

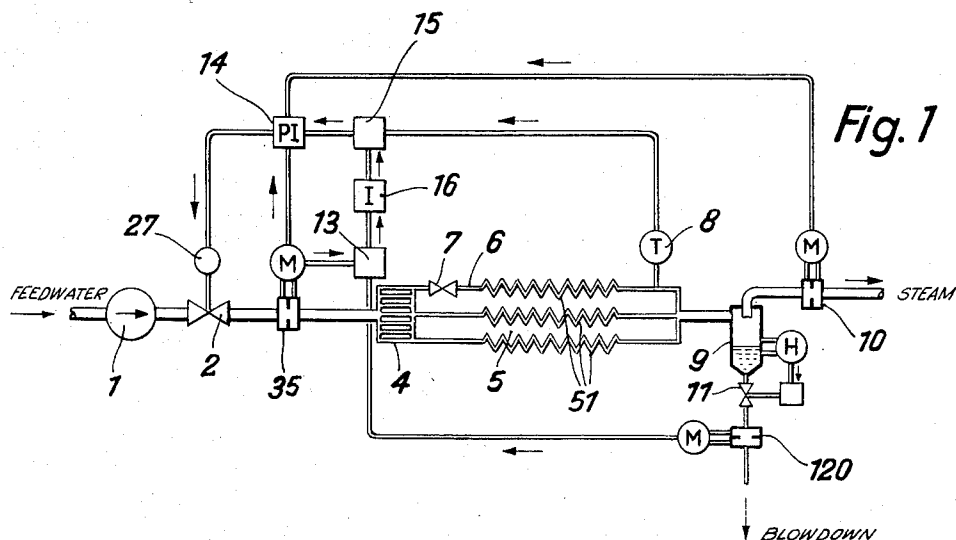
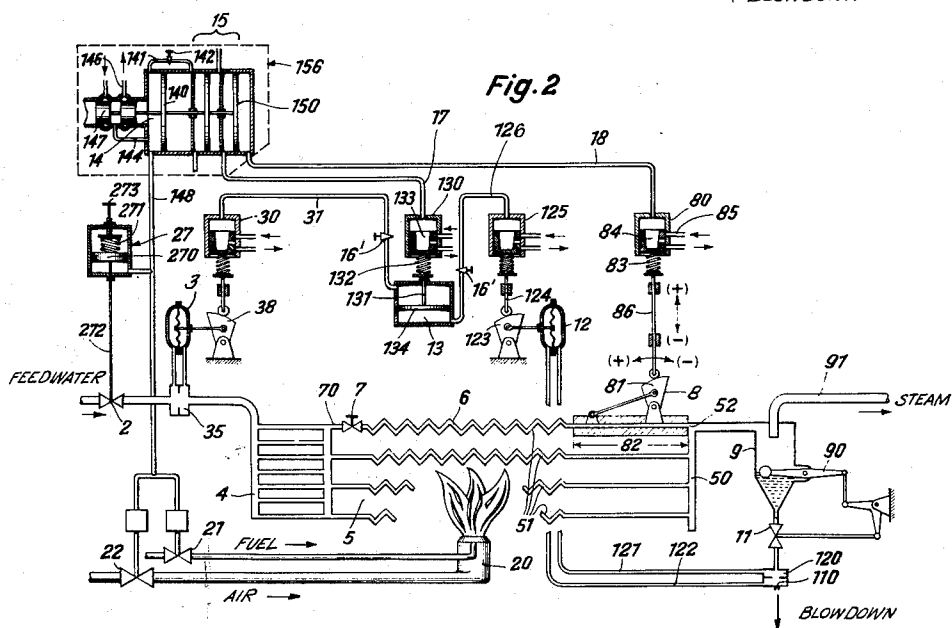
April 23, 1963

P. PROFOS
METHOD AND APPARATUS FOR CONTROLLING A FORCED
FLOW STEAM GENERATOR

3,086,504

Filed Feb. 24, 1959

3 Sheets-Sheet 1



INVENTOR.

PAUL PROFOS.

BY

K. A. May.

ATTORNEY.

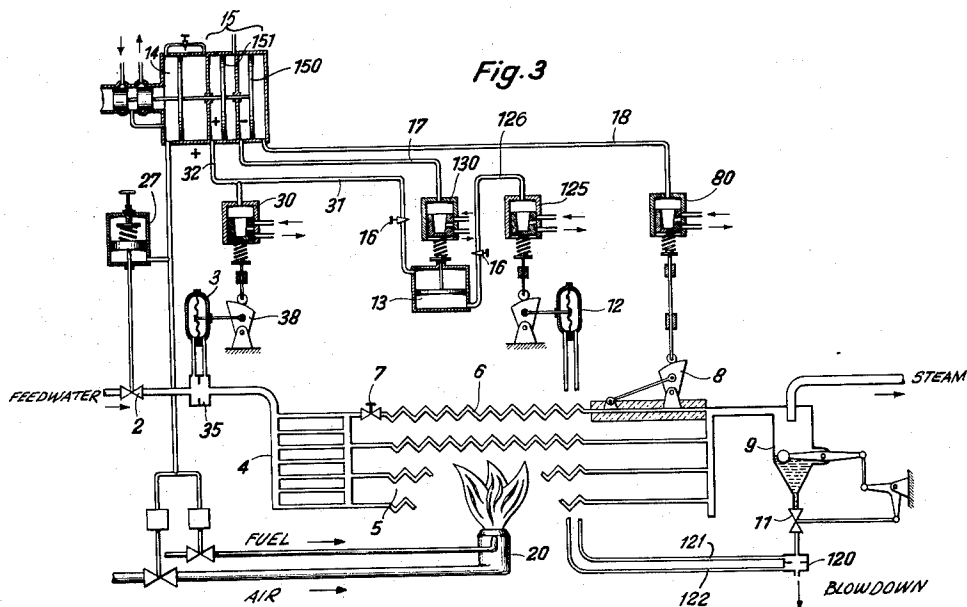
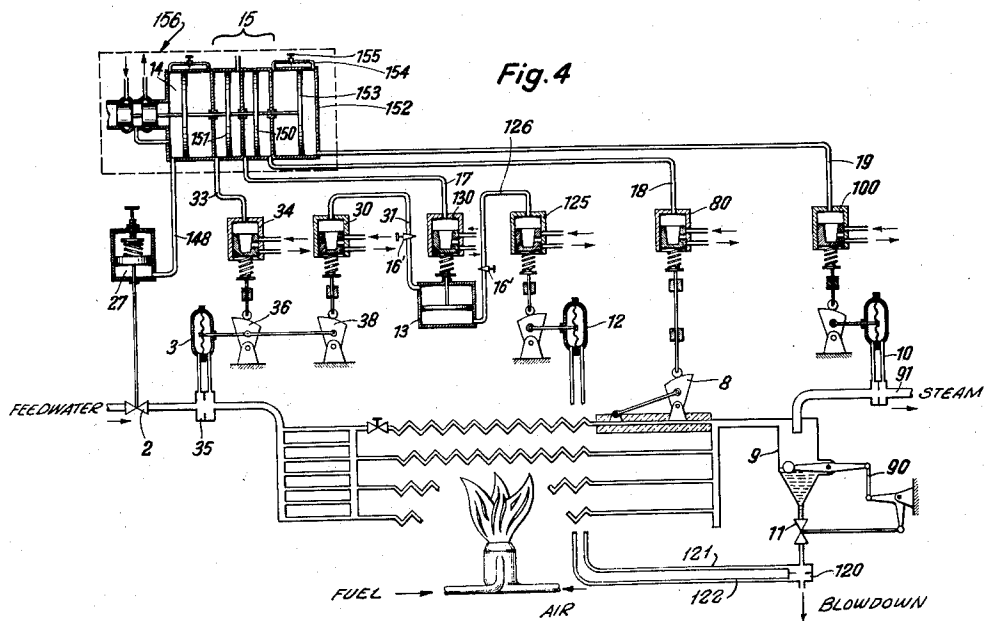
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PAUL PROFOS.
BY *K. A. May*
ATTORNEY.

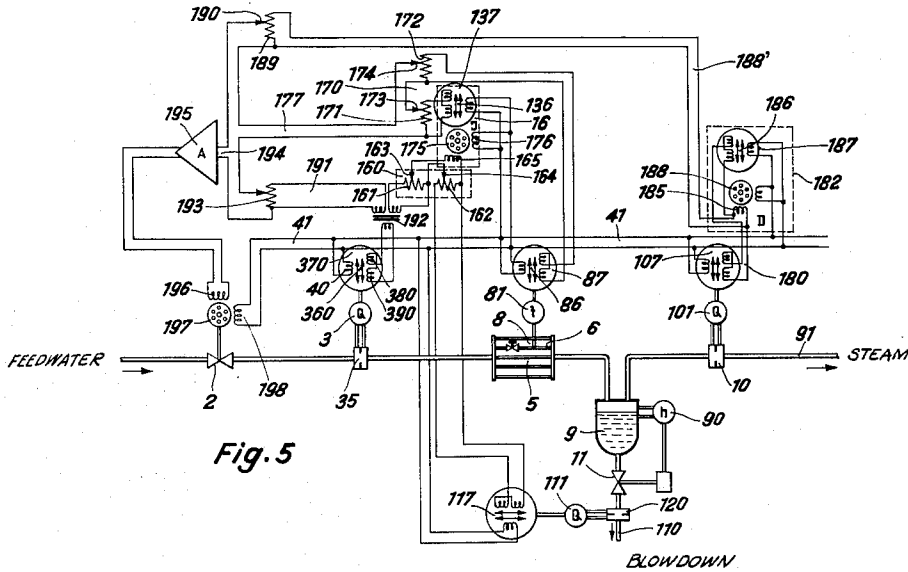
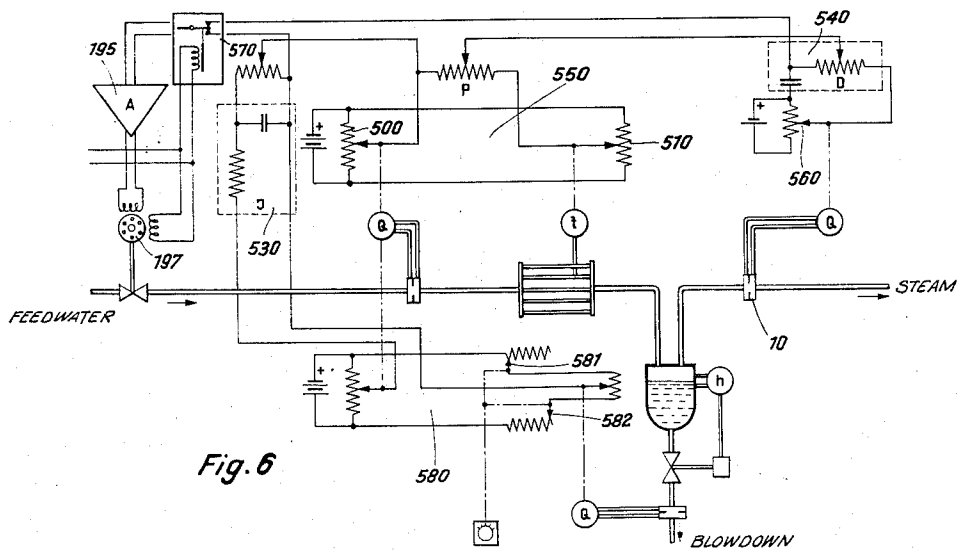
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3 Sheets-Sheet 3



INVENTOR.
PAUL PROFOS.
BY *K. A. Mays*
ATTORNEY.

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3,086,504

METHOD AND APPARATUS FOR CONTROLLING A FORCED FLOW STEAM GENERATOR

Paul Profos, Winterthur, Switzerland, assignor to Sulzer Freres, S.A., Winterthur, Switzerland, a corporation of Switzerland

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Claims priority, application Switzerland Feb. 26, 1958
10 Claims. (Cl. 122—451)

The present invention relates to a method for controlling a forced flow steam generator having a tubular heating system to one end of which a liquid operating medium is fed through a feed valve. Most of the liquid operating medium is vaporized and slightly superheated in a portion of the tubular heating system called the evaporating section. The part of the operating medium which is not evaporated is blown down and removed from the steam generator downstream of the evaporating section.

The invention is also concerned with an apparatus for carrying out the method, more particularly for controlling a forced flow steam generator to which the liquid operating medium is supplied by a feed pump through a feed valve which is arranged downstream of the feed pump. The liquid operating medium passes from the feed valve through an economizer and thereupon through a tubular evaporating section comprising a plurality of tubes arranged in parallel relation with respect to the flow of the operating medium. The inlet end of at least one of the last mentioned tubes, which shall be called the control tube, is provided with a throttling device. A steam-water separator provided with a blow down valve is arranged downstream of the evaporating section.

When operating and controlling a single tube once-through steam generator the problem arises of removing at a suitable location salts introduced with the feed water to prevent their deposit in the tubes. To do this, it has been proposed to evaporate only 95% of the water in the evaporating tube section and to blow down the salts with the remaining water in which they are concentrated and which is separated in a separator. The steam is conducted from the separator through a superheater and therefrom to the steam consumer.

In order to maintain a 95% evaporation, i.e., in order to maintain a predetermined moisture content in a certain section of the tube system of the steam generator, which is the object of the control system according to the invention, the medium flowing through one of the parallel tubes of the tube system may be throttled so that slightly superheated steam leaves this particular tube. The temperature of the superheated steam forms a measure for the moisture content of the wet steam leaving the other tubes of the system which are not throttled, and may be used as a signal or the selected reference for controlling the amount of feed water supplied to the steam generator. In order to obtain a constant mean moisture content of the steam entering the separator the temperature to which the automatic control responds must be changed when the load on the steam generator or the amount of feed water supplied to the steam generator changes, because the pressure in the evaporating section of the steam generator changes upon a change of the load.

One could think of controlling the moisture content of the steam leaving the evaporating section on the basis of the ratio between the feed water supplied to the steam generator and the amount of blow down water instead of on the basis of the temperature of the steam leaving a throttled tube. This method, however, is difficult to carry out because it is almost impossible to continuously blow down the water at the rate it is separated in the separator. Conventional blow down valves usually remove the water in

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batches. A corresponding signal would have to be extensively smoothed to make it suitable for control purposes. Such a smoothed and therefore delayed signal is too sluggish for actuating a moisture control.

It is the object of the present invention to provide a method and apparatus for controlling the operation of a forced flow steam generator which does not have the above described shortcomings of the conventional methods.

The method according to the invention comprises measuring the rate of flow of liquid medium fed into the tube system of the steam generator and transforming the measurements to a rate of flow signal, measuring the rate of flow of the blow down liquid and transforming this measurement to a second rate of flow signal, forming a signal corresponding to the ratio or to the difference between the two rate of flow signals, temporarily smoothing said combination signal for producing a first control signal, measuring the temperature of the superheated steam leaving a throttled control tube and before the steam enters the water separator and converting the temperature measurement into a second control signal, superimposing the second control signal on the first control signal for producing a main control signal, and proportioning the amount of water fed into the steam generator to the intensity of the heat supplied to the generator according to said main control signal. It is of advantage to measure the amount of the produced steam downstream of the blow down device and transferring the last mentioned measurement to an additional signal which is superimposed on the main signal. A further signal corresponding to the amount of operating medium fed into the steam generator and not smoothed may be superimposed on the main signal.

It may be of advantage to transform the main signal into a more powerful electric, hydraulic or mechanical signal.

The control apparatus according to the invention includes means for measuring the amount of feed water fed into the steam generator and producing a first signal, and measuring means for measuring the amount of blow down water removed from the steam generator and producing a second signal. These two signals actuate a comparison device which compares and measures the difference between the two signals and produces a signal corresponding to said difference. Integrating means are provided for smoothing the last mentioned signal. At the steam outlet end of the control tube line of the steam generator a temperature measuring device producing a temperature signal is arranged. There is a signal conductor connected with the aforesaid integrating means and a conductor connected with the temperature measuring means, both conductors terminating in a summing or totalizing device producing a main control signal corresponding to the difference between or to the sum of the integrated signal and the temperature signal. This main control signal activates control means which actuate the motor operator for the feed valve.

It is of advantage to arrange downstream of the steam water separator a device for measuring the amount of steam separated in the separator and for producing a signal which is conducted to the above-described summing device so that also this signal is added to the temperature signal and the integrated signal.

The signal produced by the device measuring the amount of feed water fed into the steam generator may also be added through a suitable conductor to the summing device and added thereto to the other signals received in the summing device.

In a modification of the apparatus according to the invention the device for measuring the rate of feed water flow may be provided with two coupled signal producers, one of which is directly connected by a suitable signal

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conductor to the totalizing means whereas the other signal producer is connected to the comparing device which is responsive to the signals produced by the feed water rate measuring device and by the blow down rate measuring device and measures the difference or the ratio between the rates of flow of feed water and of blow down water. The characteristics of the coupled signals may be different, i.e., the manner in which the signals are transmitted to the subsequent devices may be different for the two coupled signals.

The part of the summing device which is connected with the device for measuring the flow rate of steam leaving the steam water separator may include a differentiating device which automatically diminishes the effect of the signal produced by the steam measuring device.

The functional cooperation of the individual parts of the control apparatus may be improved by uniting the totalizing device with the controlling means for the motor operator and with the differentiating device to form a compacted unit.

The invention is a further development of the system disclosed in Patent No. 2,800,887.

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 schematic illustration of an automatic control apparatus according to the invention.

FIGURES 2, 3 and 4 are diagrammatic illustrations of three different embodiments of the invention, using hydraulic signal transmitting and operating power producing means.

FIGURES 5 and 6 are diagrammatic illustrations of two embodiments of the invention in which electric signals and operating means are used.

Referring more particularly to FIG. 1 of the drawing, numeral 1 designates a feed pump which supplies feed water through a feed valve 2 and a quantity or flow measuring device 35 to an economizer 4 from which the water is supplied to a plurality of evaporating tube lines 51 which are arranged in parallel with respect to the flow of the operating medium and which constitute the evaporating section 5 of a steam generator. At least one of the tubes 51 which shall be called the control tube 6 is provided at the inlet with a throttling device 7 and at the outlet with a temperature sensing device 8. The operating medium leaving the evaporating tubes 51 is conducted into a steam water separator 9 from which the separated steam is conducted through a quantity or flow measuring device 10 into a superheater, not shown. The liquid separated in the separator 9 is blown down through a blow down valve 11 and is measured in a quantity or flow measuring device 120 and thereupon removed from the system.

The blow down valve 11 is actuated in response to the liquid level in the separator 9 in the conventional manner, i.e., it is opened when the liquid level rises above a predetermined elevation and it is closed when the liquid level is below a predetermined elevation.

It is, for example, assumed that the average moisture content of the operating medium entering the separator 9 is 5%. The amount of feed water supplied to the steam generator is regulated by means of the feed valve 2 which is actuated in the customary manner by a temperature signal produced by the device 8 at the outlet of the leading or control tube 6, in response to signals produced by the feed water quantity measuring device 35, and in response to signals produced by the steam quantity measuring device 10 which signals all act on a controller 14. According to the invention signals produced by the device 120, which measures the rate of flow of blow down water, are compared in a comparing device 13 with sig-

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nals produced by the rate of feed water flow measuring device 35 and transformed into combination signals corresponding to the difference or the ratio between the blow down water rate and the feed water rate. This combination or comparison signal is smoothed by means of an integrating device 16 and conducted to a summing or totalizing device 15 in which the smoothed comparison signal is superimposed on the temperature signal produced by the device 8. The resulting main signal is conducted to the controller 14 which actuates a motor operator 27 operating the feed valve 2.

The control apparatus shown in FIG. 2 is fundamentally the same as that shown in FIG. 1. The feed water control valve 2 is actuated by a hydraulically operated motor operator 27. Downstream of the feed valve 2 is a feed water quantity measuring device 35 comprising an orifice and a conventional diaphragm device 3 whose diaphragm is bent according to the pressure difference upstream and downstream of the orifice, the movement of the diaphragm being transmitted to a cam 38. A cam follower member actuates a quantity or flow signal producing device 30 and delivers signals into a conductor 31. By suitable choice of the configuration of the cam 38 any desired functional relationship between the quantity of feed water and the energy of the produced signal can be obtained. The water flows from the quantity measuring device through an economizer 4 to an evaporating section 5 which has a plurality of parallel tube lines 51 one of which, the control tube line 6, is provided at the inlet 70 with a throttling device 7 and at the outlet 52 with a temperature measuring device. In the illustrated example the latter includes an insulated length 82 of the pipe 6 whose temperature elongation is used for actuating a cam 81. The latter acts through a cam follower rod 86 on a temperature signal producing device 80. Upon elongation of the pipe 82 the cam 81 is swung counterclockwise (+), lifting the rod 86 and compressing a spring 83 to which a hydraulic control piston 84 of the device 80 is connected which piston is also lifted upon lifting of the rod 86. A pressure fluid now enters the cylinder of the signal producing device 80 through a supply pipe 85 and flows therefrom through the signal conductor 18. By suitable choice of the configuration of the cam 81 any desired functional relationship between the measured temperature increase and the energy of the signal in the conductor 18 can be obtained.

The evaporating tubes 51 terminate in a header 50 from which the operating medium is conducted into a steam water separator 9, including a water level regulator 90 which actuates a blow down valve 11 in a blow down pipe 110. In the latter a quantity measuring orifice 120 is interposed. The pressures upstream and downstream of the orifice 120 are transmitted through conduits 121, 122 to the sides of a diaphragm in a device 12. The movements of the diaphragm are used for actuating a cam 123 which is so shaped and so connected to the diaphragm that upon an increase of the pressure difference a cam follower rod 124 is lifted. The rod 124 acts on a signal producing device 125 in the same manner as the rod 86 acts on the above described temperature signal producing device 80 so that when the rod 124 rises, a pressure fluid is conducted into a signal conductor 126. By suitable configuration of the cam 123 any desired functional relationship between the amount of blow down water measured by the device 120 and the energy of the signal in the conductor 126 can be obtained. In some cases it will be of advantage to make the signal in the conductor 126 proportional to the amount of blow down water.

The quantity or flow signal conductors 126 and 31 are connected to a comparing device 13 which includes a cylinder and a piston 134 movable therein, the chamber in the cylinder on top of the piston 124 being connected to the conductor 31 and the space in the cylinder below the piston 134 being connected to the conductor 126. In each of the conductors 31 and 126 a throttling device 16'

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is interposed which devices may be independently adjustable and act as integrating devices, smoothing the signals arriving through the conductors 31 and 126. The throttling or integrating elements 16' may be arranged to form a constructional and functional unit with the comparing device 13 in contradistinction to the arrangement shown in FIG. 1 in which the integrating device 16 is separated from the comparing device 13.

The integrating action of the elements 16' must not be understood in a strictly mathematical sense. The effect of these devices is a temporary transformation of the signals whereby a relatively strong signal is dynamically more braked than a smaller signal whereby energy peaks of the signals are partly reduced and energy bottoms are partly filled, resulting, to a certain extent, in a smoothing out of the signals. The degree of this smoothing effect can be changed by suitable adjustment of the throttling devices 16'.

The movement of the piston 134 is transmitted by a spring 132 to a piston valve 133 in a signal producing device 130 which sends a main control signal through a conductor 17 to a totalizing device 15. The latter also receives signals corresponding to the steam temperature at the outlet of the control tube 6 through the conductor 18 and subtractively combines the signals from the conductors 17 and 18 and transmits the resultant signal to a controller 14 which, in the arrangement shown in FIG. 2, together with the device 15 forms a functional and constructional unit 156. The latter includes a damping device 140 of the dash-pot type and having an equalizing pipe 141 with a throttling device 142 interposed therein. The controller 14 includes a hydraulic pilot valve 147 controlling flow through a feed-back pipe 144 and through a signal conduit 148 to a motor operator 27 for operating the feed valve 2 according to the main control signals in the conductors 17 and 18.

Instead of/or in combination with the actuation of the feed valve 2 the controller 14 may be used for controlling a fuel burner 20 whereby a fuel valve 21 and a combustion air valve 22 are actuated by the signals in the conductor 148.

The controller 14 may also be used for adjusting the ratio between the amount of feed water and the amount of heat supplied to the steam generator.

The control apparatus according to FIG. 2 operates as follows:

If, because of a disturbance, for example, produced by a change of load on the steam generator, the amount of blow down liquid rises because of too much moisture of the steam leaving the evaporating section 5, the device 125 produces signals in the conductor 121 corresponding to the increased amount of blow down liquid whereby the pressure in the space below the piston 134 of the comparison device 13 is increased, lifting the piston and compressing, by means of a piston rod 131, the cushioning spring 132 and lifting the valve 133 of the signal producing device 130 so that the energy of the signal in the conductor 17 increases. This causes yielding of the piston 150 in the device 15 to the right whereby this movement is damped by a dashpot piston 140 forming part of the controller 14. The pilot valve 147 connected to the piston 150 moves also to the right from its neutral position and permits pressure fluid to escape through a return pipe 146 whereby the control pressure in the pipes 144 and 148 is lowered.

This pressure reduction is transmitted through the pipe 144 to the left side of the damping piston 140 and through the conductor 148 to the lower side of the motor operator piston 270, so that a spring 271 moves the piston 270 downwards. A rod 272 connected to the piston 270 actuates the feed valve 2 in the closing direction. The tension of the spring 271 can be adjusted by actuation of a set point adjusting device 273 either by hand or automatically, for example, in accordance with the load on

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the steam generator or on the steam consumer supplied by the steam generator. The reduction of the pressure at the left side of the damping piston 140 is transmitted slowly through the conduit 141 and the throttling device 142 to the right side of the piston 140. The force acting on the piston 150 is counterbalanced only if the pressure on the left side of the piston 140 continuously drops until the force acting on the piston 150 disappears. The position of the piston 270 and of the valve 2 depends on the pressure at the left side of the piston 140.

The apparatus shown in FIG. 2 is adapted to respond relatively quickly to quantity changes and relatively slowly to temperature changes. The influence of a signal caused by a quantity change, for example feed water flow, is diminished after a brief rough correction of the feed water flow, in order to prevent control disturbances of long duration and to leave the control of the feed water supply primarily to temperature as the main control signal. In this way the temperature control acts as a delayed fine adjustment of the moisture content of the operating medium. The heat accumulating capacity of the tube length 82 delays the temperature measurements thereby delaying the action of the controlling means which are actuated by the temperature signals. A signal produced by a temperature increase produces increased pressure in the control conduit 148 and opening of the feed valve 2. In a control system including means for regulating the feed water flow relatively to the firing intensity, the firing intensity is reduced upon a decrease of the feed water supply.

Like parts are designated by like numerals in FIGURES 2 to 6.

The system illustrated in FIG. 3 is differentiated from that of FIG. 2 by the provision of a signal conductor 32 which directly connects the signal producing means 30 of the feed water flow measuring device 35 with the totalizing unit 15. In this way a preliminary correction of brief variations of feed water flow can be made within the initial time lag produced by the integrating devices 16', whereas a control signal caused by slow changes in the feed water flow, for example, due to a gradual change of load is compensated and rendered ineffective. The rate of this compensation can be influenced by providing two dissimilar cams 38 and 36 actuating two signal generators 30 and 34, respectively, as shown in FIG. 4. The compensation is effected by the action of the feed water flow signal (+) directly on the left side of the piston 151 causing an increased pressure thereat and, via the comparing device 13 and delayed by the integrating device 16', on the left side of the piston 150, decreasing the pressure thereat (-). The negative pressure acting on the piston 150 compensates wholly or partly the positive pressure acting on the piston 151.

The system shown in FIG. 4 has a steam flow measuring means 10 in addition to the systems shown in FIGURES 2 and 3. The means 10 measures the steam flowing through pipe 91 from the water-steam separator 9 and actuates via a cam on a primary element 100 producing pulses corresponding to the amount of steam flowing through the pipe 91 and being transmitted to the totalizing unit 15 through a conduit 19. In contradistinction to the other piston elements of the unit 15 the piston element 152 receiving the steam flow pulses has a differential effect produced by a pipe 154 by-passing a piston 153 forming part of the element 152 and including a throttle valve 155. The steam quantity signals become ineffective on the piston 153 after a period of time whose duration depends on the adjustment of the valve 155.

FIGURES 5 and 6 are diagrammatic illustrations of systems in which the method according to the invention is carried out by electrical means.

The system shown in FIG. 5 operates with alternating current signals and inductive signal transformers, whereas the system shown in FIG. 6 operates with D.C. sig-

nals whereby the signals are essentially transformed by means of potentiometers.

Numeral 35 in FIG. 5 designates a feed water flow meter including a quantity or flow signal producing device 3 in which the flow changes are transformed to mechanical movement in the conventional manner, for example, as shown in FIG. 2. The movement corresponding to a change of feed water flow is transmitted to an armature 360 of a variable differential transformer 370 whose secondary windings 380 and 390 are arranged in opposite direction. The primary winding 40 of the transformer is fed from a reference tension wire 41. Movement of the armature 360 causes an increasing or decreasing signal amplitude in the opposite secondary windings 380 and 390 whereby a phase change of 180° relative to the reference voltage occurs at the moment the alternating voltage becomes zero.

Measuring devices 10 and 120 of like construction are arranged in the pipe 91 conducting saturated steam from the separator 9 and in the blow down pipe 110, respectively. The devices 10 and 120 are operatively connected to signal generators 101 and 111, respectively, which may be of the mechanical or hydraulic type. The latter actuate inductive signal generators including differential transformers 107 and 117, respectively, which are identical to the aforescribed transformer 370. A temperature measuring device 81 is connected to the outlet end of the control tube 6 of the evaporating section 5 of a forced flow steam generator. The measurements of the device 8 are transformed into movements by a device 81 corresponding to the devices 3, 101 and 111. The so produced movements are transmitted to the armature 86' of a differential transformer 87 which is like the transformers 370, 107 and 117.

The signal produced in the differential transformer 117 and corresponding to the blow down water flow measured in the device 120 is compared with a flow signal produced in analogous manner by the differential transformer 370. For this purpose an electric comparing device 160 includes two variable resistors 161 and 162 arranged as a potentiometer. Wipers 163 and 164 are arranged in series relation and connected to a field coil 165 of an induction motor 175 so that the difference between the voltage of the signals coming from the inductive senders 370 and 117 produce a current in the field coil 165 which is proportional to this difference. The rate of influence of the signals can be varied by moving the wipers 163 and 164 on the potentiometer resistances 161 and 162, respectively. As long as the voltage of the coil 165 is zero the motor 175 stands still. If there is a voltage, the motor 175 turns to the left or to the right, depending on the position of the phase of this voltage whereby the speed of rotation of the motor depends on the amplitude. A second field coil 176, shown in FIG. 5 on the motor 175 as well as all other inductive senders and motors are connected to the wire 41 carrying the reference voltage. The rotation of the motor 175 is transformed, for example, mechanically, for example, by means of a pinion and a rack into a lifting or lowering movement of the armature 136 of an inductive sender 137 wherein the movement is transformed into an electric signal. This signal corresponds to the temporary sum of the signal voltage in the coil 165 and represents the temporary integral value of this voltage, however, not in the strictly mathematical sense. The motor 175 and the differential transformer 137 form an integrating element 16.

The integral value of the difference between the quantities measured by the devices 35 and 120, which value has been ascertained by the aforescribed electrical means, is compared with the temperature signal arriving from the temperature measuring device 8. This comparison is effected by an electric comparing device 170 which is arranged analogously to the devices 160 and includes two potentiometer resistances 171 and 172 and

wipers 173 and 174, respectively. The device 170 transforms the result of the comparison into a comparison voltage acting as a signal in a conduit 177.

The signal produced in the sender 107 and corresponding to the steam flow is conducted through a signal conductor 180 to a differentiating device 182 wherein the signal is compared with the signal produced by a motor driven inductive sender 187. The so produced voltage difference is effective in the field coil 185 of an induction motor 188.

The induction motor 188 is turned in the respective direction, changing the position of the armature 186 in the variable differential transformer 187 until the signal voltage of the transformer 187 corresponds to the signal voltage produced by the differential transformer 107 which acts as an inductive sender. After the equalization of the voltages the voltage in the coil 185 of the induction motor 188 disappears and the motor stops. In this manner the differentiating device 182 produces a vanishing signal at a change of flow through the device 10. This vanishing signal is conducted through a conductor 188' to a potentiometer 189 whose wiper 190 receives a portion of the signal voltage for adjustment of a suitable effect of the signal. A signal corresponding to the feed water flow measured by the device 35 is conducted through a conductor 191 pertaining to the signal range of the inductive quantity signal sender 370 through a transformer 192 to a potentiometer 193. The transformer 192 serves for galvanic separation of the potentiometers 161 and 193. In the illustrated example, the transforming ratio is 1:1 so that the voltage conditions are not changed by the galvanic separation. The potentiometers 189 and 193 as well as 171 and 172 which are at the same time under the influence of the electrically transmitted control signals add the received signal voltages and correspond as to their function to the totalizing unit 15 in the system shown in FIG. 1. The sum of the voltages of the individual potentiometers is transmitted to an inlet 194 of a conventional electric amplifier 195. Preferred are amplifiers having semi-conductive elements, electronic tubes, or magnetic amplifiers. The signal sum amplified by the amplifier 195 is conducted as control voltage to the field coil 196 of a motor operator 197 which actuates the feed valve 2. The second field coil 198 of the motor 197 is connected to the reference tension wire 41. The speed of the motor 197 depends on the amplitude of the signal transmitted to the field winding 196 whereas its direction of rotation depends on the position of the phase of the signal relatively to the position of the signal acting on the field winding 198. The motor stops, if the sum of the signals at the inlet 194 of the amplifier 195 is zero.

The aforescribed system causes operation of the motor operator 197 to close the feed valve 2 upon an increase of the amount of blow down water, whereas a temperature increase at the measuring device 8 effects the contrary. As in the hydraulic system shown in FIG. 4, change of the steam flow produces a signal which effects a quick actuation of the feed valve 2 by way of the differentiating device 182 according to a vanishing signal for a preliminary corrective change of the steam flow by increasing the feed water supply.

The relative action of the individual control means is essentially so arranged that the rough correction of the feed water supply caused by a change of steam flow diminishes as soon as the increased flow through the control tube 6 causes a change of the temperature at the location 8.

The function of the control system diagrammatically illustrated in FIG. 6 is substantially the same as the function of the system according to FIG. 5. What is different between the systems of FIGURES 5 and 6 is the manner of producing the signals. The controlled variables are measured in the same way as in the system according to FIG. 5 by transforming the measurements

first into mechanical motion of a motion transmitting member or of a liquid and thereupon transferring the movements to wipers of potentiometers. For example, a potentiometer 500 which is actuated by the feed water flow and a potentiometer 510 which is actuated by temperature in the control tube of an evaporating section of a steam generator are arranged to form a Wheatstone bridge which indicates the voltage relation of the two signals. The system according to FIG. 6 also includes an integrating element 530 and a differentiating element 540. The element 530 is formed, for example, by the conventional R-C arrangement and effects in the known manner a temporary summing of the relation between the amount of feed water and the amount of blow down water ascertained by the Wheatstone bridge arrangement 580. FIG. 6 illustrates only the principle of the electric connections of the element 530. These connections may consist of like R-C circuits arranged in series but may also consist of other suitable electric totalizing arrangements having an integrating character. The steam flow through the measuring device 10 operates the wiper of a resistor 560 producing a signal which is transformed into a vanishing signal in the differentiating device 540. The control system according to FIG. 6 includes a transformer 570 which transforms the sum of D.-C. signals received therein to an A.-C. signal which is amplified in a conventional amplifier 195 and therefrom transmitted to the motor operator 197 for the feed valve.

The function of both described electric control systems is analogous. The method according to the invention cannot only be carried out by the illustrated hydraulic and electric apparatuses and arrangements. For example, much more complicated electrical integrally and differentially acting elements may be used and include tube amplifiers and time relays. Electric, mechanical and hydraulic devices may be combined to produce an apparatus suitable for carrying out the method according to the invention.

For example, the electric comparing device 580 in FIG. 6 may include adjusting means consisting of potentiometer wipers 581 and 582 for adjusting the desired relation between the feed water flow and the blow down water flow.

I claim:

1. Method for controlling a forced flow steam generator wherein water is supplied to a tube system including an evaporating section comprising a plurality of tube lines arranged in parallel relation with respect to the flow of the operating medium and wherein the water is converted to steam containing some water which is separated from the steam in a separator downstream of the evaporating section, the evaporating section including a control tube line wherein the operating medium is slightly throttled and which discharges slightly superheated steam, the method comprising measuring the rate of flow of water fed into the tube system and producing a feedwater flow signal corresponding to the measured rate of feedwater flow, measuring the water separated in and flowing from the separator and producing a blowdown signal corresponding to the rate of flow of water from the separator, comparing the two signals and producing a first control signal corresponding to the difference between the amount of feedwater fed into the tube system and the amount of water flowing from the separator, smoothing said first control signal, measuring the steam temperature at the outlet of the control tube line and producing a second control signal corresponding to said temperature, combining the first control signal and the second control signal and producing a main control signal, and controlling the amount of feedwater fed into the tube system according to said main control signal whereby the amount of feedwater is increased upon a decrease of the amount of water flowing from the separator relative to the amount of feedwater fed into the tube system and upon an

increase of the temperature of the steam leaving the control tube line, and vice versa.

2. Method as defined in claim 1 including measuring the rate of steam flow from the separator and producing a third control signal corresponding to the rate of flow of steam from the separator, combining said third control signal with said main control signal and producing a modified main control signal, and controlling the amount of feedwater fed into the tube system in response to said modified control signal whereby the amount of feedwater is increased upon a decrease of the amount of water flowing from the separator relative to the amount of feedwater fed into the tube system and upon an increase of the temperature of the steam leaving the control tube line, and vice versa and upon an increase of the amount of steam flowing from the separator, and vice versa.

3. Method as defined in claim 1 including producing a second rate of feedwater flow signal corresponding to the measured rate of feedwater flow into the tube system, combining said second rate of feedwater flow signal with said main control signal and producing a modified main control signal, and controlling the amount of feedwater fed into the tube system in response to said modified control signal whereby the amount of feedwater is increased upon a decrease of the amount of water flowing from the separator relative to the amount of feedwater fed into the tube system and upon an increase of the temperature of the steam leaving the control tube line, and vice versa and upon a decrease of the amount of water fed into the tube system, and vice versa.

4. Method as defined in claim 1 including amplifying said main control signal.

5. In a forced flow steam generating plant including a feed pipe, a feedwater supply control means interposed in said feed pipe, an evaporating tube section connected to said feed pipe and having a plurality of tube lines arranged in parallel relation with respect to the flow of the operating medium: a control system comprising throttling means provided in the inlet portion of one of said tube lines, henceforth called the control tube line, a steam water separator connected to the outlet of said evaporating tube section for receiving steam therefrom and separating the water still contained in the steam from the latter, a blowdown pipe connected to said separator for removing the separated water therefrom, rate of feedwater flow measuring means connected to said feed pipe and including means for producing a first rate of flow signal corresponding to the rate of flow of feedwater through said feed pipe, a rate of flow measuring means connected to said blowdown pipe and including means for producing a second rate of flow signal corresponding to the rate of flow of the blowdown water, a comparing device connected to both said flow signal producing means for receiving said signals and producing a first control signal corresponding to the result of the comparison, said comparing device including signal integrating means effecting smoothing of said first control signal, a temperature measuring device connected to the outlet portion of said control tube line and including means for producing a second control signal corresponding to the temperature of the steam in said outlet portion, a signal totalizing means connected to said comparing device and to said temperature measuring device for producing a main control signal corresponding to the difference between said two control signals, and a motor operator connected to said totalizing means for receiving said main control signal therefrom to be actuated thereby, said motor operator being connected to said feedwater supply control means for actuating the latter to increase the feedwater flow in said feed pipe upon a decrease of the amount of blowdown water flow relative to the feedwater flow and upon an increase of the steam temperature in said outlet portion, and vice versa.

6. In a control system as defined in claim 5, a signal conductor directly interconnecting said rate of feedwater

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flow measuring means and said totalizing means for also directly combining said first rate of flow signal with said two control signals, to increase the feedwater flow in said feed pipe upon a decrease of the amount of blow-down water flow relative to the feedwater flow, upon a decrease of the feedwater flow, and upon an increase of the steam temperature in said outlet portion, and vice versa.

7. In a control system as defined in claim 5 and wherein said rate of feedwater flow measuring means includes two coupled means for producing two signals, each signal corresponding to the rate of flow of feedwater through said feed pipe, one of said coupled means being connected to said comparing device and the second coupled means being directly connected to said totalizing means for combining the signal produced by the second coupled means with said two control signals, to increase the feedwater flow in said feed pipe upon a decrease of the amount of blowdown water flow relative to the feedwater flow, upon a decrease of the feedwater flow, and upon an increase of the steam temperature in said outlet portion, and vice versa.

8. In a control system as defined in claim 5 and wherein a controller connected to and controlling the flow of energizing medium to said motor operator for actuation thereof is connected to said totalizing means for actuation thereby and forms a structural unit therewith.

9. In a control system as defined in claim 5 and wherein a steam pipe is connected to said separator for receiving the separated steam therefrom, a rate of steam flow

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measuring device being interposed in said steam pipe and including means producing a third control signal corresponding to the rate of steam flow, said rate of steam flow measuring device being connected to said totalizing means for combining said third control signal with said first two control signals, to increase the feedwater flow in said feed pipe upon a decrease of the amount of blow-down water flow relative to the feedwater flow, upon an increase of the steam flow in said steam pipe, and upon an increase of the steam temperature in said outlet portion, and vice versa.

10. In a control system according to claim 9 and wherein said totalizing means includes differentiating means receiving said third control signal and gradually diminishing the value of said third signal as it is added to the other signals received by said totalizing means.

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