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FORCED FLOW STEAM GENERATING PLANT

Filed Nov. 12, 1957

2 Sheets-Sheet 1

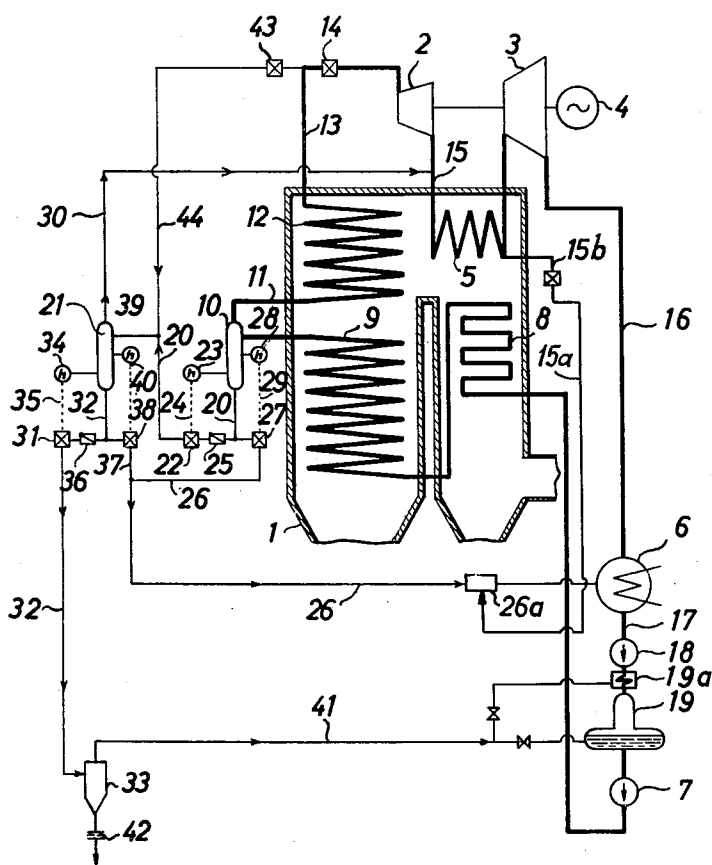


Fig. 1

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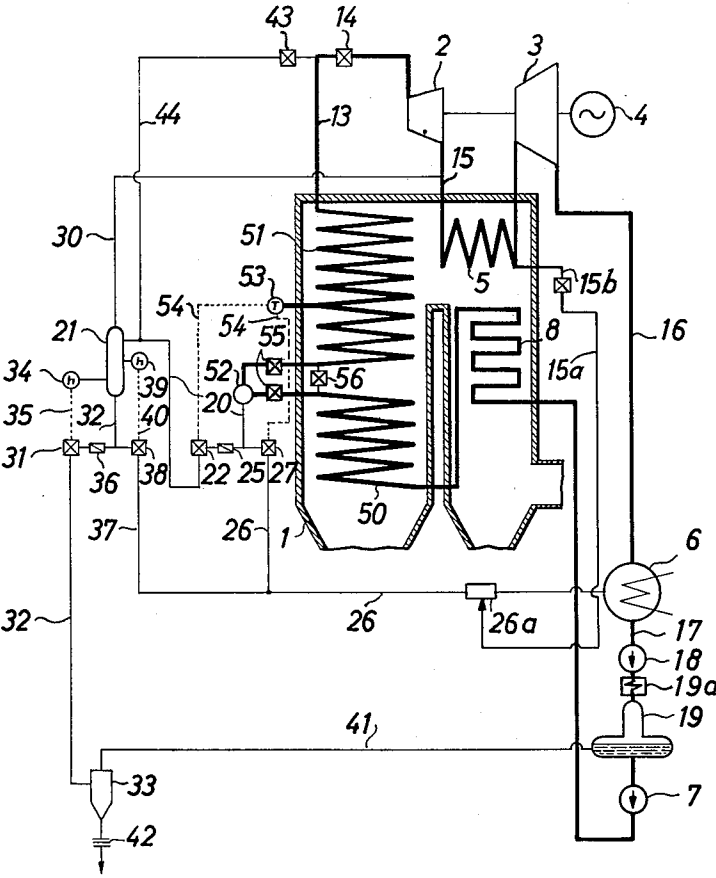


Fig. 2

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FORCED FLOW STEAM GENERATING PLANT
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The present invention relates to a steam generating plant forming part of a power plant the operating medium of which flows in a cycle through a forced flow steam generator of the once through type including a superheater, a prime mover having at least two pressure stages, a steam reheater interposed between two pressure stages of the prime mover, and a condenser for condensing the steam exhausted by the prime mover, the condensate being returned to the steam generator.

According to the invention operating medium is bled through first bleeder means from the cycle between a zone in the steam generator in which zone the medium is in liquid state and a zone in the steam generator in which zone the medium is in the form of superheated steam. Operating medium is also bled from the cycle through second bleeder means connected with the outlet of the superheater. The two bleeder means are connected with a pipe returning bled operating medium to the cycle at a point between the steam outlet of the prime mover and the feed water inlet of the steam generator so that the bled operating medium flows in parallel relation through the two bleeder means. There is also a valved pipe connecting the outlet of the first bleeder means with the second bleeder means for conducting, if desired, operating medium consecutively through the first and through the second bleeder means. The outlet of the second bleeder means is connected with a device for removing contaminated bled operating medium from the cycle. This device may be in the form of a water separator having a water space connected with the outside of the cycle and having a steam space connected with the cycle between the steam outlet of the prime mover and the feed water inlet of the steam generator.

The water removed by the aforesaid separator may be purified and then be returned to the cycle. The second bleeder means may include a steam separator for separating steam contained in the bled operating medium from water contained in the bled operating medium, the separated steam being returned to the cycle at a point upstream of the reheater.

In pipes connected with the outlets of the two bleeder means and with the pipe returning bled operating medium to the cycle control valves are preferably provided for controlling the amounts of operating medium bled from and returned to the cycle. These valves may be automatically controlled to regulate the amount of operating medium bled from the cycle during starting of the plant and during periods in which the operating conditions are not normal, i.e., when there is an amount of water passing through the steam generator which amount is excessive in relation to the steam passing through the steam generator. In plants having steam generators operating at a pressure below the critical pressure of water a water separator is preferably interposed in each bleeder means and the aforesaid automatic control is made responsive to a relatively high water level in these separators so that the valves are opened when the water level rises beyond a predetermined position and are closed when the water level falls below a predetermined position, whereby the predetermined positions are in the upper part of the water separators. In plants having steam generators operating at or above the critical pressure of water the control of the valve in the pipe connected with the outlet of the first

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bleeder means is made responsive to relatively low temperatures of the operating medium in the superheater so that the valve is opened when the temperature falls below a predetermined value and is closed when the temperature rises above a predetermined value.

A valve is provided in the pipe connecting the outlet of the first bleeder means with the second bleeder means for connecting the two bleeder means in series relation during normal operation of the plant, when the valves described in the paragraph next above are closed. The last mentioned valve is preferably automatically controlled. In plants having a steam generator operating at subcritical pressure of water the control is made responsive to a relatively low water level in a water separator interposed in the first bleeder means and is opened when the water level rises beyond a predetermined position and is closed when the water level falls below a predetermined position, these positions being in the lower part of the water separator. In plants having a steam generator operating at or above the critical pressure of water the control is made responsive to relatively high temperatures of the operating medium in the superheater so that the valve is opened when the temperature falls below a predetermined value and is closed when the temperature rises above a predetermined value.

For controlling the amount of water removed from the cycle during normal operation of the plant a separate pipe is connected with the outlet of the second bleeder means, the pipe being provided with a valve. This valve is preferably automatically actuated in response to a relatively low water level in a water separator interposed in the second bleeder means so that the valve is opened when the water level rises beyond a predetermined position and is closed when the water level falls below a predetermined position, these positions being in the lower part of the water separator.

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 diagram illustrating an arrangement according to the invention in which the maximum pressure of the operating medium is below the critical pressure of the medium.

FIG. 2 is a diagram illustrating an arrangement according to the invention in which the maximum pressure in the cycle is equal to or greater than the critical pressure of the operating medium.

Like elements are designated by like numerals in both figures of the drawing.

Referring more particularly to the drawing, numeral 1 designates a forced flow steam generator. The superheated steam produced in the steam generator is expanded in a prime mover having two consecutive pressure stages 2 and 3. The prime mover operates an electric generator 4. The steam exhausted from the high pressure stage 2 is reheated in a reheater 5 before the steam enters the low pressure stage 3. The steam exhausted from the low pressure stage 3 is condensed in a condenser 6, the condensate being returned by means of a feed pump 7 to an economizer 8 forming part of the steam generator 1.

The steam generator includes a vaporizing section 9 receiving preheated liquid from the economizer 8. Numeral 10 designates a bleeder device receiving operating medium from the heating section 9. The part of the operating medium which is not removed in the device 10 is conducted through a conduit 11 into a superheater 12. The superheated steam is conducted from the out-

let of the superheater 12 through a pipe 13 which is equipped with a conventional valve 14 to the high pressure stage 2. After expansion of the steam in the high pressure stage 2 the steam is conducted through a pipe 15 into the reheater 5 and thereafter through the low pressure stage 3 and a conduit 16 into the condenser 6. A conduit 17 equipped with a pump 18 conducts the condensate into a feed water accumulator 19 from which the feed water is transported by the feed pump 7 into the economizer 8.

In the device 10 the steam contained in the operating medium leaving the evaporating section 9 is separated from the liquid which is not evaporated in the heating section 9. The separated liquid leaves the device 10 through a pipe 20 which is connected with a second bleeder device 21. A regulating valve 22 is interposed in the pipe 20 which valve is actuated by an actuator 23 which responds to a relatively low liquid level in the separator 10. The operative connection between the actuator 23 and the valve 22 is diagrammatically indicated by a dotted line 24. A check valve 25 is arranged in the pipe 20 between the liquid outlet of the device 10 and the valve 22. A pipe 26 is connected to the pipe 20 between the check valve 25 and the device 10. The pipe 26 conducts liquid operating medium separated in the separator 10 to the condenser 6, a cooler, for example, an injecting device 26a, being interposed in the pipe 26. The cooling agent for the device 26a may be taken from the outlet of the reheater 5 through a conduit 15a provided with a valve 15b. Flow of liquid into the pipe 26 is controlled by a valve 27 which is operated by an actuator 28 connected to and responsive to the liquid level in the upper region of the device 10. The operative connection between the actuator 28 and the valve 27 is indicated by a dotted line 29.

The device 21 is also designed to act as a water separator but can be built for a lower internal pressure than the device 10. Vapor still contained in the liquid leaving the separator 10 through the pipe 20 is separated in the separator 21. The vapor or steam separated from the liquid in the device 21 is returned to the cycle by means of a pipe 30 terminating in the pipe 15 connecting the prime mover stage 2 with the reheater 5. The liquid separated in the device 21 is conducted through a pipe 32 provided with a valve 31 to a steam separating device 33. The valve 31 is controlled by an actuator 34 which responds to the water level in a relatively low zone of the separator 21, for closing the valve 31 to which the actuator 34 is operatively connected by conventional means 35, when the water level in the device 21 falls below a predetermined position. A check valve 36 is interposed in the pipe 32 between the valve 31 and the separator 21 for preventing flow of medium back into the separator. A pipe 37 is connected with the pipe 32 between the check valve 36 and the device 21 and terminates in the pipe 26 which leads to the condenser 6. The pipe 37 is equipped with a valve 38 which is connected by conventional means 40 for operation by an actuator 39 which responds to the water level in a relatively high zone of the device 21.

The operating medium conducted through the pipe 32 into the evaporating vessel 33 is once more separated into vapor and liquid, the vapor being conducted through a pipe 41 into the feed water accumulator 19 or, if desired, as a heating agent into a preheater 19a. The latter is interposed in the conduit 17 between the pump 18 and the accumulator 19. If the plant is operated by steam, the water separated in the vessel 33 contains salt and is preferably returned to the cycle through a desalting plant, not shown. For limiting the amount of water blown down from the vessel 33 an orifice plate 42 is preferably interposed in the water outlet conduit of the device 33.

When the plant is in normal operation the valves 22 and 31 which are controlled by the liquid level re-

sponsive actuators 23 and 34, respectively, control the removal of the liquid separated in the devices 10 and 21. About 4% of the operating medium circulating through the plant when the plant is in normal operation is admitted by the valve 22 through the pipe 20 to the separator 21. About one third of the operating medium received in the device 21 is separated therein in the form of vapor which is returned to the cycle through the reheater 5. The liquid separated in the device 21 is conducted to the vessel 33 from which the separated vapor enters the feed water accumulator 19. It is of advantage to return at least a part of the blow-down water available in the vessel 33 through a control device 42 and a feed water make-up or purifying plant, not shown, to the cycle, if water is used as an operating medium. By repeatedly separating vapor from the operating medium leaving the evaporating section 9 in several pressure stages and by returning the separated vapor into the highest possible pressure portion of the cycle and by returning the hot liquid to the cycle, the economy of operation of the whole plant is improved.

When the plant is started and operated at a low load or when the normal operation is disturbed, a considerable greater amount of liquid is received by the bleeder devices. It is not advisable to remove such great amounts of liquid in the same manner in which the liquid is removed when the plant is in normal operation because, due to the great amount of vapor separated in the device 21, the temperature at the inlet of the reheater would be too much reduced and because the feed water accumulator 19 in which the major portion of the liquid separated in the device 21 is ultimately received, would have to be equipped with unduly large safety valves or other means for relieving waste vapor. To avoid this the valves 27 and 38 provided in the conduits 26 and 37 are preferably larger than the valves 22 and 31 so that they can control the flow of the relatively great amounts of liquid or condensate into the condenser when the plant is not in normal operation. If the water level in the devices 10 and 21 rises beyond the location which is controlled by the actuators 23 and 34, the actuators 28 and 39 controlling the valves 27 and 37, respectively, take over and the relatively great amounts of liquid separated in the devices 10 and 21 are removed through the injection cooler 26a into the condenser. The injection cooler may be so designed that the rather voluminous vapor clouds produced during the expansion of the relieved operating medium are conducted into the exhaust pipe of the prime mover and only the residual liquid is conducted into the lower part of the condenser.

Whereas, for example, the valves 22 and 31 are designed for passing a maximum amount of 10% of the circulating operating medium, the valve 22 passes about 4% of the operating medium during normal operation. The valve 31 admits about 2.5% of the liquid operating medium to the evaporating vessel 33, about 1.5% of the operating medium being admitted as vapor to the reheater 5. The valves 27 and 38 are closed during normal operation of the plant. At abnormal operation the valve 27 passes approximately up to 20% and the valve 38 passes approximately up to 30% and even 50% of the operating medium. The valve 38 also receives the operating medium conducted through a conduit 44 in which a valve 43 is arranged which is open, for example, when the steam generator is started. About 1% of the operating medium is blown down from the evaporating vessel 33. About 1.5% of the operating medium is returned in the form of vapor to the accumulator 19.

The regulating valves 22 and 31 are continuously operated and must, therefore, repeatedly be overhauled. During the periods when the valves 22 and 31 are out of service the valves 27 and 38 can be used which valves automatically take over, if the valves 22 and 31 are replaced by standard stop valves and the liquid level in

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the devices 10 and 21 rises beyond a predetermined upper location.

The arrangement according to the invention makes it possible to remove 4% or, if desired, more operating medium from the vapor generating part of the cycle, depending on the pressure of the operating medium. In plants using steam and water as operating medium it has been found that, if the aforesaid amount is bled from the cycle, a desirable salt concentration is obtained in the most favorable manner, whereas, for economic reasons, only 0.5% to 1% of this amount need be continuously removed for preparing the feed water. The arrangement according to the invention makes it also possible to return the heat contained in the removed liquid to a highest possible stage or to two pressure stages of the cycle of the operating medium and to approximately double the salt concentration in the finally removed residual water due to the two-stage evaporation.

In the foregoing the application of the invention to a steam generator operated at subcritical pressure of water has been described. The invention can equally well be applied to a plant in which the steam generator is operated at a supercritical pressure of water. The system according to the invention affords economic operation of a supercritical pressure steam generator whereby the amounts of blow-down water are much reduced. FIG. 2 shows the system in combination with a supercritical pressure steam generator. The first bleeder device can be arranged outside or inside the steam generator. Since in a supercritical pressure steam generator only one phase of the operating medium, i.e., steam or water, is present in any part of the tube system, the amount of operating medium removed through the bleeder device cannot be controlled in response to a water level. Therefore, the amount of operating medium bled from the cycle is controlled, for example, according to the temperature of the operating medium at certain points of the tube system of the steam generator. The control may, however, also be effected in response to the salt content of the operating medium.

In the arrangement illustrated in FIG. 2 the feed water preheated in the economizer 8 is conducted into a second water heating section 50 which is located in the combustion chamber of the steam generator 1. From the heating section 50 the operating medium flows into a steam drying and superheater section 51. A bleeder device 52 is interposed in the flow of the operating medium between the sections 50 and 51 and preferably located outside of the steam generator, a by-pass pipe being provided, affording by-passing the device 52 by closing valves 55 provided in the connections for the operating medium flowing from the tube section 50 through the device 52 to the tube section 51. A stop valve 56 is provided in the by-pass conduit. A bleeder pipe 20 is connected with the device 52, the pipe 20 being connected with valves 22 and 27 which are arranged in parallel relation with respect to the flow of the operating medium through the valves. In the embodiment illustrated in FIG. 2 the valves 22 and 27 are operated by an actuator 53 which is responsive to the temperature within the superheater tube section 51. The actuator 53 is connected by conventional means with the valves 22 and 27 which means are indicated by dotted lines 54.

The valves 22 and 27 are closed when the plant is in normal operation. When heating up the plant and at other abnormal operating conditions the valves 22 and 27 are actuated according to the temperature sensed by the device 53. If, for example, the temperature in the superheater 51 is only little below a desired temperature the valve 22 is opened and admits a portion of the operating medium into the device 21. If the temperature in the superheater 51 falls much below the desired temperature so that a great amount of water must be removed, the valve 27 is opened, permitting flow of the water through pipe 26 to the condenser 6. The valves 22 and

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27 which have different sizes are operated in the supercritical pressure arrangement according to FIG. 2 in the same manner as the valves 22 and 27 in the sub-critical pressure arrangement illustrated in FIG. 1, the only difference being that the valves 22 and 27 in FIG. 2 are controlled according to the temperature of the operating medium in the superheater whereas the valves 22 and 27 in FIG. 1 are controlled according to the water level in the device 10.

If the amount of water passing through the steam generator is very great as it is the case when the steam generator is started, the temperature actuating the device 53 is very low and the valve 27 permits a certain amount of water to pass into the condenser. If there is not so much water in the steam generator and the temperature to which the device 53 is responsive is higher, the valve 22 is opened and admits a relatively smaller amount of water to the second bleeder device 21. Since the pressure in this device is lower, steam will be generated which steam is conducted to the reheater 5. The water separated in the device 21 is conducted through pipe 32 to the evaporating vessel 33 in the same manner as in the subcritical pressure arrangement shown in FIG. 1. The arrangements according to FIG. 2 as well as according to FIG. 1 afford quick starting of the plant and the heat contained in the removed water is returned to the cycle at the highest possible pressure. In the supercritical pressure plant according to FIG. 2 as well as in the subcritical pressure plant shown in FIG. 1, the disadvantages of the arrangement which is very economical as long as the plant is in normal operation, when the plant is not in normal operation are avoided.

I claim:

1. A forced flow steam generating plant comprising a source of feedwater supply, a tube system connected to said source for receiving feedwater therefrom, said tube system including an evaporating section wherein water is converted into steam, said tube system including a superheating section connected to said evaporating section for receiving steam therefrom, a first separator interposed in said tube system between said evaporating section and said superheating section and adapted to tap liquid operating medium from said tube system, a second separator connected to the outlet of said superheating section and adapted to tap liquid operating medium therefrom, each of said separators having an outlet for the liquid operating medium, valved first conduit means connected to both outlets and to said source of feedwater supply for returning water thereto during the heating up period of said tube system when the plant is started and at abnormal operating conditions of the plant, valved second conduit means connecting the outlet of said first separator to said second separator for conducting operating medium from said first separator into said second separator during normal operation of the plant, and blow-down means connecting the outlet of said second separator to the outside of the plant for removing contaminated water from the plant.

2. A steam generating plant as defined in claim 1 wherein said blowdown means includes a steam separator, a conduit being connected to the steam space in said separator and to said source of feedwater supply for returning the separated steam to said source.

3. A steam generating plant as defined in claim 1 wherein said first conduit means includes a portion connected to the water outlet of said first separator, a valve in said portion, control means being connected to said first water separator and to said valve, said control means being responsive to the water level in said first water separator for opening said valve when the water level rises above a predetermined level.

4. A steam generating plant as defined in claim 1 wherein said first conduit means includes a portion connected to the water outlet of said first separator, a valve in said portion, control means being connected to said

superheating section and to said valve, said control means being responsive to the temperature of the operating medium in said superheating section for opening said valve when said temperature drops below a predetermined value.

5. A steam generating plant as defined in claim 1 including a pipe connecting the water outlet of said second separator and said blowdown means, a valve in said pipe, and actuating means connected to and being responsive to the amount of water present in said second separator and connected to said valve for opening the latter when said amount of water exceeds a predetermined value.

6. A steam generating plant as defined in claim 1 wherein said first conduit means includes a first portion connected to the water outlet of said first separator and a second portion connected to the water outlet of said second separator, a first valve being interposed in said first portion, a second valve being interposed in said second portion, a third valve being interposed in said second conduit means, actuating means being connected to and responsive to a relatively high water level in said first separator and connected to said first valve for closing said valve when said water level is below a predetermined relatively high level, actuating means being connected to and responsive to a relatively high water level in said second separator and connected to said second valve for closing the latter when the water level in said second separator is below a predetermined relatively high level, and actuating means being connected to and responsive to a relatively low water level in said first separator and connected to said third valve for opening the latter when the water level in said first separator is above a predetermined relatively low level.

7. A steam generating plant as defined in claim 1 wherein said first conduit means includes a first portion connected to the water outlet of said first separator and a second portion connected to the water outlet of said second separator, a first valve being interposed in said first portion, a second valve being interposed in said second portion, a third valve being interposed in said second conduit means, actuating means being connected to said superheating section and responsive to a relatively

low temperature of the operating medium therein and connected to said first valve for closing said valve when said temperature is above a predetermined relatively low value, and actuating means being connected to and responsive to a relatively high water level in said second separator and connected to said second valve for closing the latter when the water level in said second separator is below a predetermined relatively high level, said actuating means which is connected to said superheating section, being also responsive to a relatively high temperature of the operating medium therein and connected to said third valve for opening the latter when the temperature of the operating medium in said superheating section is below a predetermined relatively high value.

8. A steam generating plant according to claim 7 including a conduit interposed between the water outlet of said second separator and said blowdown means, a valve in said last mentioned conduit, and actuating means connected to and being responsive to a relatively low water level in said second separator and connected to said last mentioned valve for opening the latter when the water level in said second separator is above a predetermined relatively low level.

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