

Nov. 20, 1962

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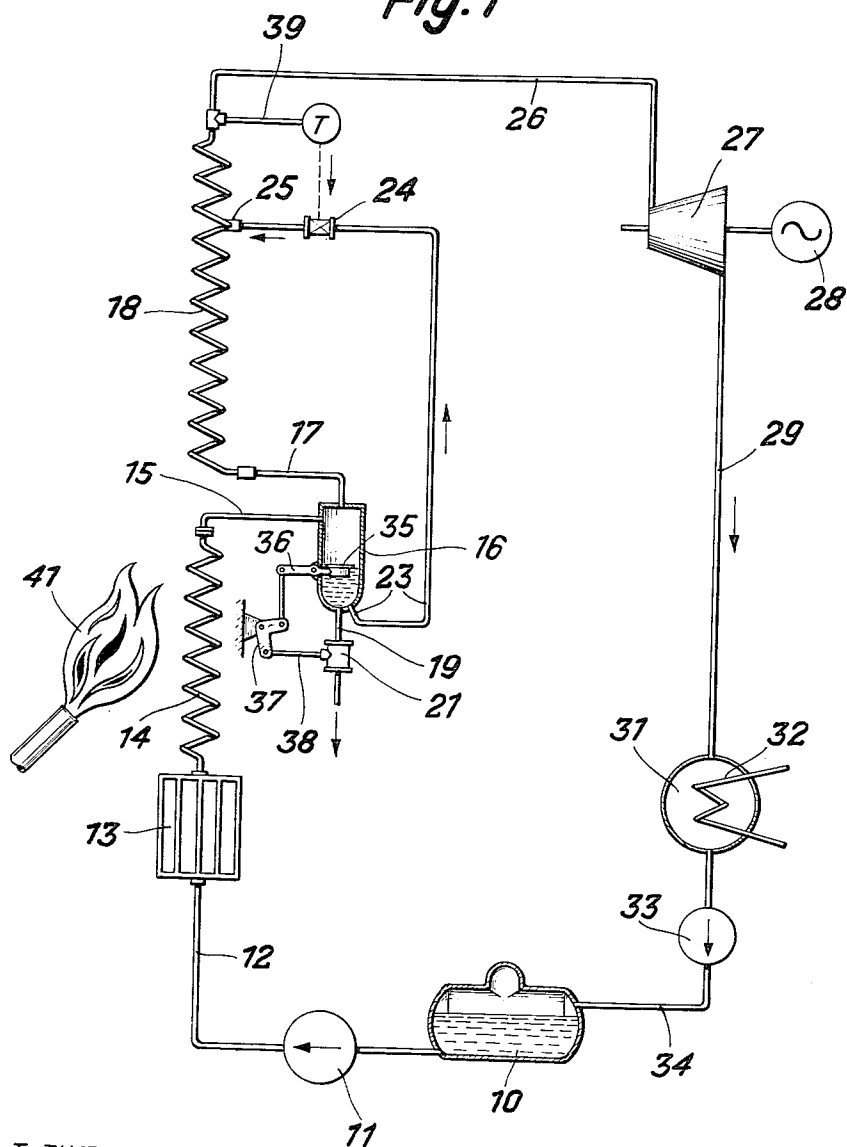
3,064,630

METHOD AND APPARATUS FOR OPERATING A FORCED FLOW
STEAM GENERATOR HAVING A WATER SEPARATOR
INTERPOSED IN ITS TUBE SYSTEM

Filed May 20, 1959

5 Sheets-Sheet 1

Fig. 1



T = THERMOSTAT
P = PRESSURESTAT
S = SALT METER

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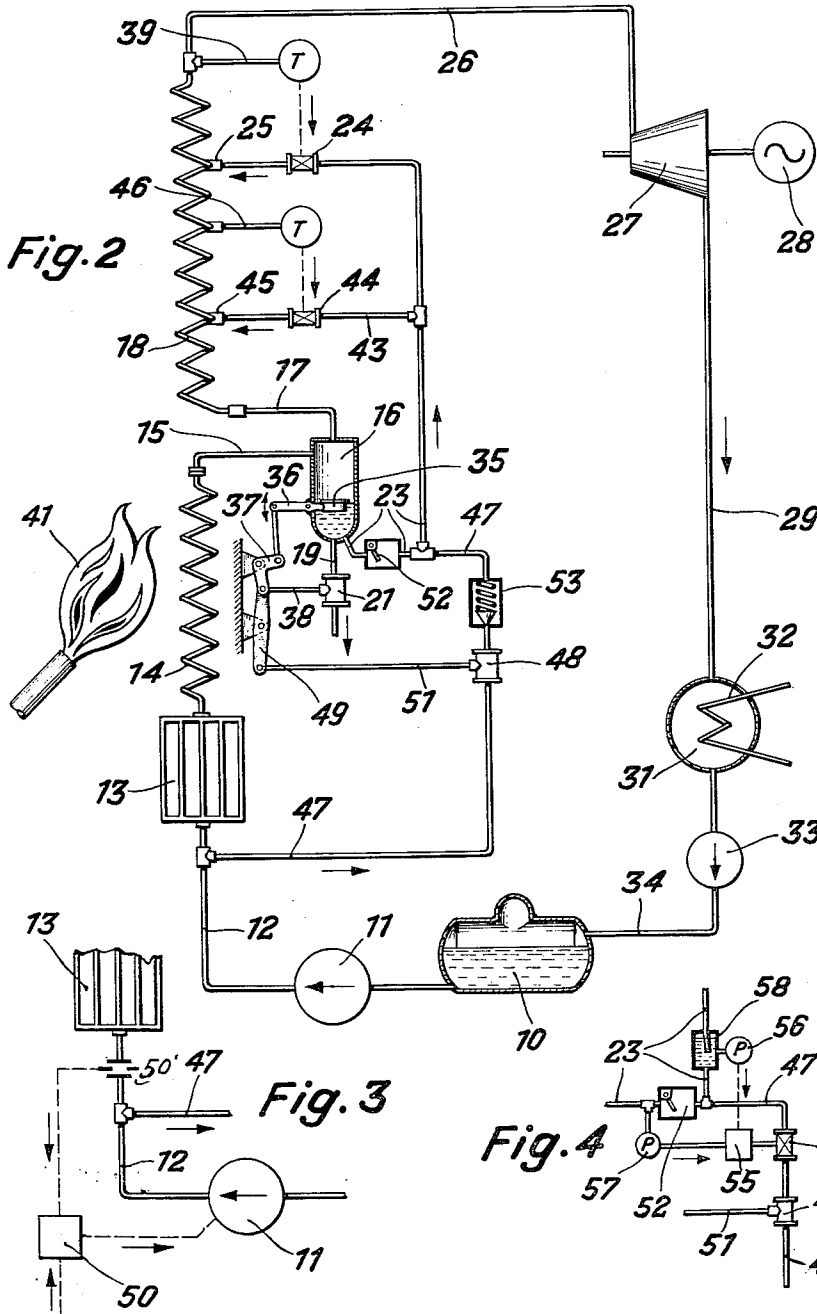
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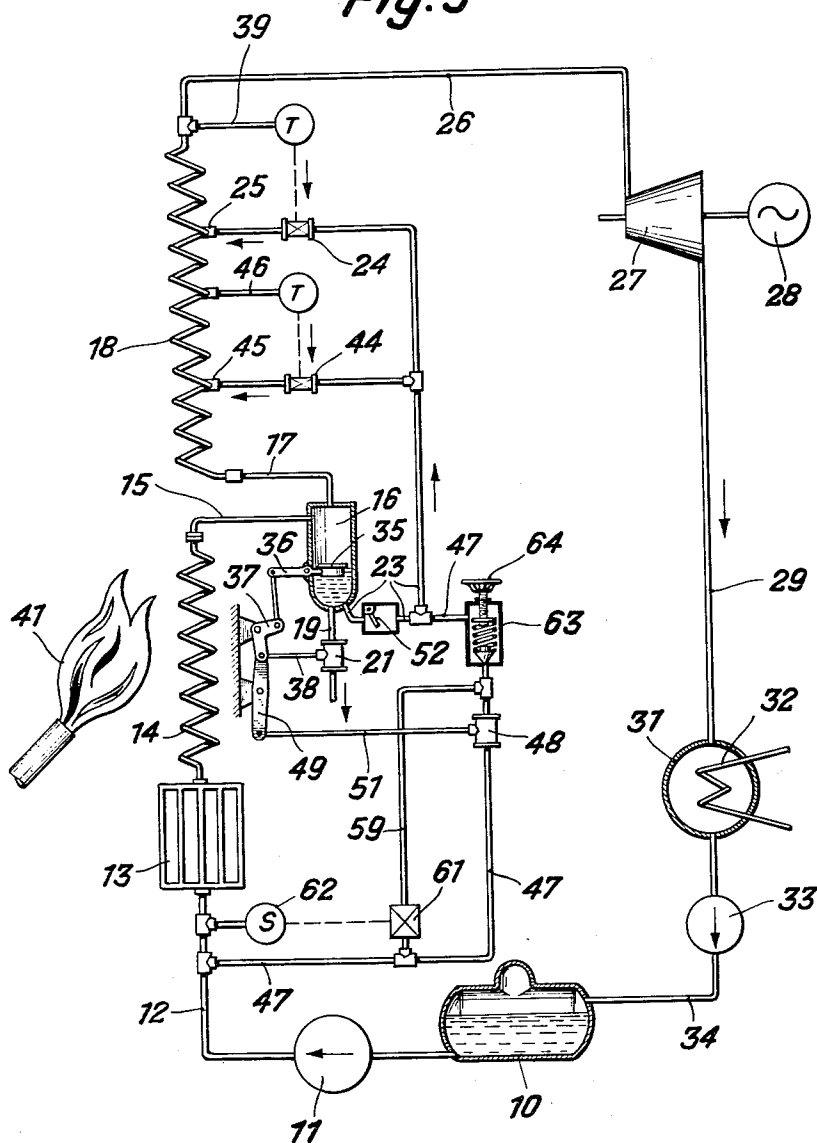
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Fig. 5



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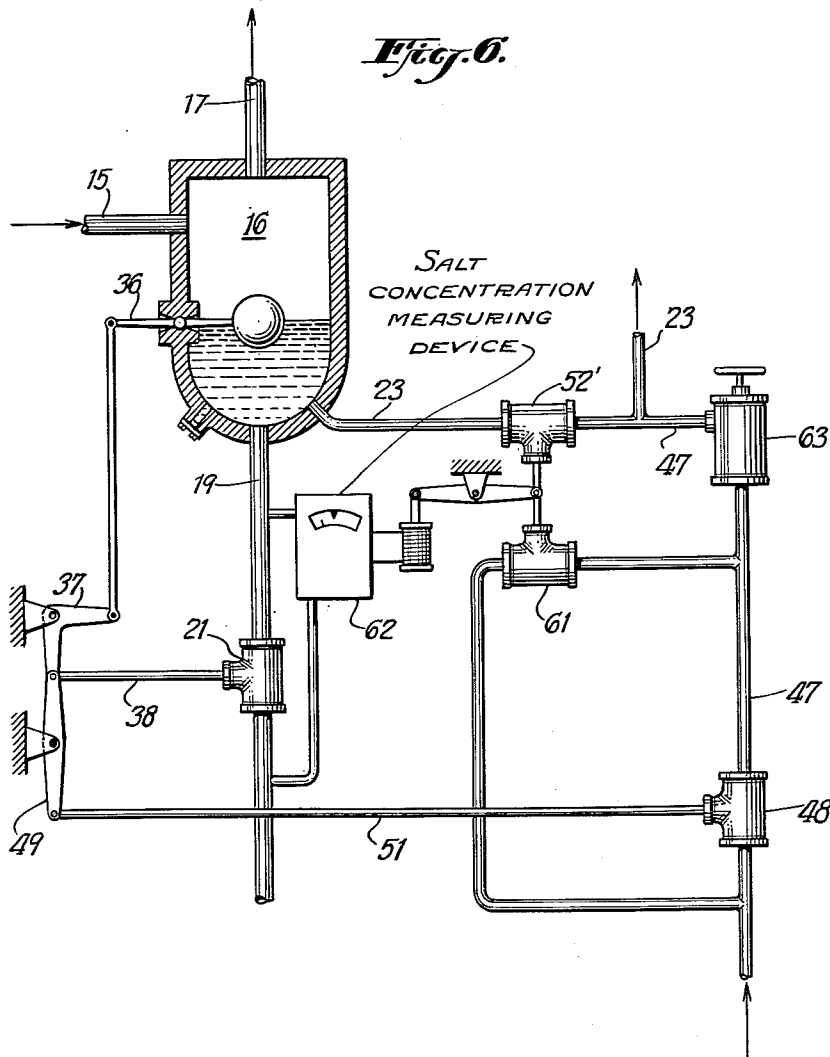
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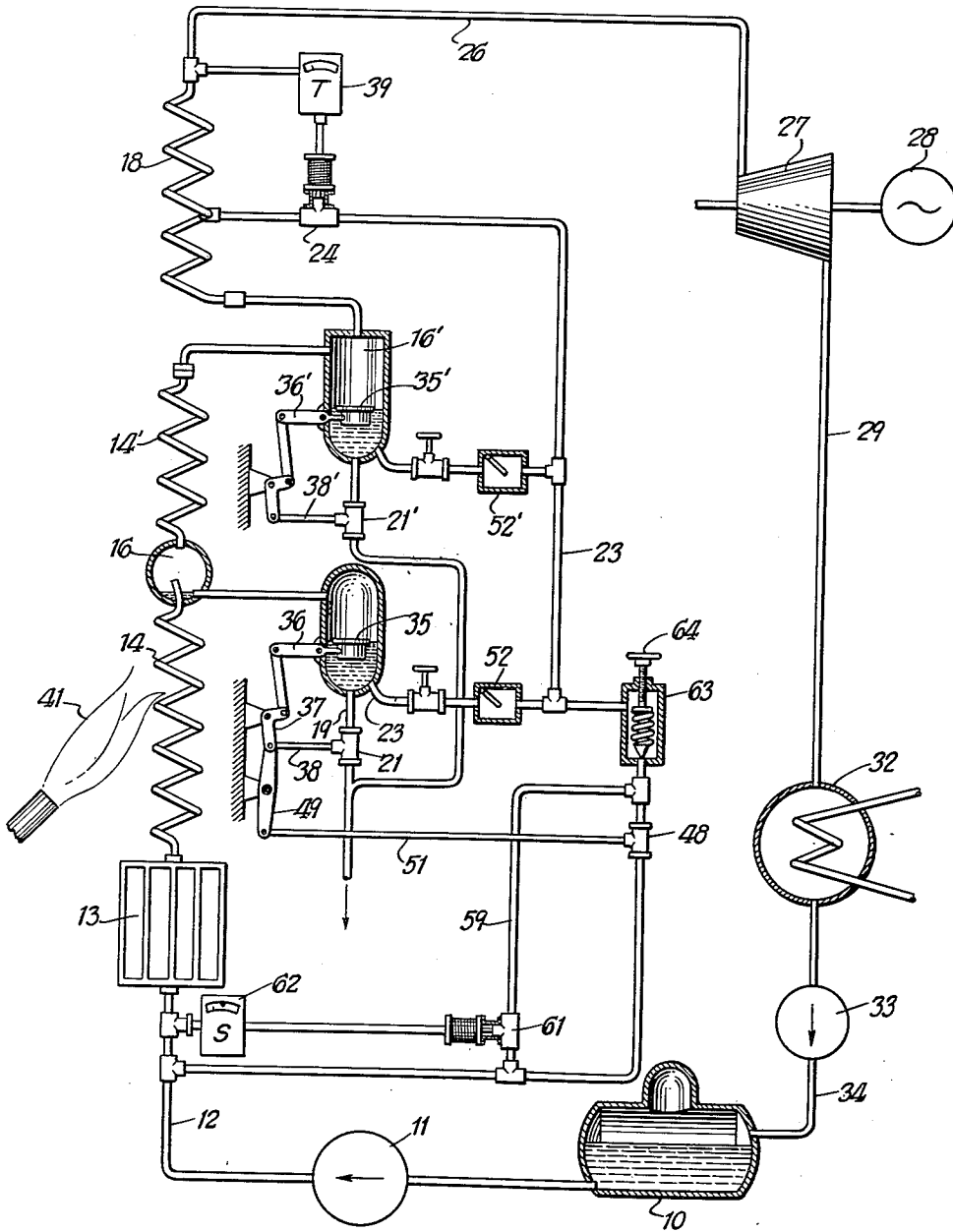
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Fig. 7.



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METHOD AND APPARATUS FOR OPERATING A FORCED FLOW STEAM GENERATOR HAVING A WATER SEPARATOR INTERPOSED IN ITS TUBE SYSTEM

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Claims priority, application Switzerland May 22, 1958

6 Claims. (Cl. 122-379)

The present invention relates to a method for operating a forced flow steam generator including a tube system having an evaporating portion and a superheating portion and a water separator interposed therebetween. The invention also relates to an apparatus for practicing the method.

It is known to provide separators between the evaporating zone and the superheating zone of a forced flow steam generator. A purpose of these separators is to blow down water having a high concentration of salt so that the steam leaving the separator contains little or no salt. Another purpose of these separators is to define a locality in the tube system of a forced flow steam generator downstream of which locality there is only substantially dry steam.

In steam generators operating at a substantially lower pressure than the critical pressure of steam both aforesaid purposes are usually of the same importance. In steam generators producing a live steam at substantially the critical pressure of steam the second purpose is of predominant importance, particularly since the problem of desalting is usually solved in a different way in these high pressure steam generators.

In steam generators operating in the neighborhood of the critical pressure and provided with control systems which require a great flexibility, elasticity and quick adjustment of the entire control apparatus to sudden and great changes of the load, it is important that the moisture content of the steam entering the separator during continuous normal operation constitutes a reserve which is so great that it will not be fully consumed even at a sudden and substantially increase of the fire intensity so that the steam entering the separator is never superheated because, otherwise, the evaporator in steam generators of the size as they are built today is likely to be damaged.

If the maximal live steam pressure of the steam generator is far below the critical pressure, a much smaller reserve of moisture content in the steam is needed when the heat supply is suddenly increased, than in a steam generator operating in the neighborhood of the critical pressure wherein it may be necessary that the whole range between 100% and 0% moisture content is available as a reserve.

Therefore, in a steam generator operating in the neighborhood of the critical pressure considerable amounts of water must be separated during normal operation. Removal of these amounts of water and introduction into the evaporating zone of the steam generator in the conventional manner or even into the feedwater storage tank is very uneconomical.

method and an apparatus which avoid the aforesaid disadvantages of conventional systems and to make possible a flexible control of the steam generator even if it pro-

It is an object of the present invention to provide a duces live steam at a pressure in the neighborhood of the critical pressure. According to the invention, separated water is removed from the separator according to the amount of separated water momentarily present in the separator and is also removed in an amount depending on the superheat temperature of the produced steam and

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is introduced into the superheating zone of the tube system of the steam generator. To provide cooling of the steam in the superheater also at times when insufficient water is available from the separator, the invention provides introduction of feedwater into the superheating zone of the tube system of the steam generator.

The apparatus according to the invention includes outlet means for removing separated liquid from a separator interposed between the evaporating portion and the superheating portion of a forced flow steam generator whereby said means are operated in dependence on the separated water momentarily present in the separator. The apparatus according to the invention includes at least one additional outlet for the liquid separated in the separator and a connection between said additional outlet and the superheating portion of the steam generator as well as control means for said outlet to control the amount of liquid removed from the separator and introduced into the superheater according to the superheat temperature produced in the steam generator.

The aforescribed system has the advantage that even if great amounts of liquid operating medium enter the separator the liquid is economically used without a substantial sacrifice of pressure and temperature. Since the superheater of such a system is so designed as to require more cooling than a superheater of a system without superheater cooling by blowdown water, the invention provides means for supplementing the blowdown water cooling by introducing feedwater into the superheater at times when insufficient blowdown water is available and/or if the salt content of the blowdown water makes it unsuitable for introduction into the superheater.

The novel features which are considered characteristic of the invention are set forth with particularity in the appended claims. The invention itself, however, and additional objects and advantages thereof will best be understood from the following description of embodiments thereof when read in connection with the accompanying drawing, in which:

FIG. 1 is a diagrammatic part sectional illustration of a forced flow steam generating plant in which water separated in the separator is injected into the superheater whereby the injection is controlled according to the temperature of the superheated steam.

FIG. 2 is a diagrammatic illustration of a forced flow steam generating plant in which water separated in a separator as well as feedwater is injected into the superheater.

FIG. 3 shows a portion of the system shown in FIG. 2 and of control means therefor.

FIG. 4 illustrates another portion of the system according to FIG. 2 and control means therefor.

FIG. 5 is a diagrammatic part sectional illustration of a steam generating plant equipped according to the invention and wherein the feedwater injection into the superheater is controlled according to the degree of purity of the operating medium of the steam generator.

FIGS. 6 and 7 are diagrammatic part sectional illustrations of modified plants according to the invention.

Referring more particularly to the drawing, numeral 10 designates a feedwater storage tank from which feedwater is pumped by a pump 11 through a feed pipe 12 into an economizer 13 wherefrom the water flows into an evaporating section 14 of the tube system of a forced flow steam generator. During normal operation almost the entire amount of water is evaporated in the tube section 14 and only so much water is not evaporated as is needed to provided a reserve for control operations required when the load changes.

A mixture of steam and water flows through an outlet conduit 15 connected to the evaporating section 14

into a separator 16 wherein the water is separated from the steam and accumulated in the lower portion of the separator, the steam leaving the separator through a pipe 17 and flowing into a superheater 18.

An outlet conduit 19, provided with a control valve 21, is connected to the separator 16 for removing the liquid portion of the operating medium. There is an additional outlet 23, provided with a valve 24, connected to the separator 16 for conducting water separated in the separator into the superheater portion 18 of the tube system of the steam generator. The water is injected into the superheater at 25. The superheater 18 discharges live steam into a pipe 26 connecting the outlet of the steam generator with a turbine plant 27 driving an electric generator 28. The turbine 27 is of conventional type having a suitable number of stages. The exhaust of the turbine 27 is conducted through a pipe 29 into a condenser 31 having a cooling system 32. The condensate is pumped by means of a condensate pump 33 through a pipe 34 into the feedwater reservoir 10.

Separators are available today which are equipped with means for weighing the liquid present or for measuring the liquid level in the separator. These means define a value corresponding to the liquid momentarily present in the separator and may produce a control signal by conventional means for controlling the valve 21. For simplicity's sake, a float 35 is shown in the drawing which actuates a lever 36 which is operatively connected to an elbow lever 37. The latter actuates a rod 38 which is connected to the valve 21 for opening the latter upon a rise of the liquid level in the separator and conversely.

Numeral 39 designates a thermostat which is responsive to the temperature of the steam at the outlet of the superheater 18 and which is operatively connected to the valve 24 for opening the valve and increasing the amount of water injected at 25 into the superheater upon a rise of the temperature at the outlet of the superheater beyond a predetermined value and conversely.

Operation

If the intensity of the fire 41 is suddenly increased because of a change of load, more water is evaporated in the evaporator 14 and less water is separated in the separator 16. Therefore, the water level in the separator and the float 35 move downward, clockwise swinging the lever 36 and the lever 37 in the opposite direction so that the rod 38 moves to the right for closing the valve 21. Therefore less water is removed through the outlet conduit 19. The water removed through the outlet conduit 23 remains unchanged so long as the thermostat 39 does not indicate a change of the superheat temperature.

In the system illustrated in FIG. 2 water is not only injected into the superheater at the point 25, but at two points. A pipe 43 branches from the pipe 23 and is equipped with a control valve 44 for injecting water from the separator 16 at the point 45 into the superheater 18 in dependence on a superheat temperature measured by a thermostat 46 between the points 45 and 25. When the temperature sensed by the thermostat 46 rises above a predetermined value the valve 44 is opened and conversely.

The two-stage injection is of advantage, for example, if the superheater is relatively long because, if water is injected only at the end of a long superheater, control of the superheat temperature is sluggish. A two-stage injection system also affords introduction of greater amounts of water and therefore a quicker, aperiodic control, avoiding control undulations.

In order to satisfy the increased water demand at the injection points 25 and 45 at a great positive firing disturbance, a supply pipe 47 is connected to the feedwater pipe 12. If the amount of feedwater supplied by the pump 11 is controlled in the conventional manner by an apparatus 50, schematically shown in FIG. 3, which responds to the feedwater flow at the inlet of the economizer 13 and measured by a conventional device 50',

the pipe 47 is connected to the feed pipe 12 upstream of the measuring device 50'. A control valve 48 is interposed in the pipe 47 which is responsive to the amount of separated water momentarily present in the separator 16. The valve 48, however, is operated in a direction which is opposite to the operation of the valve 21 so that when the latter closes, the valve 48 opens.

To produce the aforescribed action a two-arm lever 49 is pivoted to the arm of the lever 37 where the rod 38 is connected. A rod 51 is connected to the free end of the lever 49 and to the valve 48 for actuating the latter. The pipe 47 terminates in the pipe 23. A check valve 52 is provided in the pipe 23 between the separator 16 and the connection with the pipe 47. This check valve prevents entry of feedwater from the pipe 47 which would seriously interfere with the operation of the evaporator 14, if the water content of the separator 16 is small and the valve 21 is closed. In the absence of the check valve 52 it would also be possible that an insufficient amount of water is injected at the points 25 and 45. These disturbances are avoided by the provision of the check valve 52.

When the water supply to the injection points 25, 45 is switched from the separator 16 to the feed pipe 12, a sudden pressure increase may occur at the injection points, if the pressure drop in the pipe 47 is substantially smaller than the combined pressure drop in the economizer 13, in the evaporator 14 and in the separator 16. If, at the aforescribed switch of the water supply, the pressure is increased without a change of the opening of the control valves 24 and 44 by the thermostats 39 and 46, too much water would be injected, and the control of the superheat temperature and of the entire steam generator would be disturbed.

In order to avoid such disturbances, a pressure reducing valve 53 is interposed in the pipe 47 upstream of the connection of the latter to the pipe 23. This valve 53 causes a pressure drop in the pipe 47 which is approximately equal to the combined pressure drop in the economizer 13, the evaporator 14 and the separator 16. The pressure drop in the pipe 47 is preferably adjusted to be somewhat smaller than the pressure drop in the economizer 13, evaporator 14 and separator 16 so that the check valve 52 will be closed. The pressure reducing valve 53 may be arranged upstream or downstream of the control valve 48.

FIG. 4 illustrates a modified arrangement for reducing or avoiding the aforescribed undesired sudden pressure increase upon switching of the injection water supply from the separator 16 to the feed pipe 12. An additional control valve 54 is arranged downstream of the control valve 48 in lieu of the pressure reducing valve 53 shown in FIG. 2. The valve 54 is actuated by a regulator 55 which is responsive to control signals received from pressure sensitive devices 56 and 57. The device 56 is responsive to the pressure in the pipe 23 downstream of the connection of the pipe 47. The device 57 is responsive to the pressure in the pipe 23 upstream of the check valve 52, i.e., it is responsive to the pressure prevailing in the separator 16. The device 57 provides the set point for the regulator 55, i.e., the desired pressure at which the regulator closes the valve 54 when the pressure in the conduit 23 which is sensed by the device 56, exceeds the set point value defined by the device 57 and opens the valve 54 when the pressure sensed by the device 56 is below the set point value. If the water supply is switched from the separator to the feed pipe, the pressure to which the device 56 is responsive increases above the pressure sensed by the device 57, causing closing of the valve 54 by the regulator 55.

To prevent that the control of the valve 54 becomes unstable because the device 56 follows the pressure variations too closely, it is advisable to interpose a pressure accumulator 58 in the pipe 23 and to connect the device 56 to this pressure accumulator. The latter equalizes

momentary pressure fluctuations in the conventional manner and may be provided with an air cushion as shown, or with other resilient means having the same effect.

FIG. 5 shows an arrangement in which an additional injection water supply is added to the system shown in FIG. 2. This additional water supply forms a by-pass around the control valve 48. A pipe 59 containing a control valve 61 is connected to the pipe 47 upstream of the valve 48 and terminates in the pipe 47 downstream of the valve 48 and upstream of a pressure reducing valve 63 corresponding to the valve 53 in FIG. 2. The valve 63 can be adjusted to produce a desired pressure drop by manipulating a hand wheel 64. The valve 61 is controlled by a conventional device 62 which is responsive to the salt concentration of the feedwater flowing through the pipe 12 into the economizer 13, whereby the valve 61 is opened if the salt concentration exceeds a predetermined value and conversely. The device 62 may be of the type in which the electric conductivity of the feedwater is measured for producing signals operating a solenoid for actuating the valve 61.

If, for example, due to a failure in the condenser 31, salt enters the condensate and the salt concentration in the feedwater becomes too high, the injection of water from the separator 16 is stopped independently of the action of the float 35 and a sufficient amount of injection water is conducted from the feed pipe 12 through the pipe 59 even if the valve 48 is closed or only little opened so that supply of injection water by the separator 16 is made unnecessary. If there is a leakage in the condenser 31, the water separated in the separator 16 contains too much salt and it is advisable to remove all of the separated water through the valve 21 and to use only feedwater whose salt concentration, though increased, is not as high as that of the water removed in the separator 16, for the water injection into the superheater 18. Since the pipe 59 by-passes the valve 48, water from the feed pipe 12 is continuously supplied to the pipe 23 and the check valve 52 remains closed. The float 35, therefore, will open the valve 21 so that the entire water separated in the separator 16 is blown down.

The device 62 may be arranged to measure the salt concentration at another point of the circuit for opening the valve 61. It will be particularly desirable to measure the salt concentration in the water separated in the separator 16 and it is within the purview of this invention to connect the device 62 to the separator 16 or to the pipe 19, as shown in FIG. 6. A controlled valve 52' is provided in lieu of the automatic check valve 52. This valve is controlled by the device 62 which measures the salt concentration in the water in the separator 16 and is closed when the valve 61 is opened. The valve 52' may be so constructed as to immediately close upon an excess pressure in the pipe 47. In this way flow of operating medium from the separator 16 to the superheater 18 would be automatically stopped.

If the valve 52 is in the form of a controlled valve, this valve as well as the valves 48 and 61 may be designed as stop valves having only two positions in which they are either fully opened or fully closed.

It is immaterial for the invention whether an additional evaporator is interposed between the separator 16 and the superheater 18.

If desired, a second separator 16' may be provided downstream of an additional evaporator 14' and separated liquid may be taken from one or the other, or from both separators for injection into the superheater. An arrangement of this type is shown in FIG. 7.

When switching the injection water supply from the separator 16 to the feed pipe 12 of the system shown in FIG. 2 not only an undesired pressure increase, as described, but also an undesired difference of temperature may occur. If the switching is effected gradually so that aside from the water supplied from the feed pipe 12 there is still injection water supplied by the separator 16, mix-

ing of the two liquids produces an intermediate temperature. If, however, the water supply from the separator 16 is suddenly stopped and the injection points 25, 45 receive exclusively water from the feed pipe 12, the sudden temperature drop may cause a disturbance. Such a disturbance may be prevented by changing the effects of the thermostats 39, 46 on the motor operators for actuating the valves 24, 44, or the effects of the motor operators on these valves according to the temperature drop. For example, when the difference between the temperatures of the water in the separator 16 and of the feedwater increases the thermostats 39 and 46 may be so adjusted that the opening effect of a temperature increase of the superheated steam above the predetermined value on the valves 24 and 44 may be decreased and vice versa.

Since the temperature of the operating medium taken from the separator 16, a control of the leverage of the lever 49 may be provided whereby, for example, an increase of the rate of increase of the actual temperature of the superheated steam relative to the set point of the temperature of the thermostat 39 and/or 46 changes the leverage to decrease the amount of the medium supplied by the feed pipe 12 relative to the amount of the medium supplied from the separator 16 and vice versa.

I claim:

1. In a forced flow steam generator a tube system, a steam-water separator interposed in said tube system, a first controllable outlet connected to said separator for removing separated water therefrom, a device connected to and being responsive to the amount of separated water present in said separator, said device being operatively connected to said outlet for opening said outlet upon an increase of the separated water in said separator beyond a predetermined value, a second outlet connected to said separator for removing separated water therefrom, a conduit connecting said second outlet to said tube system downstream of the separator for introducing the separated water into the operating medium of the steam generator, a first valve interposed in said conduit, temperature responsive means connected to said tube system downstream of said separator and operatively connected to said first valve for opening said first valve upon a rise of the temperature of the operating medium of the steam generator above a predetermined value, a second valve interposed in said conduit, and a salt concentration responsive device connected to said tube system for measuring the salt concentration of the operating medium of the steam generator, said salt concentration responsive device operatively connected to said second valve for closing said second valve upon an increase of the salt concentration above a predetermined value.

2. In a forced flow steam generator a tube system including a feed pipe, a steam-water separator interposed in said tube system, a first controllable outlet connected to said separator for removing separated water therefrom, a device connected to and being responsive to the amount of separated water present in said separator, said device being operatively connected to said outlet for opening said outlet upon an increase of the separated water in said separator beyond a predetermined value, a second outlet connected to said separator for removing separated water therefrom, a conduit connecting said second outlet to said tube system downstream of the separator for introducing the separated water into the operating medium of the steam generator, a first valve interposed in said conduit, temperature responsive means connected to said tube system downstream of said separator and operatively connected to said first valve for opening said first valve upon a rise of the temperature of the operating medium of the steam generator above a predetermined value, a tube interconnecting said feed pipe and said conduit upstream of said first valve, a second valve interposed in said tube, a salt concentration responsive device connected to said tube system for measuring the salt concentration of the

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operating medium of the steam generator, said salt concentration responsive device being operatively connected to said second valve for opening said second valve upon an increase of the salt concentration above a predetermined value, a third valve interposed in said conduit between said second outlet and the connection of said tube to said conduit, and means operatively interconnecting said second valve and said third valve for closing said third valve upon opening of said second valve and for opening said third valve upon closing of said second valve.

3. The method of removing liquid from a separator interposed in a conduit system including a feed pump and a forced flow steam generator receiving feedwater from said pump, the method including removing liquid from the separator to the outside when the amount of liquid separated in the separator rises above a predetermined value, removing liquid from the separator when the temperature of the operating medium in the steam generator downstream of the separator rises above a predetermined temperature, introducing the last mentioned liquid into the operating medium of the steam generator downstream of the separator, diverting water from the feedwater of the steam generator into the last mentioned liquid after removal thereof from the separator and prior to introduction of the liquid into the operating medium of the steam generator, and maintaining the amount of the water diverted from the feedwater into the liquid removed from the separator for introduction into the operating medium of the steam generator proportional to the salt concentration of the liquid operating medium flowing through the steam generator.

4. The method of removing liquid from a separator interposed in a conduit system including a feed pump and a forced flow steam generator receiving feedwater from said pump, the method including removing liquid from the separator to the outside when the amount of liquid separated in the separator rises above a predetermined value, removing liquid from the separator when the temperature of the operating medium in the steam generator downstream of the separator rises above a predetermined temperature, introducing the last mentioned liquid into the operating medium of the steam generator downstream of the separator, diverting water from the feedwater of the steam generator into the last mentioned liquid after removal thereof from the separator and prior to introduction of the liquid into the operating medium of the steam generator, and stopping of the temperature responsive removal of liquid from the separator and introduction of liquid from the sep-

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arator into the operating medium of the steam generator downstream of the separator upon an increase of the salt concentration of the liquid operating medium flowing through the steam generator above a predetermined concentration.

5. In a forced flow steam generator a tube system, a steam-water separator interposed in said tube system, a first controllable outlet connected to said separator for removing separated water therefrom, a device connected to and being responsive to the amount of separated water present in said separator, said device being operatively connected to said outlet for opening said outlet upon an increase of the separated water in said separator beyond a predetermined value, a second controllable outlet connected to said separator for removing separated water therefrom, a conduit connecting said second outlet to said tube system downstream of the separator for introducing the separated water into the operating medium of the steam generator, temperature responsive means connected to said tube system downstream of said separator and operatively connected to said second outlet for opening said second outlet upon a rise of the temperature of the operating medium of the steam generator above a predetermined value, a feed pipe, a conduit interconnecting said feed pipe and said tube system downstream of said separator for injecting feedwater into the operating medium of the steam generator, a valve interposed in said last mentioned conduit, and a salt concentration responsive device connected to said tube system for measuring the salt concentration of the operating medium of the steam generator, said salt concentration responsive device being operatively connected to said valve for opening said valve upon an increase of the salt concentration above a predetermined value.

6. In a forced flow steam generator according to claim 5 and wherein said salt concentration responsive device is connected to said separator.

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