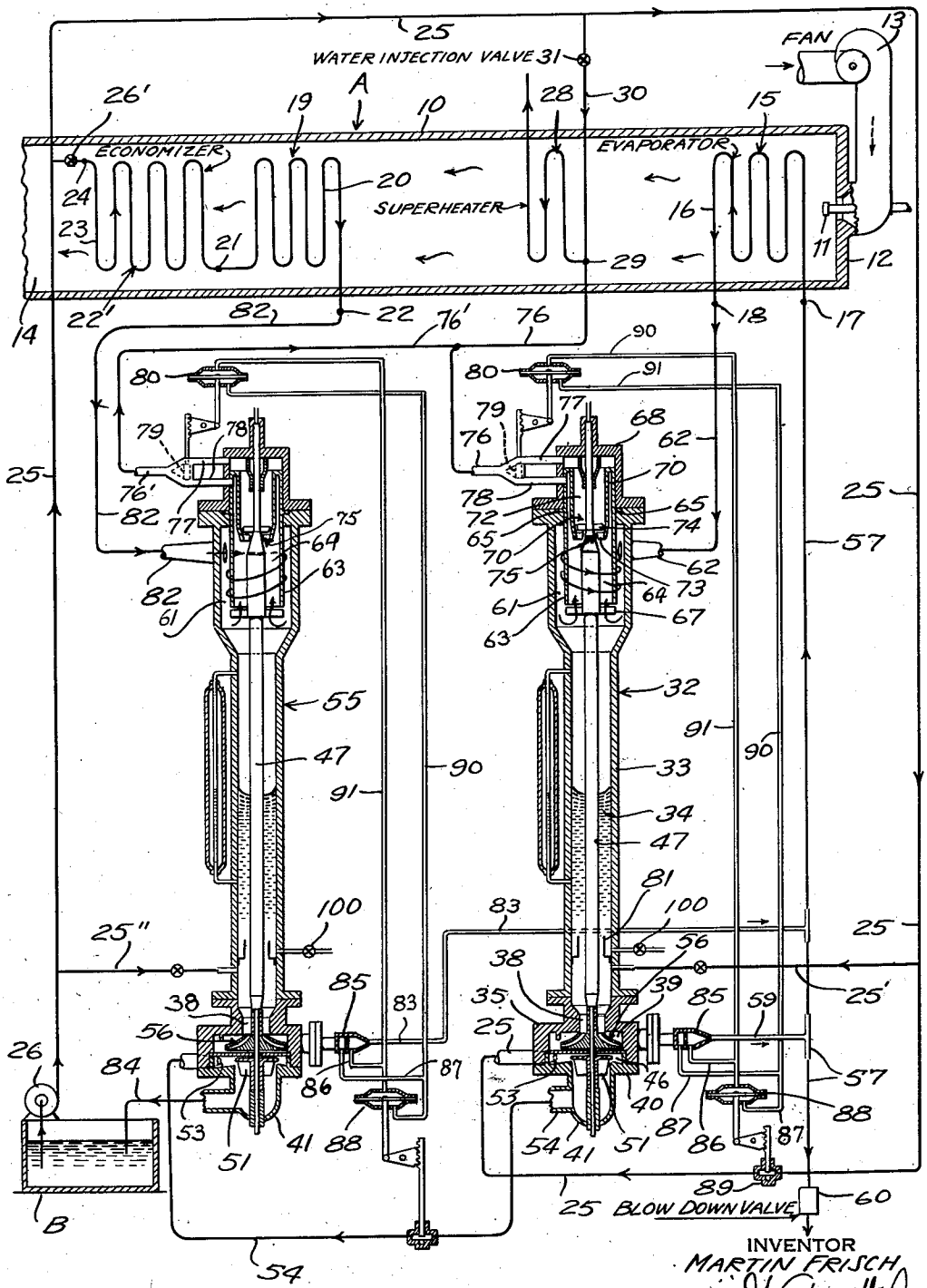


Fig. 1.

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Fig. 2.

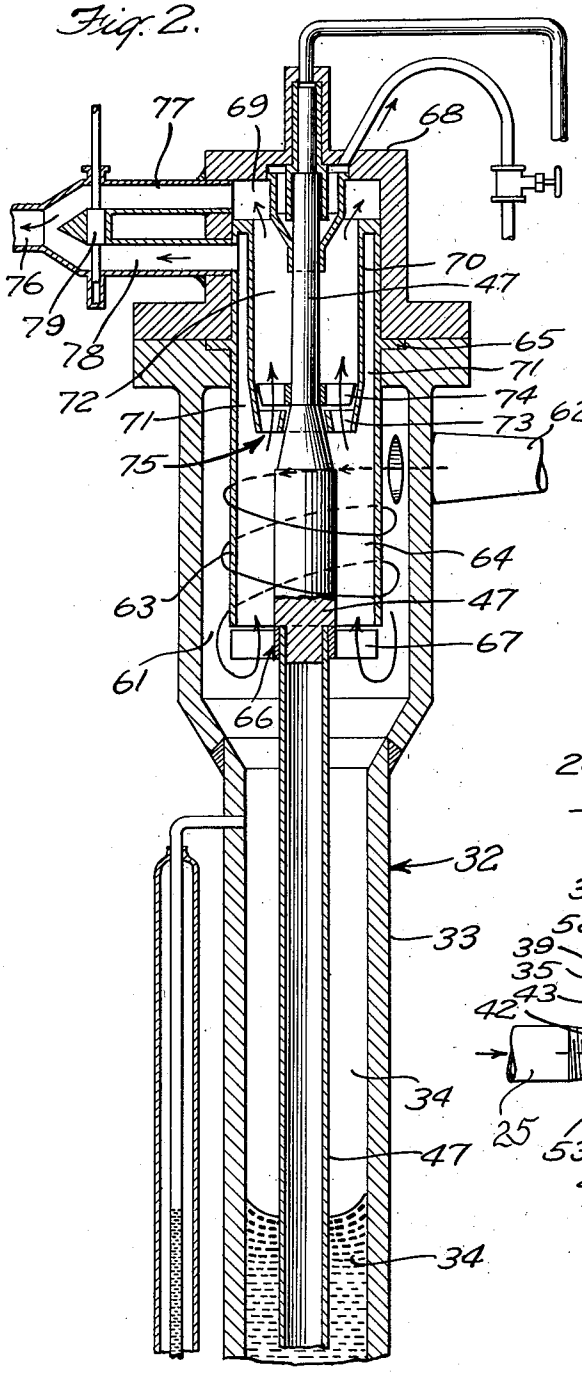
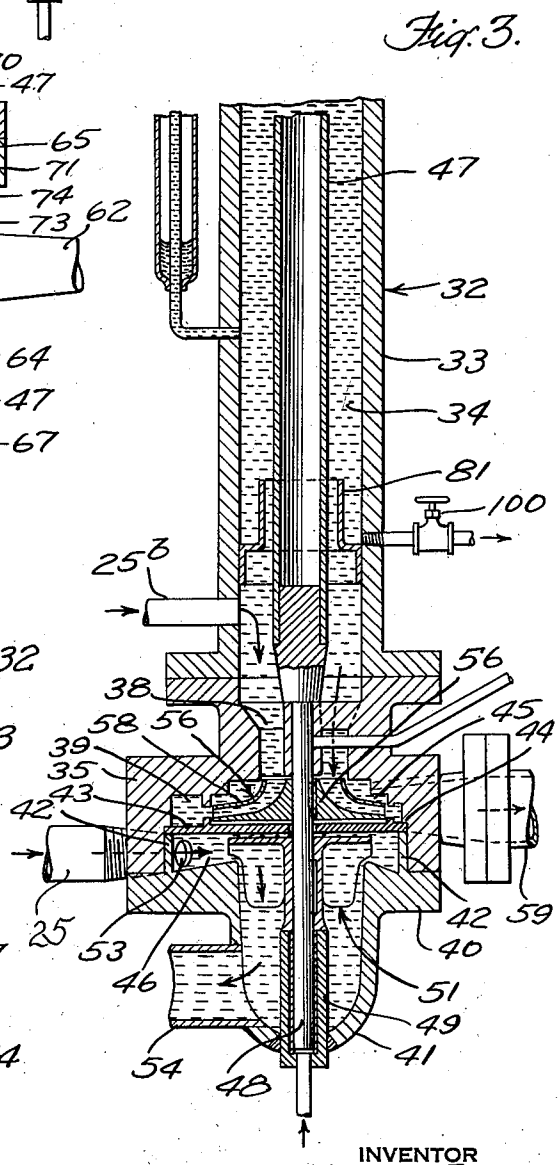


Fig. 3.



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VAPOR GENERATOR

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7 Claims. (Cl. 122—406)

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This invention relates to vapor generators and more particularly to vapor generators of the once-through type.

The present invention, as applied to the generation of steam, provides a once-through forced circulation vapor generator in which the separation of steam from the circulating water is effected mechanically by rapid rotation of separating means which are operative with the circulating pump or pumps and in which the highly concentrated water separated from the steam is fed to a vapor generating section of said vapor generator.

In the preferred arrangement of the present invention, the separating and circulating means for delivering water to a steam generating section is of the type disclosed in my co-pending application for United States Patent Serial No. 418,650, filed November 12, 1941, now Patent No. 2,405,573, in which the circulating pump is driven, after the generator is started, by steam flowing from the separator. In my above-mentioned type of circulating and separating device, an auxiliary water turbine is utilized to drive the circulating pump by feed water to assure immediate and adequate circulation when the generator is started, the feed water used for actuating said auxiliary pump being returned to the suction of the feed pump or to some intermediate stage thereof. The once-through forced circulation generator of the present invention may be controlled manually in the same manner a natural circulation steam generator is controlled or it may be controlled automatically.

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

Fig. 1 is a more or less diagrammatic view of a steam generator embodying the present invention with parts thereof in vertical section;

Fig. 2 is an enlarged vertical sectional view of the upper portion of the separating and circulating device shown 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 the drawings, the vapor generator shown diagrammatically at A comprises a setting 10 having burner means 11 at one end 12 thereof. The burner is supplied with air for combustion through a fan 13, the gases of combustion from the burner flowing through the setting 10 from the end 12 thereof toward the

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opposite end 14 through which opposite end the gases pass from the setting.

An evaporator or first vapor generating section 15 is positioned adjacent the burner end 12 of the setting. The first evaporator section 15 is shown diagrammatically and comprises a fluid flow path 16 having an inlet 17 and an outlet 18. Disposed beyond in the direction of flow of the gases of combustion and in spaced relationship with the first evaporator section 15 is a second evaporator or second vapor generating section 19 which comprises a fluid flow path 20 in the path of flow of the gases which flow path has an inlet 21 and an outlet 22. The inlet of the second evaporator 19 is connected to an economizer section 22' comprising a tubular flow path 23 positioned in the path of flow of the gases beyond the second evaporator section 19 in the direction of flow of said gases. The inlet 24 of the economizer is connected to a feed water inlet pipe 25 through a control valve 26'. Feed line 25 is connected at one end to the discharge of a feed pump 26 the suction of which pump is in communication with a container B containing feed water.

A superheater 28 is positioned in the setting 10 in the path of flow of the gases of combustion at a point intermediate the evaporator sections 15 and 19. The superheater inlet 29 is in communication with the feed water line 25 through a conduit 30 controlled by a water injection valve 31 so that the superheated steam temperature may be controlled by the injection of cool feed water.

Feed water line 25 is also in communication with the water turbine 51 of a first separating and circulating means 32 for delivering water to the evaporator or first vapor generating section 15. The first separating and circulating means or device 32 comprises an elongated vertically disposed housing 33 having a fluid chamber 34 therein and a circulating pump casing 35 at the bottom of the housing. The lower end of the chamber 34 is connected by a passage 38 with a chamber 39 in the casing. The lower end of the casing 35 is closed by a cap 40 having a hollow extension 41. Cap 40 has an annular flange 42 which projects into the chamber 39 and engages a partition 43 holding it tightly against an annular shoulder 44 to divide the chamber 39 into two separate chambers, a circulating pump chamber 45 and a water turbine chamber 46. A drive shaft 47 having a reduced lower end portion 48 mounted in a thrust bearing 49 is disposed in the closed end of the cap

40 in fluid-tight relationship thereto and extends through the chambers 34, 45 and 46. A water turbine or auxiliary actuating means 51, the blades of which extend into the cap 40 is fixed to shaft 47 in chamber 46. Chamber 46 has an inlet port 53 which is in communication with the feed water line 25 and an outlet port in communication with an outlet conduit 54 which conducts water to an inlet port 53 of an auxiliary water turbine 51 of a second separating and circulating means or device 55 which, as shown, is identical to the first separating and circulating device 32.

A circulating impeller or other circulating means 56 is fixed to the shaft 47 above the water turbine and in the chamber 45. The impeller 56 has a plurality of blades 58 which are curved downwardly and outwardly from the passage 38 to the periphery of the impeller. Concentrated feed water flows into the impeller from the chamber 34 and is discharged into a concentrated feed water line 57 through a conduit 59. Line 57 is in communication at one end thereof with the inlet 17 of the evaporator section 15 and at the opposite end with a blowdown valve 60.

The upper part of the first separating and circulating device 32 has a separating chamber 61 into which a mixture of steam and water from the first evaporator section 15 is discharged. Steam and water conduit 62 is in communication with the outlet 18 of the evaporator section and with the chamber 61, the conduit 62 being connected to said chamber so as to discharge steam and water tangentially thereof. The separating chamber 61 communicates at its lower end with the upper part of the chamber 34. Tubular member 63, of lesser diameter than the chamber 61 and having a passage 64 therein, is disposed in the chamber 61 and, as shown, is provided with a peripheral flange 65 which maintains the tubular member in position. A mechanical steam and water separator 66 is provided by a plurality of radial blades 67 fixed to shaft 47 in chamber 61 closely adjacent the lower end of the tubular member 63 in the path of steam flowing from the separating chamber 61. Other forms of separators may be employed. Tubular member 63 projects upwardly into a hollow cap 68, which closes the upper end of the first circulator and separator 32, to a point short of the upper end thereof thereby forming space 69 between the end of the tubular member and the cap. A cylindrical member 70 is secured at its upper end to the upper end of member 63 and extends downwardly of the member 63 in spaced relationship to the inner wall thereof to provide an annular steam by-pass passage 71. The interior of member 70 provides a main steam passage 72, which communicates with space 69, for steam flowing from passage 64. A plurality of spaced turbine blades 73 at the lower end of the member 70, and a plurality of rotatable blades 74 fixed to shaft 47 above the blades 73 provide driving means for actuating the other circulating means 56 which driving means comprises a steam turbine 75 which is operated by steam flowing from passage 64 into passage 72.

Means for rendering the auxiliary actuating means 51 operative and inoperative is provided. Steam conduit 76, which conducts steam from the first circulating and separating device 32 to the inlet 29 of superheater 28, is connected at its inlet end to space 69 through branch conduit 77 and to passage 71 through by-pass conduit 78, the conduits 77 and 78 being controlled by a slide valve 79 which is operated by pressure responsive device 80. A trap 81 is secured in the lower portion of the chamber 34 above passage 38 and is shaped to provide a passage around the shaft 47 through which water will flow from chamber 34 into the passage 39 and the circulating pump 56.

To insure cooling of the circulating impellers 56 of circulating and separating means or devices 32 and 55 so that flashing and cavitation will be prevented, a relatively small controlled amount of feed water from the feed water line 25 is introduced into said impellers through lines 25' and 25'' respectively.

The separating chamber 61 of second circulating device 55 is in communication with outlet 22 of evaporator section 19 through conduit 82 while steam conduit 76' of device 55 is in communication with superheater inlet 29 through line 76. The discharge of the circulating impeller 56 of the device 55 is in communication with the concentrated feed water line 57 through conduit 83. The discharge of auxiliary water turbine or actuating means 51 of the device 55 is in communication with the source of feed water B through conduit 84.

The quantity of water delivered to the actuating means 51 and the quantity of steam flowing to the steam turbine 75 is varied in response to variations in the quantity of water delivered to the first evaporator section 15 by the circulating pumps 56 of the device 32. To this end a flow nozzle 85 is positioned in the conduit 59 and pressure conduits 86 and 87 connect opposite sides of the nozzle 85 with opposite sides of the diaphragm of a pressure responsive device 88 which controls the flow of water in the conduit 25 through a valve 89, conduits 90 and 91 connecting opposite sides of the diaphragm of pressure responsive device 80 with the conduits 86 and 87, respectively. Pressure responsive devices 88 and 80 are so arranged that an increase in flow of circulating water through the conduit 59 will cause the device 88 to operate the valve 89 to decrease the flow of water through conduit 25 and to the auxiliary water turbine 51 of device 32 and at the same time to cause the device 80 to operate the valve 79 to decrease the flow of vapor through the by-pass conduit 78 thereby increasing the flow through branch conduit 77 and to superheater 28. A decrease in the flow of circulating water through conduit 59 will have the opposite effect. Device 55 is controlled in a manner similar to device 32.

In operation, feed water is forced through a conduit 25 by feed pump 26, the amount of feed water entering the inlet 24 of the economizer 22' being regulated by the control valve 26'. The remainder of the feed water, except for the small quantity flowing through lines 25' and 25'' to insure cooling of impellers 56 of circulating devices 32 and 55 as hereinabove set forth, flows through the conduit 25 into the chamber 46 of first circulating device 32 through the inlet port 53 and over auxiliary water turbine 51 to rotate shaft 47 and the circulating impeller 56 of said device. Water discharged by the turbine 51 flows through conduit 54 into the inlet port 53 of second separating and circulating device 55 to pass over the auxiliary water turbine 51 thereof thereby rotating shaft 47 and circulating impeller 56 of the device 55. The pump 51 of device 55 discharges water therefrom through the conduit 84 into the feed water supply B. Concentrated water from the chambers 34 of the devices 32

and 55, which water was separated from steam flowing into said devices, as will hereinafter be fully described, flows downwardly through passages 38 into the circulating impellers 56, the impeller 56 of first circulating device 32 forcing the water through line 59 into concentrated feed water conduit 57 while impeller 56 of second circulating device 55 forces the water into conduit 83 thence into conduit 57. First evaporator section 15 is thereby supplied with feed water of high concentration.

Feed water flowing into the economizer 22' from the feed water line 25 flows through the tubular flow path 23 and enters second evaporator section 19 through inlet 21. Steam is generated in the evaporator section by passage of the gases of combustion over said section, the steam flowing from flow path 20 through steam outlet 22 into conduit 62 thence into the separating chamber 61 of the second circulating and separating device 55. Steam generated in the first evaporator section 15 flows from the flow path 16 through steam outlet 18 thence into separating chamber 61 of the first circulating and separating device 32 through conduit 62. Steam generated in said evaporating sections together with unvaporized water flows in a spiral path through the separating chambers 61, causing the water and solids entrained in the steam to be separated from said steam. The separated water and solids flow downwardly into chambers 34 wherein the separated solids are deposited in the traps 81 and are removed by blowdowns 100. Separated water flows into the lower part of chambers 34 and is circulated through lines 83 and 59 respectively by pumps 56 into the concentrated feed water line 57. The separated steam in chambers 61 flows over the rotating blades 67 of the separators 66 which effects a further separation of water and entrained solids from the steam, the steam thereafter flowing upwardly through passages 64. Depending upon the position of valves 79, the steam in passages 64 will flow to superheater 28 through passages 71 and by-passes 78 or it will flow to the superheater 28 through passages 72, chambers 69, and passages 77, or both these paths of flow. When the generator is started up, valves 79 are positioned to permit maximum flow of steam through the by-passes 78 inasmuch as the circulating impellers 56 are being driven by the water turbines 51. Flow of steam from passages 64 into passages 72 drives turbines 75 and the shafts 47. The steam flowing through passages 71, by-passes 78, or both, flows through conduits 76 and 76' into the superheater 28 whence it is conducted to the point of use.

Steam flowing into passages 72 of the separating and circulating devices 32 and 55 will rotate the turbines 75 and the shafts 47 at greater speed than that at which the shafts are driven by the water turbines 51 so that as soon as steam is produced in sufficient quantity to drive the shafts 47 by the turbines 75 the speed of shafts 47 will increase and the circulating pumps 56 will be driven faster and concentrated feed water will be forced into and through conduits 59 and 83 and conduit 57 thence into the first evaporating section 15 at a higher velocity than when the circulating impellers are driven by the water turbines and at a rate considerably greater than the rate of evaporation thereof in the evaporating sections 15 and 19 so as to assure sufficient feed water in the tubes of said sections. This increase in the flow of water through the conduits 59 and 83 and the flow nozzles 85 therein causes the devices 88 to operate valves 89 in lines 25 and 54 toward closed position thereby reducing the quantity of water delivered to the auxiliary turbines 51. Simultaneously, the pressure responsive devices 80 actuate the valves 79 to decrease the flow of steam through the by-pass conduits 78 and to increase the flow of steam to the steam turbines 75 thereby increasing the speed of rotation of the shafts 47 and the circulating impellers 56. Consequently, as the load and the rate of the evaporation increases, the quantity of steam delivered to the steam turbines progressively increases and the quantity of water delivered to the water turbines progressively decreases until at maximum load the quantity of water delivered to the water turbines is sufficient only to provide substantially the minimum circulation in the water turbine chamber 46 to prevent boiling due to churning of the water therein resulting from the rotation of the water turbines.

With this arrangement and operation, it will be perceived that while only highly concentrated feed water, except for the small quantity of feed water flowing through lines 25' and 25'' to insure cooling of impellers 56 of circulating devices 32 and 55 as hereinbefore set forth, is passed through an evaporating section in the highest temperature zone of a once-through forced circulation vapor generator, the rate at which the feed water is pased through said section is many times the rate of evaporation thereof in the sections thereby insuring sufficient feed water in the tubes of the evaporator sections and precluding burning out of said tubes through dryness caused by lack of water. 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 circfulation when the generator is started up by utilizing part of the feed water to operate the auxiliary circulating pumps until the rate of steam generation is adequate to operate the pumps by steam.

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 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 once-through forced circulation vapor generator having a setting, a combustion chamber in the setting, burner means for producing a stream of gases of combustion in the chamber, means for delivering liquid under pressure, an economizer section and at least two vapor generating sections in the setting and in heat exchange relationship with said gases of combustion, said sections being disposed so that the gases flow in heat exchange relationship with said sections serially, the gases passing in heat exchange relationship with a first of the vapor generating sections before passing in heat exchange relationship with a second vapor generating section, and flow in heat exchange relationship with the economizer section after flowing in heat exchange relationship with the vapor generating sections, the economizer having an inlet and an outlet, the inlet of the economizer being in communication with said liquid delivering means, each of

said vapor generating sections having feed liquid inlet means through which the feed liquid to be vaporized enters said sections and an outlet through which the mixture of vapor and liquid generated in the respective said vapor generating sections flows therefrom, the inlet of said second vapor generating section being in communication with the outlet of the economizer, a second vapor and liquid separating means in communication with the outlet of said second of the vapor generating sections to receive the mixture of vapor and liquid therefrom, a second circulating means in communication with said second separating means to receive separated liquid therefrom, said second circulating means also being in communication with the feed liquid inlet means of said first vapor generating section, a first vapor and liquid separating means, said first separating means being in communication with the outlet of said first vapor generating section to receive a mixture of vapor and liquid therefrom, a first circulating means in communication with said first separating means to receive separated liquid therefrom, said first circulating means also being in communication with the feed liquid inlet means of said first vapor generating section, vapor actuated driving means for actuating said first circulating means and said second circulating means, means forming a discharge passage for vapor flowing from said driving means, said driving means being actuated by vapor flowing from the vapor generating sections through said driving means to said discharge passage, 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, auxiliary actuating means for actuating said first circulating and said second circulating means, said auxiliary actuating means being driven by liquid under pressure, and means for rendering said auxiliary actuating means inoperative and for moving said valve means to close 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 means to close the discharge passage when the circulating means is not actuated by said vapor actuated driving means.

2. A once-through forced circulation vapor generator having a setting, a combustion chamber in the setting, burner means for producing a stream of gases of combustion in the chamber, at least two vapor generating sections in the setting and in heat exchange relationship with said gases of combustion, said sections being so disposed in relationship to one another that the gases flow in heat exchange relationship with a first of the sections before passing in heat exchange relationship with a second section, each of said sections having feed liquid inlet means through which the feed liquid to be vaporized enters said sections and an outlet through which the mixture of vapor and liquid generated in the respective said sections flows therefrom, means for delivering liquid under pressure to the inlet of said second section, a second vapor and liquid separating means in communication with the outlet of said second section to receive a mixture of vapor and liquid therefrom, a second circulating means in communication with said second separating means to receive separated liquid therefrom, said second circulating means also being in communication with the feed liquid inlet means of said first vapor generating section, separated vapor conduit means in communication with said second vapor and liquid separating means to receive separated vapor therefrom, a first vapor and liquid separating means in communication with the outlet of said first vapor generating section to receive a mixture of vapor and liquid therefrom, vapor outlet means in communication with the first vapor and liquid separating means to receive separated vapor therefrom, a first circulating means in communication with said first separating means to receive separated liquid therefrom, said first circulating means also being in communication with the feed liquid inlet means of said first vapor generating section whereby said first vapor generating section receives liquid separated from the mixture of liquid and vapor generated in said first and second vapor generating sections which liquid constitutes substantially all the feed liquid to be vaporized in said first section, driving means for actuating each of the circulating means to deliver said separated liquid therefrom to the feed liquid inlet means of said first vapor generating section, an auxiliary actuator associated with each of the circulating means, said auxiliary actuators being driven by liquid under pressure, and control means associated with each of said separating means and circulating means and responsive to the flow of liquid from said circulating means to the feed liquid inlet means of said first vapor generating section for rendering the auxiliary actuators inoperative when the driving means is operative.

3. A once-through forced circulation vapor generator having a setting, a combustion chamber in the setting, burner means for producing a stream of gases of combustion in the chamber, at least two vapor generating sections in the setting and in heat exchange relationship with said gases of combustion, said sections being so disposed in relationship to one another that the gases flow in heat exchange relationship with the first of the sections before passing in heat exchange relationship with a second section, each of said sections having feed liquid inlet means through which the feed liquid to be vaporized enters said sections and an outlet through which the mixture of vapor and liquid generated in the respective said sections flows therefrom, means for delivering liquid under pressure to the inlet of said second section, a second vapor and liquid separating means in communication with the outlet of said second of the sections to receive a mixture of vapor and liquid therefrom, a second circulating means in communicating with the second separating means to receive separated liquid therefrom, said second circulating means also being in communication with the feed liquid inlet means of said first vapor generating section, separated vapor conduit means in communication with said second vapor and liquid separating means to reecive separated vapor therefrom, a first vapor and liquid separating means in communicating with the outlet of said first vapor generating section to receive a mixture of vapor and liquid therefrom, vapor outlet means in communication with the first vapor and liquid separating means to receive separated vapor therefrom, a first circulating means in communication with said first separating means to receive separated liquid therefrom, said first circulating means also being in communication with the feed liquid inlet means of said first vapor generating section whereby said first vapor generating section receives liquid separated from

the mixture of liquid and vapor generated in said vapor generating sections which liquid constitutes substantially all the feed liquid to be vaporized in said first section, driving means for actuating each of the circulating means to deliver said separated liquid therefrom to the feed liquid inlet means of said first vapor generating section, an auxiliary actuator associated with each of the circulating means, said auxiliary actuators being driven by liquid under pressure, and control means associated with each of said separating and circulating means and responsive to the flow of liquid from said circulating means, for rendering the auxiliary actuators inoperative when the circulating means is actuated by the driving means and for rendering the auxiliary actuators operative when the circulating means is not actuated by said driving means.

4. A once-through forced circulation vapor generator having a setting, a combustion chamber in the setting, burner means for producing a stream of gases of combustion in the chamber, at least two vapor generating sections in the setting and in heat exchange relationship with said gases of combustion, said sections being so disposed in relationship to one another that the gases flow in heat exchange relationship with a first of the sections before passing in heat exchange relationship with a second section, each of said sections having feed liquid inlet means through which the feed liquid to be vaporized enters said sections and an outlet through which the mixture of vapor and liquid generated in the respective said sections flows therefrom, means for delivering liquid under pressure to the inlet of said second section, a second vapor and liquid separating means in communication with the outlet of said second of the sections to receive a mixture of vapor and liquid therefrom, a second circulating means in communication with the second separating means to receive separated liquid therefrom, said second circulating means also being in communication with the feed liquid inlet means of said first vapor generating section, separated vapor conduit means in communication with said second vapor and liquid separating means to receive separated vapor therefrom, a first vapor and liquid separating means in communication with the outlet of said first vapor generating section to receive a mixture of vapor and liquid therefrom, vapor outlet means in communication with the first vapor and liquid separating means to receive separated vapor therefrom, a first circulating means in communication with said first separating means to receive separated liquid therefrom, said first circulating means also being in communication with the feed liquid inlet means of said first vapor generating section whereby said first vapor generating section receives liquid separated from the mixture of liquid and vapor generated in said vapor generating sections which liquid constitutes substantially all the feed liquid to be vaporized in said first section, vapor actuated driving means for actuating each of the circulating means to deliver said separated liquid therefrom to the feed liquid inlet means of said first vapor generating section, an auxiliary actuator associated with each of the circulating means, said auxiliary actuators being driven by liquid under pressure, and control means associated with each of said separating and circulating means and responsive to the flow of liquid from the circulating means for controlling the flow of liquid to said auxiliary actuators and the flow of vapor to said vapor actuated driving means and operative to diminish the flow of liquid to said auxiliary actuators and to increase the flow of vapor to said vapor actuated driving means upon an increase in the flow of liquid from said circulating means.

5. A once-through forced circulation vapor generator having a setting, a combustion chamber in the setting, burner means for producing a stream of gases of combustion in the chamber, at least two vapor generating sections in the setting and in heat exchange relationship with said gases of combustion, said sections being so disposed in relationship to one another that the gases flow in heat exchange relationship with a first of the sections before passing in heat exchange relationship with a second section, each of said sections having feed liquid inlet means through which the feed liquid to be vaporized enters said sections and an outlet through which the mixture of vapor and liquid generated in the respective said sections flows therefrom, means for delivering liquid under pressure to the inlet of said second section, a second vapor and liquid separating means in communication with the outlet of said second of the sections to receive a mixture of vapor and liquid therefrom, a second circulating means in communication with the second separating means to receive separated liquid therefrom, said second circulating means also being in communication with the feed liquid inlet means of said first vapor generating section, separated vapor conduit means in communication with said second vapor and liquid separating means to receive separated vapor therefrom, a first vapor and liquid separating means in communication with the outlet of said first vapor generating section to receive a mixture of vapor and liquid therefrom, vapor outlet means in communication with the first vapor and liquid separating means to receive separated vapor therefrom, a first circulating means in communication with the outlet of said first separating means to receive separated liquid therefrom, said first circulating means also being in communication with the feed liquid inlet means of said first vapor generating section whereby said first vapor generating section receives liquid separated from the mixture of liquid and vapor generated in said vapor generating sections which liquid constitutes substantially all the feed liquid to be vaporized in said first section, vapor actuated driving means for actuating each of the circulating means to deliver said separated liquid therefrom to the feed liquid inlet means of said first vapor generating section, an auxiliary actuator associated with each of the circulating means, said auxiliary actuators being driven by liquid under pressure, and control means associated with each of said separating and circulating means and responsive to the flow of liquid from the circulating means and operative to increase the flow of liquid to the auxiliary actuators and to decrease the flow of vapor to the vapor actuated driving means upon a decrease in the flow of liquid from said circulating means, thereby to actuate the circulating means by said auxiliary actuators and to increase the flow of vapor to said vapor actuated driving means and to decrease the flow of liquid to the auxiliary actuators upon an increase in the flow of liquid from the circulating means, thereby to actuate the circulating means by the vapor actuated driving means.

6. A once-through forced circulation vapor generator having a setting, a combustion chamber in the setting, burner means for producing a stream of gases of combustion in the chamber, at

least two vapor generating sections in the setting and in heat exchange relationship with said gases of combustion, said sections being so disposed in relationship to one another that the gases flow in heat exchange relationship with a first of the sections before passing in heat exchange relationship with a second section, each of said sections having feed liquid inlet means through which the feed liquid to be vaporized enters said sections and an outlet through which the mixture of vapor and liquid generated in the respective said sections flows therefrom, means for delivering liquid under pressure to the inlet of said second section, a second vapor and liquid separator in communication with the outlet of said second of the sections to receive a mixture of vapor and liquid therefrom, movable vapor and liquid separating means in the path of flow of the vapor flowing from the second separator, second circulating means in communication with the second separator to receive separated liquid therefrom, said second circulating means also being in communication with the feed liquid inlet means of said first vapor generating section, separated vapor conduit means in communication with said second vapor and liquid separator to receive separated vapor therefrom, second driving means for normally actuating the second circulating means to deliver separated liquid to the inlet of said first vapor generating section, a first vapor and liquid separator in communication with the outlet of said first vapor generating section to receive vapor therefrom, further movable vapor and liquid separating means in the path of flow of the vapor flowing from the first vapor and liquid separator, vapor outlet means in communication with the first vapor and liquid separator to receive separated vapor therefrom, first circulating means in communication with the first separator to receive separated liquid therefrom, said first circulating means also being in communication with the feed liquid inlet means of said first vapor generating section, first driving means for normally actuating said first circulating means to deliver separated liquid to the inlet of said first vapor generating section whereby said first vapor generating section receives liquid separated from the mixture of liquid and vapor generated in said vapor generating sections which liquid constitutes substantially all the feed liquid to be vaporized in said one section, an auxiliary actuator associated with each of the circulating means, said auxiliary actuators being driven by liquid under pressure, and control means associated with each of the separating and circulating means and responsive to the flow of liquid from the circulating means to the inlet of said first vapor generating section for rendering the auxiliary actuators inoperative when the first and second driving means are operative.

7. A once-through forced circulation vapor generator having a setting, a combustion chamber in the setting, burner means for producing a stream of gases of combustion in the chamber, at least two vapor generating sections in the setting and in heat exchange relationship with said gases of combustion, said sections being so disposed in relationship to one another that the gases flow in heat exchange relationship with a first of the sections before passing in heat exchange relationship with a second section, each of said sections having feed liquid inlet means through which the feed liquid to be vaporized enters said sections and an outlet through which the mixture of vapor and liquid generated in the respective said sections flows therefrom, means for delivering liquid under pressure to the inlet of said second section, second separating and circulating means comprising a second housing, vapor and liquid separating means in the second housing, said separating means being in communication with the outlet of said second of the sections to receive vapor therefrom, a second circulating pump in the second housing, said second circulating pump being in communication with the separating means to receive separated liquid therefrom, said pump being in communication with the feed liquid inlet means of said first vapor generating section, a second vapor actuated turbine in the second housing for driving the second circulating pump, a second liquid actuated means in the second housing constituting second auxiliary means for driving the second circulating pump, first separating and circulating means comprising a first housing, vapor and liquid separating means in the first housing in communication with the outlet of said first vapor generating section to receive vapor therefrom, a first circulating pump in the first housing in communication with the feed liquid inlet means of said first vapor generating section whereby said first vapor generating section receives liquid separated from the mixture of liquid and vapor generated in said vapor generating sections which liquid constitutes substantially all the feed liquid to be vaporized in said first section, a vapor actuated turbine in the first housing and constituting normal means for driving the circulating pump in said first housing, liquid actuated means also in said first housing and constituting auxiliary means for driving said first circulating pump, and control means associated with each of said separating and circulating means for rendering its auxiliary liquid actuated means inoperative when its circulating pump is actuated by its vapor actuated turbine and for rendering its auxiliary liquid actuated means operative when its circulating pump is not actuated by its vapor actuated turbine.

MARTIN FRISCH.

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