

Aug. 23, 1966

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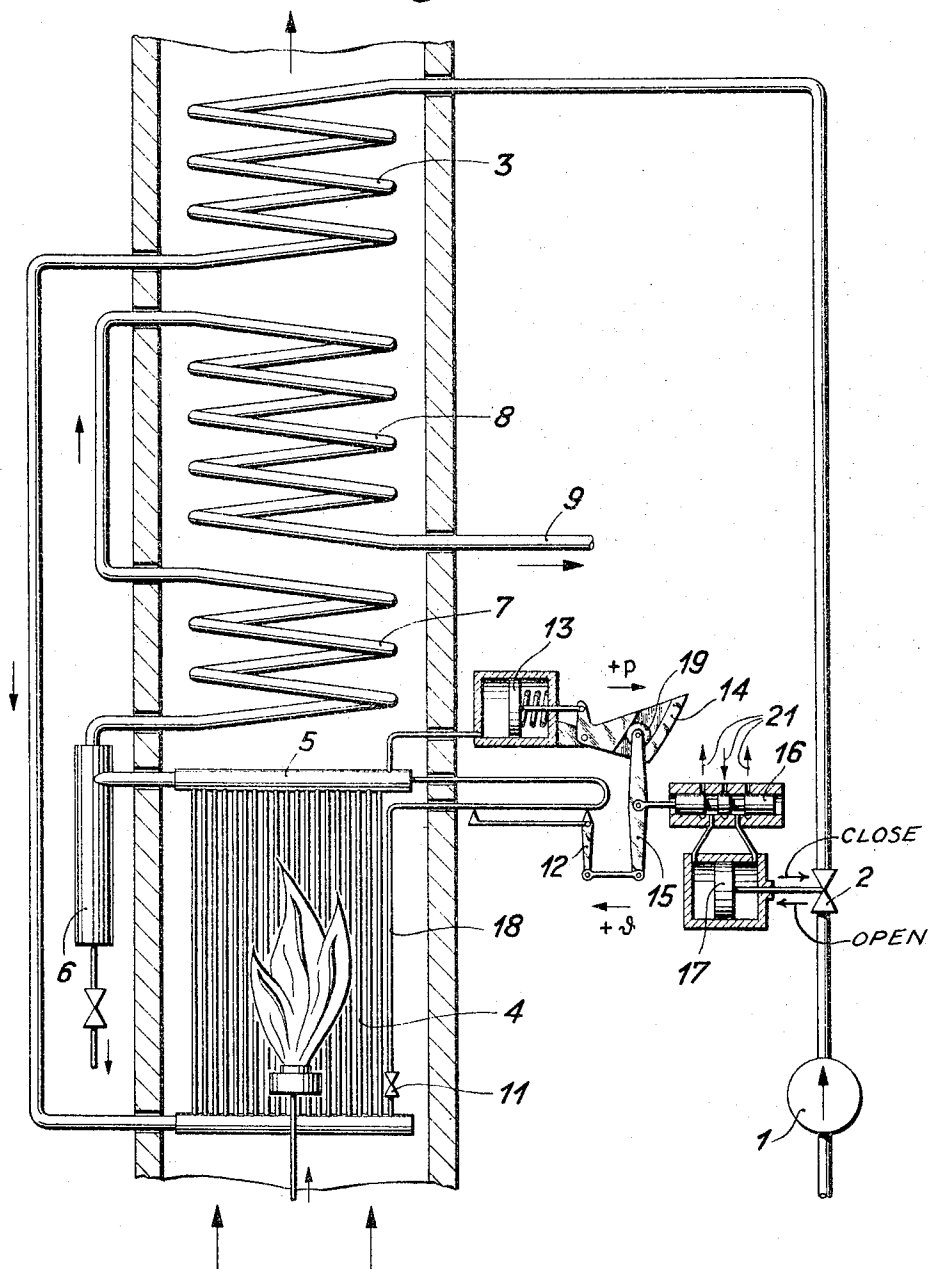
3,267,912

METHOD OF AND APPARATUS FOR INFLUENCING THE RATE OF FEEDWATER
SUPPLY TO FORCED FLOW STEAM GENERATORS

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3 Sheets-Sheet 1

Fig. 1



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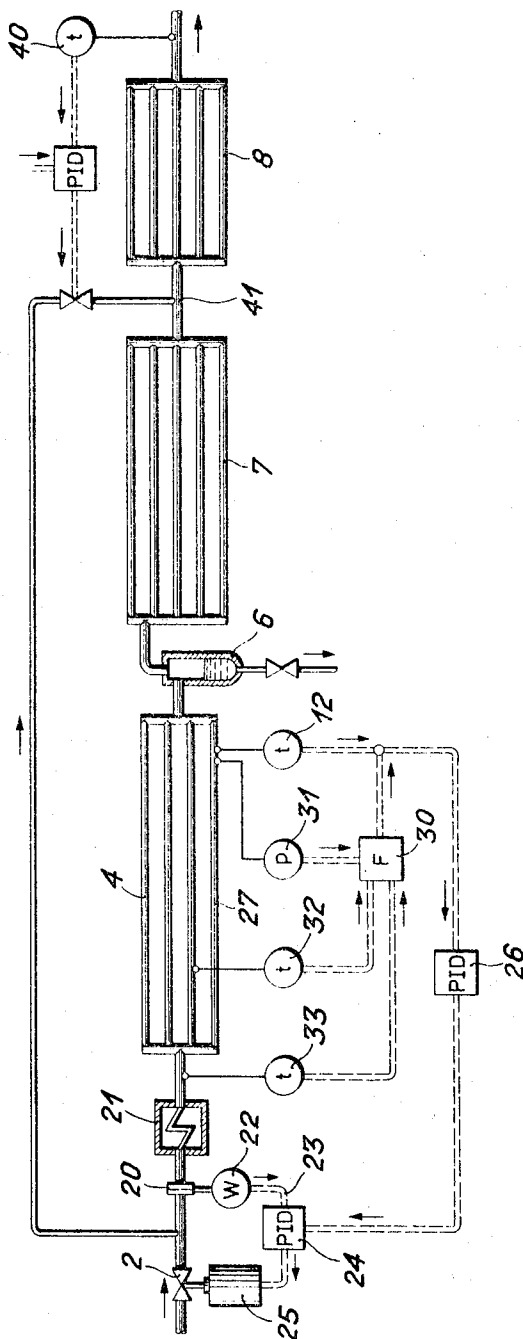
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3 Sheets-Sheet 2

Fig. 2



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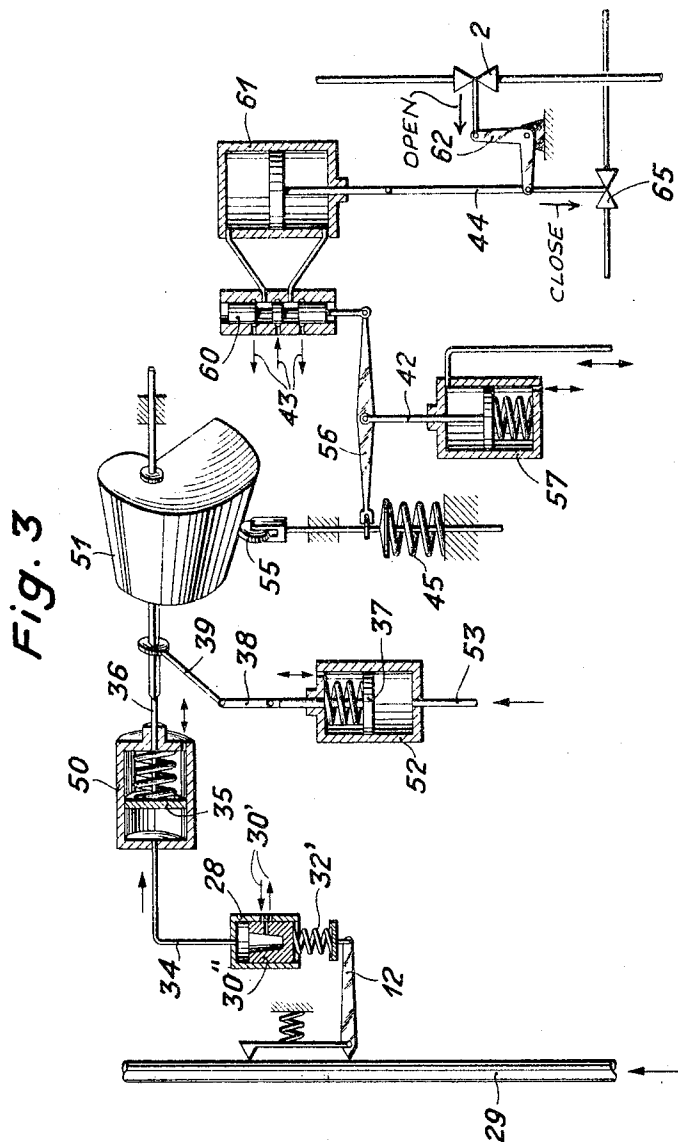
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3 Sheets-Sheet 3



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1

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METHOD OF AND APPARATUS FOR INFLUENCING THE RATE OF FEEDWATER SUPPLY TO FORCED FLOW STEAM GENERATORS**Fritz Läubli, Winterthur, Switzerland, assignor to Sulzer Brothers Limited, Winterthur, Switzerland, a corporation of Switzerland**

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Claims priority, application Switzerland, July 4, 1963, 8,332/63

10 Claims. (Cl. 122—451)

The present invention relates to a method of and apparatus for influencing the rate of feedwater supply to forced flow steam generators having water separators. The reference input signal in the aforescribed method is the temperature of a tube of the evaporating section of the forced flow steam generator which tube is so operated as to produce slightly superheated steam.

It is known to measure the temperature near the outlet end of at least one of a plurality of tubes of a forced flow steam generator which tubes form the evaporator of the steam generator and to influence the rate of feedwater supply to the steam generator according to said temperature. The tube or tubes of the evaporator at the outlet of which the temperature is measured are operated to produce slightly superheated steam whereas the outlet ends of the other tubes of the evaporator generally conduct saturated steam. A temperature change at the outlet of one of the tubes which is operated to produce slightly superheated steam corresponds to a change of the moisture content of the operating medium at the outlets of the other tubes of the evaporator which outlets are upstream of a water separator. In order to obtain a constant average moisture content and, consequently, a predetermined rate of blowdown the set point for the temperature of the steam at the outlet of the tube or tubes which is or are operated to produce slightly superheated steam is conventionally controlled in response to the load on the steam generator.

Ascertaining the relation between the load and the set point for the temperature of the steam leaving the tube of the evaporator producing slightly superheated steam is difficult and uncertain. Scaling and fouling of the tubes have a disturbing effect. Disturbances due to pressure variations at the steam-consuming end of the plant cannot be corrected.

It is an object of the present invention to provide a method and apparatus which avoid the aforescribed disadvantages of conventional arrangements.

In the method according to the invention the set point for the temperature of the steam leaving a tube of the evaporator which tube is operated to produce slightly superheated steam is influenced by a signal which depends at least on the steam pressure measured in the neighborhood of a water separator which is arranged immediately downstream of the evaporator.

In a modification of the invention the set point is additionally influenced by a signal which depends at least on one temperature which is measured in the evaporator upstream of the location where evaporation of the operating medium begins.

In the method according to the invention disturbing influences which are caused by changes of the tempera-

2

ture upstream or within the zone wherein the operating medium is evaporated are used to advantage for forming the set point for the temperature at the outlet of the evaporator tube which is operated to produce slightly superheated steam and for thereby maintaining a constant moisture content of the steam in the water separator. In the method according to the invention the aforesaid set point is reduced upon increasing temperature upstream of or within the evaporating zone.

In a forced flow steam generator wherein the rate of feedwater supply is influenced according to the aforescribed method a pressure-sensitive device is arranged in the neighborhood of the water separator and a temperature-sensitive device is placed at the outlet of a tube of the evaporator which is operated to produce slightly superheated steam. Both devices are operatively connected to a regulator for influencing the rate of feedwater supply to the evaporator.

In a further development of the invention at least one temperature-sensitive device is additionally provided at a location in the evaporator upstream of the point where evaporation of the operating medium begins. This additional temperature-sensitive device influences the set point for the temperature of the steam at the outlet of the tube of the evaporator which is operated to produce slightly superheated steam.

In another embodiment of the invention a function transmitter is used for forming the set point for the outlet temperature of at least one of the evaporator tubes which is operated to produce slightly superheated steam. The input side of this transmitter is operatively connected to a pressure-sensitive device placed in the neighborhood of the water separator and is also operatively connected to a temperature sensitive device which is placed upstream of the location where evaporation of the operating medium in the evaporator begins.

The regulator to which the pressure-sensitive device located in the neighborhood of the water separator and the temperature-sensitive device measuring the temperature at the outlet of an evaporating tube are operatively connected preferably has a proportional-integral-derivative character. The output signal of this regulator may be used as set point signal for an additional control circuit which controls the rate of feedwater supply of the forced flow steam generator.

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 wherein:

FIG. 1 is a diagrammatic part-sectional illustration of a control arrangement according to the invention and shows parts of a forced flow steam generator essential for the arrangement according to the invention.

FIG. 2 is a diagram illustrating a modified control arrangement according to the invention.

FIG. 3 is a diagrammatic part-sectional illustration of a further embodiment of a control arrangement according to the invention.

FIG. 1 is a schematic illustration of a portion of a forced flow steam generator into which water is fed by

a feed pump 1 through a feed valve 2. The generator comprises an economizer 3, an evaporator 4, a collector 5 at the outlet of the evaporator, a water separator 6, a preliminary superheater 7, and a final superheater 8 wherefrom steam is conducted to a consumer, not shown, through a pipe 9. The evaporator 4 comprises a plurality of tubes arranged in parallel relation with respect to the flow of operating medium therethrough. Flow of operating medium through one of the evaporating tubes, which is designated by numeral 18, is throttled by means of a valve 11. This has the effect that the operating medium at the outlet of at least one of the evaporating tubes is slightly superheated whereas the other tubes forming the evaporator generally produce wet steam. The temperature at the outlet portion of the tube 18 is measured by means of a temperature-sensitive device 12. The pressure in the collector 5 is measured by means of a spring-biased piston 13 which adjusts the position of a groove cam 14. A cam follower roller 19 is movable in the groove of the cam 14 and connected to the end of a two-arm lever 15 on the second end of which acts the temperature-sensitive device 12. The fulcrum of the two-arm lever 15 is mounted to the end of a piston rod connected to the end of a pilot valve 16 which controls flow of an actuating fluid to and from a piston 17. The latter is operatively connected to the feed valve 2 for actuating the feed valve.

With the aforescribed arrangement the pressure in the collector 5 produces by way of the groove cam 14 a set point for the temperature which is measured by the device 12. If, for example, at unchanged temperature at the outlet of the tube 18 the pressure in the collector rises, the piston 13 moves to the right as indicated by arrow $+p$ in FIG. 1. This causes clockwise swinging of the groove cam and movement of the roller 19 to the right in FIG. 1. Consequently, the piston valve 16 also moves to the right so that pressure fluid can flow (central arrow 21) to the left or front side of the piston 17 whereby the feed valve 2 is moved in a closing direction. If it is assumed that the pressure in the collector 5 is not changed and the temperature measured by the device 12 rises, the lower end of the lever 15 moves to the left as seen in FIG. 1 (arrow $+\delta$). This causes movement of the pilot valve 16 to the left and flow of pressure fluid to the right of the piston 17 for opening the feed valve 2. It is obvious that in lieu of the single tube 18 through which the flow of operating medium is throttled and at the end of which flows slightly superheated steam a plurality of such reduced-flow tubes may be provided as is shown, for example, in United States Patent No. 2,800,887. In this case a signal corresponding to the temperatures at the outlet of these tubes may be used for influencing the feedwater supply to the steam generator.

Without departing from the scope of the present invention the pressure may be measured at the outlet of an evaporator tube, in the steam space of the liquid separator 6 or in the pipe connecting the liquid separator to the preliminary superheater 7, instead of measuring the pressure in the collector 5. However, it is advisable to measure the pressure at a location which is close to the location where the temperature is measured.

In the embodiment of the invention shown in FIG. 2, the feedwater passes through a feed valve 2 into a preheater 21 and therefrom into an evaporator 4. The effluent of the evaporator flows into a water separator 6. The part of the operating medium not removed from the generator through the water separator flows consecutively through a preliminary superheater 7, a final superheater and therefrom to a steam consumer, not shown. A restrictor 20 is arranged downstream of the feed valve 2 and operatively connected to a device 22 for producing a signal corresponding to the flow rate of the feedwater. This signal is supplied through a conduit 23 to a proportional-integral-derivative (PID) regulator 24 which produces a set point for a motor operator 25 which actuates

the feed valve 2. The set point of the quick-acting control circuit 20, 22, 24, 25, 2 is supplied from a PID regulator 26 which compares the actual value of the controlled variable, i.e., the temperature measured at the outlet of a tube 27 forming part of the evaporator 4 by means of a temperature-sensitive device 12 with a set point value produced by a function transmitter 30. If the temperature sensed by the device 12 is too high the regulator 26 transmits a set point signal to the regulator 24 which causes increase of the rate of feedwater supply. The set point signal which is produced by the function transmitter 30 is dependent on a signal produced by a device 31 which senses the pressure at the outlet of the tube 27. The signal produced by the device 30 also depends on the temperature at an intermediate point of one of the tubes of the evaporator 4 measured by a device 32 and on the temperature of the feedwater entering the evaporator 4 and measured by a device 33. The device 31 measures the pressure in the tube 27 close to the location where the temperature is measured by the device 12. The locations where temperatures are measured by the devices 32 and 33 are upstream of the location where the operating medium is evaporated.

The temperature of the steam leaving the final superheater 8 which is measured by a temperature-sensitive device 40 is controlled in the conventional manner by injecting feedwater into the steam passing from the preliminary superheater 7 to the final superheater 8.

The operation of the function transmitter 30 will now be described with reference to FIG. 3 which shows another embodiment of the invention. A device 12 measures the temperature at the outlet end of evaporator tube 29. A spring-biased piston 30' is moved by the temperature-sensitive device 12 according to the measured temperature. The piston 30' controls ports for admitting and releasing a pressure fluid to and from a cylinder 28 wherein the piston 30' is movable (arrows 30'). When the piston 30' is in rest position the pressure in the cylinder counterbalances the pressure of spring 32' tending to press the piston 30' into the cylinder 28. The latter is connected by a pipe 34 to a servomotor cylinder 50 containing a spring-biased piston 35. The position of the piston 35 depends on the pressure of the pressure fluid in the cylinders 28 and 50. A cam means or shaped body 51 is connected to the piston 35 by a rod 36 for axial displacement of the body 51 upon movement of the piston 35. The pressure of a pressure fluid controlled by the pressure measured by the device 31 (FIG. 2) in the neighborhood of the separator 6 is conducted to the cylinder 52 through a conduit 53 and acts on a spring-biased piston 37 reciprocable in the cylinder 52. A change of the pressure in the conduit 53 causes movement of the piston 37 which movement is transmitted to the rod 36 by means of a linkage 38, 39 for rotating the body 51. A follower roller 55 is pressed onto the cam surface of the body 51 by means of a spring 45. The roller 55 is operatively connected to one end of a two-arm lever 56. The fulcrum of the lever 56 is formed by the free end of a piston rod 42 of a servomotor 57 which is hydraulically connected to a temperature-sensitive device, for example 32 or 33 in FIG. 2. The second end of the lever 56 is connected to a pilot valve 60 which controls supply and release of a pressure fluid to and from a servomotor 61. The latter includes a piston provided with a piston rod 44 which acts through an angle lever 62 on the feed valve 2 and which also acts on a fuel control device 65 for controlling the fire intensity or rate of fuel supply to the steam generator.

Operation of control arrangement according to FIG. 3:

An increase of the temperature in the evaporator tube 29 causes upward movement of the piston 30' so that pressure fluid is admitted to the cylinders 28 (upper arrow 30') and 50 and acts on the piston 35. The latter is thereby moved to the right in FIG. 3 and moves the body 51 also to the right, causing clockwise movement

of lever 56 so that pilot valve 60 is moved downward and pressure fluid (arrows 43) is admitted to the space in the cylinder 61 above the piston reciprocable therein. The result is a downward movement of the piston rod 44 and actuation of the feed valve 2 in opening direction and of the fuel valve 65 in closing direction. An increase of the steam pressure in the neighborhood of the water separator 6 causes upward movement of the piston 37 of the servomotor 52 and revolving of the body 51 in clockwise direction. The result is a downward movement of the roller 55 and counterclockwise swinging of the lever 56. This causes an upward movement of the pilot valve 60 and of the piston of the servomotor 61. The feed valve 2 is thereby moved in closing direction and the fuel valve 65 in opening direction. An increase of the temperature at the location upstream of the location where the operating medium is evaporated causes a downward movement of the piston of the servomotor 57 and a downward movement of the fulcrum of the lever 56 and of the pilot valve 60 and of the piston of the servomotor 61. This effects an increase of the rate of feedwater supply and a reduction of the rate of fuel supply.

In the embodiment of the invention shown in FIG. 2 the function transmitter 30 produces a signal depending on the temperatures of the operating medium at the locations 32, 33 upstream of the evaporation of the operating medium and depending on the pressure measured by the device 31 in the neighborhood of the water separator 6. This signal forms the set point for the temperature of the slightly superheated steam at the outlet of the throttled evaporator tube 27.

The arrangement shown in FIG. 3 may be interpreted as producing a set point for the temperature at a location upstream of the evaporation of the operating fluid by means of the function transmitter 51 in dependence on the temperature at the outlet of the throttled tube 27 and in dependence on the pressure measured by the device 31 in the neighborhood of the water separator 6.

In the method and apparatus according to the invention, of three variables, namely the temperature at the outlet of a throttled evaporator tube, the pressure in the neighborhood of a water separator arranged immediately downstream of the evaporator, and the temperature upstream of the zone where evaporation begins in the evaporator, two variables are used for producing a set point signal for controlling the third variable.

I claim:

1. A method of influencing the rate of feedwater supply to a forced flow steam generator including means for regulating the rate of feedwater supply to the steam generator, an evaporator composed of a plurality of tubes arranged in parallel relation with respect to the flow of operating medium therethrough, one of said tubes being provided with a throttling means and being operated to produce slightly superheated steam, the others of said tubes being operated to produce substantially saturated steam, and a water separator arranged downstream of said evaporator, the method comprising:

measuring the temperature of the steam substantially at the outlet of said tube producing slightly superheated steam for producing a signal corresponding to said temperature,

measuring the pressure of the steam adjacent said water separator for producing a signal corresponding to said pressure,

combining said two signals for producing a combined signal, and

influencing said means for regulating the rate of feedwater supply by said combined signal for increasing the rate of feedwater supply upon an increase of the temperature and for decreasing the rate of feed water supply upon an increase of the pressure, and conversely.

2. A method as defined in claim 1 wherein said two signals are combined in predetermined proportions.

3. A method of influencing the rate of feedwater supply to a forced flow steam generator including means for regulating the rate of feedwater supply to the steam generator, an evaporator composed of a plurality of tubes arranged in parallel relation with respect to the flow of operating medium therethrough, one of said tubes being provided with a throttling means and being operated to produce slightly superheated steam, the others of said tubes being operated to produce substantially saturated steam, and a water separator arranged downstream of said evaporator, the method comprising:

measuring the temperature of the steam substantially at the outlet of said tube producing slightly superheated steam for producing a signal corresponding to said temperature,

measuring the pressure of the steam adjacent said water separator for producing a signal corresponding to said pressure,

measuring the temperature in said evaporator upstream, with respect to the flow of the operating medium, of the location where evaporation of the operating medium begins, for producing an additional temperature-responsive signal,

combining said three signals for producing a combined signal, and

influencing said means for regulating the rate of feedwater supply by said combined signal for increasing the rate of feedwater supply upon an increase of the first mentioned temperature and of the additional temperature and for decreasing the rate of feedwater supply upon an increase of the pressure, and conversely.

4. In combination with a forced flow steam generator having an evaporator, means for supplying feedwater thereto, said evaporator comprising a plurality of tubes arranged in parallel relation with respect to the flow of operating medium therethrough, one of said tubes having an outlet portion and a throttling means for delivering slightly superheated steam through said outlet portion, the others of said tubes delivering substantially saturated steam, and conduit means connected to said evaporator for receiving operating medium therefrom, said conduit means including a water separator:

temperature-sensitive means connected to said outlet portion for producing a signal corresponding to the temperature of the steam delivered through said outlet portion,

pressure-sensitive means connected to said conduit means for producing a signal corresponding to the pressure of the steam adjacent said separator, and means for combining said two signals for producing a combined signal,

said feedwater supply means including means for influencing the rate of feedwater supply to said evaporator,

said last mentioned means being operatively connected to said signal combining means for receiving the combined signal therefrom and for actuation by said combined signal, for increasing the rate of feedwater supply upon an increase of the temperature and for decreasing the rate of feedwater supply upon an increase of the pressure, and conversely.

5. In the combination defined in claim 4, wherein said signal combining means includes means for combining said signals in predetermined proportions.

6. In the combination defined in claim 4, wherein said signal combining means is in the form of a proportional, integral, derivative regulator.

7. In combination with a forced flow steam generator having an evaporator, means for supplying feedwater thereto, said evaporator comprising a plurality of tubes arranged in parallel relation with respect to the flow of operating medium therethrough, one of said tubes having an outlet portion and a throttling means for delivering slightly superheated steam through said outlet portion,

the others of said tubes delivering substantially saturated steam, and conduit means connected to said evaporator for receiving operating medium therefrom, said conduit means including a water separator:

temperature-sensitive means connected to said outlet 5
portion for producing a signal corresponding to the
temperature of the steam delivered through said
outlet portion,
pressure-sensitive means connected to said conduit
means for producing a signal corresponding to the 10
pressure of the steam adjacent said separator,
second temperature-sensitive means connected to said
evaporator upstream, with respect to the flow of
the operating medium, of the location where evapo- 15
ration of the operating medium begins, for producing
an additional temperature-corresponding signal, and
means for combining said three signals for producing
a combined signal,
said feedwater supply means including means for in- 20
fluencing the rate of feedwater supply to said evap-
orator,
said last mentioned means being operatively connected
to said signal combining means for receiving the
combined signal therefrom and for actuation by
said combined signal, for increasing the rate of
feedwater supply upon an increase of the first men- 25
tioned temperature and of the additional tempera-
ture and for decreasing the rate of feedwater supply
upon an increasing of the pressure, and conversely.

8. In combination with a forced flow steam generator 30
having an evaporator, means for supplying feedwater
thereto, said evaporator comprising a plurality of tubes
arranged in parallel relation with respect to the flow of
operating medium therethrough, one of said tubes hav-
ing an outlet portion and a throttling means for deliver-
ing slightly superheated steam through said outlet por-
tion, the others of said tubes delivering substantially 35
saturated steam, and conduit means connected to said
evaporator for receiving operating medium therefrom,
said conduit means including a water separator:
temperature-sensitive means connected to said outlet
portion for producing a signal corresponding to the
temperature of the steam delivered through said out-
let portion,
pressure-sensitive means connected to said conduit 45
means for producing a signal corresponding to the
pressure of the steam adjacent said separator,
second temperature-sensitive means connected to said
evaporator upstream, with respect to the flow of the
operating medium, of the location where evapora- 50
tion of the operating medium begins, for producing
an additional temperature-corresponding signal,
a function transmitter operatively connected to said
second temperature-sensitive means and to said pres- 55
sure-sensitive means for receiving signals therefrom
and producing a combined signal, and
means for combining said combined signal with said
first temperature-corresponding signal for producing
a set point signal,
said feedwater supply means including means for 60
measuring the rate of flow of feedwater, and means
for influencing the rate of feedwater supply to said
evaporator,
said means for influencing the rate of feedwater supply 65
to the steam generator being connected to said
measuring means and to said last mentioned com-
bining means for receiving said set point signal there-
from and for increasing the rate of feedwater supply
upon an increase of said set point signal, and con- 70
versely.

9. In combination with a forced flow steam generator
having an evaporator, means for supplying feedwater
thereto, said evaporator comprising a plurality of tubes
arranged in parallel relation with respect to the flow of
operating medium therethrough, one of said tubes having 75

an outlet portion and a throttling means for delivering
slightly superheated steam through said outlet portion,
the others of said tubes delivering substantially saturated
steam, and conduit means connected to said evaporator
for receiving operating medium therefrom, said conduit
means including a water separator:

temperature-sensitive means connected to said outlet
portion for producing a signal corresponding to the
temperature of the steam delivered through said out-
let portion,
pressure-sensitive means connected to said conduit
means for producing a signal corresponding to the
pressure of the steam adjacent said separator,
second temperature-sensitive means connected to said
evaporator upstream, with respect to the flow of the
operating medium, of the location where evapora- 15
tion of the operating medium begins, for producing
an additional temperature-corresponding signal,
a function transmitter operatively connected to said
second temperature-sensitive means and to said pres-
sure-sensitive means for receiving signals therefrom
and producing a combined signal, and
means for combining said combined signal with said
first temperature-corresponding signal for producing 25
a set point signal,
said feedwater supply means including means for
measuring the rate of flow of feedwater, means for
influencing the rate of feedwater supply to said evap-
orator, a motor operator for said rate of feedwater
supply influencing means, and a regulator for said
motor operator,
said regulator being connected to said measuring means
and to said combining means for receiving said set
point signal therefrom and for actuation by said set
point signal for increasing the rate of feedwater sup- 35
ply upon an increase of said set point signal, and
conversely.

10. In combination with a forced flow steam generator
having an evaporator, means for supplying feedwater
thereto, said evaporator comprising a plurality of tubes
arranged in parallel relation with respect to the flow of
operating medium therethrough, one of said tubes having 40
an outlet portion and a throttling means for delivering
slightly superheated steam through said outlet portion,
the others of said tubes delivering substantially saturated
steam, and conduit means connected to said evaporator
for receiving operating medium therefrom, said conduit
means including a water separator:
temperature-sensitive means connected to said outlet
portion for producing a signal corresponding to the
temperature of the steam delivered through said out-
let portion,
pressure-sensitive means connected to said conduit 45
means for producing a signal corresponding to the
pressure of the steam adjacent said separator,
second-temperature-sensitive means connected to said
evaporator at a point upstream of the location where
evaporation of the operating medium begins for pro- 50
ducing a signal corresponding to the temperature
of the operating medium before evaporation thereof
begins,
a function transmitter operatively connected to said
pressure-sensitive means and to said first tempera-
ture-sensitive means for receiving the respective sig-
nals and for producing a signal therefrom, and
means connected to said function transmitter and to
said second temperature-sensitive means for com- 55
bining the signal produced by said second tempera-
ture-sensitive means with the signal produced by said
function transmitter for producing a set point signal,
said feedwater supply means including means for
measuring the rate of flow of feedwater and means
for influencing the rate of feedwater supply to said
evaporator,

said last mentioned means including a motor operator
and a regulator therefor,

said regulator being operatively connected to said
measuring means and to said combining means for
receiving said set point signal therefrom and for
actuation by said set point signal for increasing the
feedwater supply upon an increase of said set point
signal, and conversely.

5

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