

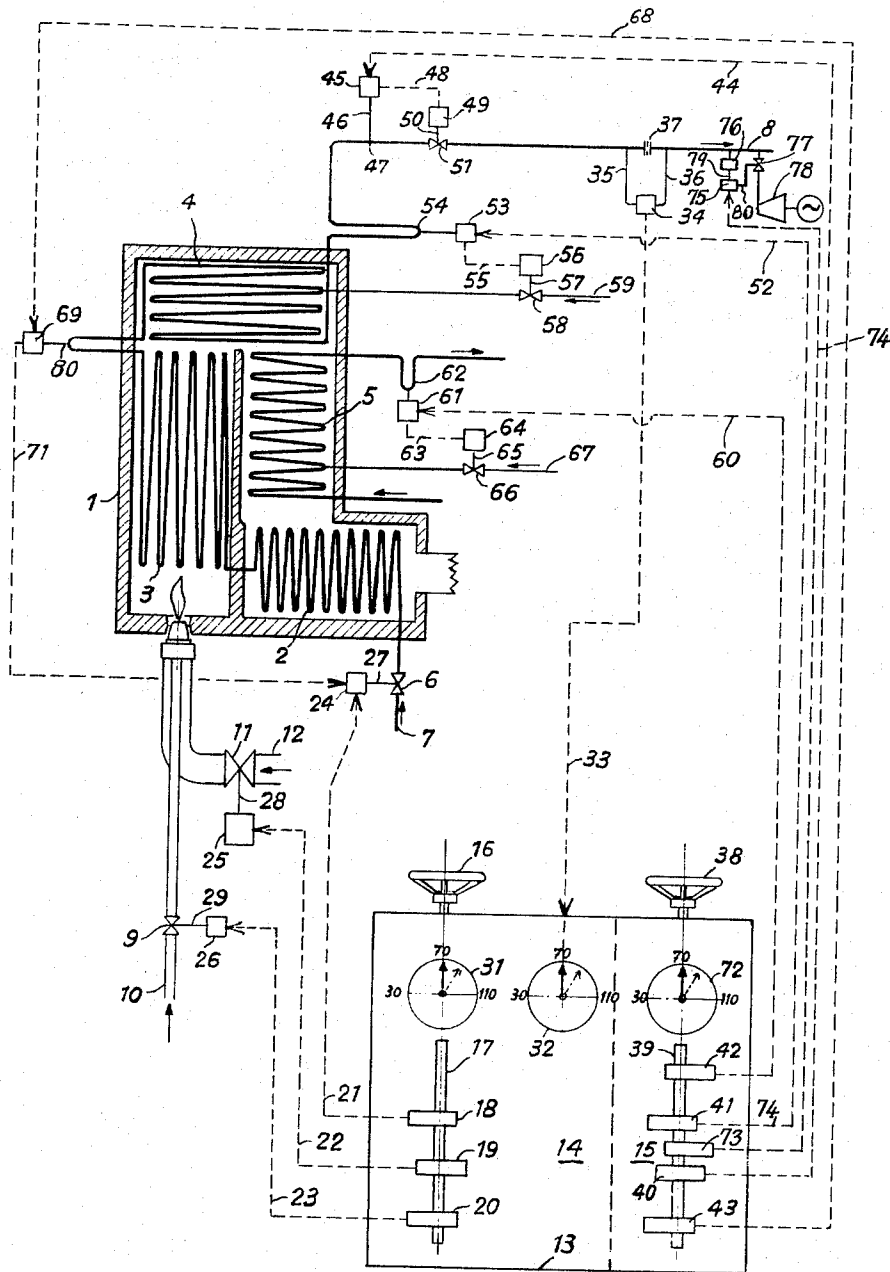
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CONTROL OF FORCED FLOW STEAM GENERATORS

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CONTROL OF FORCED FLOW STEAM GENERATORS

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The present invention relates to a system for regulating a forced flow steam generator supplying steam to a prime mover. The invention is particularly concerned with forced flow steam generators operating at supercritical pressure and including a resuperheater.

In the system according to the invention the supply of the operating media, i.e., fuel, air, and water to the steam generator are adjusted to conform the amount of steam produced to the load. After equilibrium between the amount of operating media supplied to the steam generator and the steam delivered by the steam generator has been attained, the steam pressure is adjusted to suit the new load.

The system according to the invention provides readjustment of the supply of the operating media at every change of load without initially affecting the steam pressure at a predetermined point of the plant and thereupon adjustment of the steam pressure to best suit the new load.

It may be advisable to control the steam temperature simultaneously with the adjustment of the steam pressure at at least one point of the tube system of the steam generator according to the load of the plant. Preferably also the temperature of the resuperheated steam is adjusted according to the load so that an optimum resuperheat temperature is provided at every individual load condition.

The system according to the invention includes a regulating mechanism which actuates at least one control device for the supply of the operating media to the steam generator, i.e., the feed water, the fuel, and the combustion air. Forced flow high pressure steam generators are usually provided with a device maintaining the pressure of the steam at the outlet of the steam generator at a predetermined level. In order to obtain a most efficient operation of the steam generator and of the apparatus driven by the live steam it is desirable that the pressure of the live steam be different at different load conditions. The system according to the invention includes a second regulating mechanism which actuates the pressure control device for the live steam to effect a predetermined live steam pressure for every individual load condition.

Forced flow high pressure steam generators are usually also provided with means for producing a predetermined temperature of the water or steam passing certain points of the tube system of the steam generator. In order to operate the steam generator at best efficiency at different load conditions the temperature at the aforesaid temperature control points must be different at different load conditions. The present invention, therefore, provides means for readjusting the setting of the temperature control means, this resetting being effected by the regulating mechanism which also actuates the control device for the live steam pressure control means.

If the steam produced in a forced flow high pressure steam generator is used for driving a turbine which is provided with an admission valve for automatically controlling the pressure of the steam entering the turbine,

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it is advisable to reset the control mechanism for this admission valve to produce a different predetermined or rated admission pressure for different load conditions of the turbine. The aforesaid second regulating mechanism according to the invention actuates a means for resetting the rated value of the setting of the turbine admission valve to suit different load conditions.

Forced flow steam generators are usually operated at substantially constant pressure, i.e., at a pressure which is independent of the load of the steam generator. It has also been proposed to operate forced flow steam generators at a variable pressure so that the pressure of the live steam is higher at greater loads and lower at low loads. One conventional method of operating forced flow steam generators is known as the sliding pressure method in which the steam pressure corresponds at every moment to the load on the steam generator. The use of this method involves considerable disadvantages because the regulating problems become very difficult and a quick change, particularly a quick increase, of the load is almost impossible with this method.

It is an object of the present invention to provide means for avoiding the aforesaid control difficulties by coordinating the steam pressure with the load only after a state of equilibrium has been obtained in the operation of the forced flow steam generator after each change of load. Changes of load are taken care of without changing the steam pressure which is measured at a certain point of the tube system of the steam generator. Only after the output of the steam generator has been changed to the new requirements and steady conditions prevail the pressure of the live steam is readjusted to a pressure corresponding to the new load.

The advantages of the system according to the invention include, inter alia, the possibility of absorbing sudden load increases by drawing on the steam and heat accumulating capacity of the steam generator, this capacity being quite considerable in forced flow steam generators although these generators contain a relatively very small amount of water and steam. Only after using up the heat accumulating capacity of the steam generator are the settings of the regulators of the steam pressure, of the steam temperature, and of other characteristics of the plant changed to suit the new load condition. This change of the rated values of the regulators for improving the efficiency of operation at various load conditions is effected only after equilibrium is restored between the output of the steam generator and the load. With the new system, in contradistinction to the conventional sliding pressure method, it is not necessary to simultaneously change the rate of evaporation and the steam pressure when the load changes. The new system considerably facilitates the control of the heating system as well as of the supply of feed water, of the temperature in individual sections of the tube system of the steam generator, and of the pressure of the live steam.

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 an embodiment thereof when read in connection with the accompanying drawing the one figure of which is a diagrammatic showing of a system according to the invention.

Referring more particularly to the drawing, numeral 1 designates a steam generator comprising an economizer 2, an evaporator 3, a steam superheater 4, and a resuperheater 5. The liquid operating medium is supplied through a pipe 7 which is provided with a feed water regulating valve 6. Numeral 8 designates a steam main receiving steam produced in the generator 1. The fuel is supplied to the steam generator through a conduit 10 provided

with a control valve 9. The air required for burning the fuel is supplied through a conduit 12 provided with a control valve 11.

Numeral 13 designates a regulating mechanism which includes a part 14 serving for changing the output of the steam generator and a part 15 separate from and independent of part 14 and serving for adjusting the rated values or set points of a plurality of control devices.

The part 14 of the regulating mechanism 13 includes a cam shaft 17 which can be rotated by means of a hand wheel 16 and on which three cams 18, 19, and 20 are mounted. The cams 18, 19, and 20 are individually connected by conventional pulse conduits 21, 22, 23, respectively, with control devices 24, 25, and 26, respectively. The control device 24 actuates through conventional transmitting means 27 the feed water regulating valve 6. The control device 25 actuates through a conventional transmitting means 28 the valve or damper 11 for controlling the supply of combustion air to the steam generator. The control device 26 actuates through a conventional transmission 29 the control device 9 for the fuel supply.

The hand wheel 16 and the shaft 17 are connected to an indicating device 31.

The regulating mechanism 13 includes also an indicating device 32 which is connected by a pulse conduit 33 with a steam flow meter 34, the latter being actuated by the pressure difference upstream and downstream of an orifice plate 37 in the steam main 8 with which the device 34 is connected by conduits 35 and 36.

The part 15 of the regulating mechanism 13 includes a cam shaft 39 which can be rotated by means of a hand wheel 38 and on which five cams 40, 41, 42, 43, and 73 are mounted. The cam 40 is connected by a pulse conduit 44 with a pressure sensitive means 45 which is connected with the point 47 of the steam main 8 by means of a conduit 46. A pulse conduit 48 connects the pressure sensitive device 45 with a control device 49 which actuates, through a transmission means 50, a valve 51 interposed in the steam main 8.

The cam 41 is connected by a pulse conduit 52 with a thermostat 53 which is connected with and responsive to the steam temperature at point 54 which is at the outlet of the steam generator 1. The thermostat 53 is connected by a pulse conduit 55 with a control device 56 which actuates by means of transmission means 57 a regulating valve 58 for controlling the amount of water injected through a pipe 59 into the superheater 4.

The cam 42 is connected by means of a pulse conduit 60 with a thermostat 61 which is arranged at the outlet 62 of the resuperheater 5. The thermostat 61 is connected by means of a pulse conduit 63 with a control device 64 which actuates by means of transmission means 65 a valve 66 for controlling the amount of water injected into the resuperheater 5 through a pipe 67.

The cam 43 is connected by means of a pulse conduit 68 with a thermostat 69 which is arranged at a point 80 of the tube system of the steam generator, the point 80 being between the outlet of the evaporator 3 and the inlet of the superheater 4. The thermostat 69 is connected by a pulse conduit 71 with the control device 24 for actuating the feed water regulating valve 6.

The cam 73 is connected by means of a pulse conduit 74 with and controls a device 75 which controls, through a transmission means 80, a valve 77 controlling the admission of steam to the turbine 78. The device 75 is also actuated by a device 76 which is responsive to the pressure in the steam main 8 and which transmits control pulses to the device 75 through a pulse conduit 79. The pulses transmitted through the conduit 74 change the setting of the device 75 so that the effect of the live steam pressure on the valve 77 is different at different output settings of the regulating mechanism 13 so that the turbine 78 can operate at best efficiency at all output conditions.

An indicating device 72 is connected with the cam shaft 39 and the hand wheel 38.

When the plant is normally operating, each control device produces a certain predetermined condition which is related to the load on the plant. These conditions, however, are only established after a steady operating condition or equilibrium is obtained after a change of load. In this case the indicating devices 31, 32, and 72 show the same values. In the illustrated arrangement the pointers of the three indicators point to the load condition 70, other load conditions being designated by numerals 30 and 110.

If it is desired to change the output, for example, to increase the output, the supply of the operating media to the steam generator must be changed accordingly. This is done by manipulation of the wheel 16, rotating the shaft 17 with the cams 18 to 20 until the hand of the indicator 31 assumes the position shown by a dotted line. Rotation of the cams 18 to 20 causes a change of the pulse pressures in the conduits 21 to 23 in the conventional manner. The feed water regulating device 24 is adjusted for increased feed water supply by the pressure in the pulse conduit 21. The supply of fuel and air is correspondingly changed by the control devices 26 and 25 due to the changed pressures in the pulse conduits 23 and 22. The increased steam output is indicated by the device 34 which transmits pulses by conventional, for example, hydraulic means through the conduit 33 to the indicator 32 moving the hand of the latter to the position shown by a dotted line so that eventually the indicators 31 and 32 will indicate the same output.

After change of the supply of the operating media to conform the steam output to the new load the setting or set point of the pressure and temperature control devices is changed to suit the new load whereby particularly the steam pressure in the steam main is adjusted to suit the new load. For this purpose the operator rotates the wheel 38 until the hand of the indicator 72 assumes the position shown by a dotted line, coordinating the indication of the indicator 72 with the indications of the indicators 31 and 32. Manipulation of the hand wheel 38 causes rotation of the shaft 39 and of the cams 40 to 43 and 73. This causes a change of the pressure in the pulse conduits 44, 52, 60, 68, and 74 by conventional, for example, hydraulic means. Rotation of the cam 40 affects the pressure sensitive device 45 through the pulse conduit 44 so that the control device 49 for the valve 51 is readjusted for changing the pressure maintained in the steam main to suit the new load condition. Likewise, rotation of the cam 43 affects the thermostat 69 through the pulse conduit 68 so that the feed water control valve 6 is so operated that a new temperature is produced at point 80 which new temperature corresponds to the new output of the steam generator. Rotation of the cam 41 changes the pressure in the pulse conduit 52 which affects the temperature sensitive device 53 to adjust the control device 56 in such manner that the valve 58 admits so much water to the superheater 4 that the steam temperature at point 54 is readjusted to suit the new load condition. Rotation of the cam 42 causes a change in the pulse conduit 60 which effects adjustment of the thermostat 61 to actuate the control device 64 in such manner that the valve 66 admits so much water to the resuperheater 5 that a new resuperheat temperature is maintained at point 62 which new resuperheat temperature assures most effective operation of the device operated by the resuperheated steam at the new load condition. Rotation of the cam 73 affects through the pulse conduit 74 the device 75 which is connected by means of a conduit 79 with a device 76 which responds to the pressure in the steam main 8. The device 75 controls the turbine steam admission valve 77 through a transmission means 80 in such manner that the admission pressure at the new load condition is adapted to operate the turbine at a pressure which ensures better operating

efficiency than the pressure which would be adjusted by the valve 77 if the rated value or set point of the automatic control of this valve would not have been adjusted for the new load condition.

If it is desired to adjust the plant for a reduced output, the supply of fuel, air, and water is reduced by manipulation of the wheel 16. The operator then waits until the hand of the indicator 32 indicates the same output as the hand of the indicator 31. Thereupon the wheel 38 is manipulated until the hand of the indicator 72 is in the same position as the hands of the indicators 31 and 32. By manipulation of the hand wheel 38 the part 15 of the regulating mechanism 13 effects change of the rated values or set points of the devices for automatically adjusting the steam pressure and the steam temperature to best suit the new load condition.

The invention is not limited to the specific arrangement shown in the drawing. The new system may, if desired, be adapted to adjust the control of the temperatures at more than two points of the tube system of the steam generator for effecting an optimum operating efficiency at all load conditions. The system may be adapted to serve two or more resuperheaters instead of only one resuperheater, as shown in the drawing. Superheaters at more than one pressure stage are particularly useful in plants in which the steam is produced at supercritical pressure.

Instead of arranging all control cams on a common shaft, as shown, an individual shaft and an individual hand wheel may be provided for each individual cam. Instead of actuating the shaft 17 of the first regulating mechanism 14 and the shaft 39 of the second regulating mechanism 15 by hand, the shafts 17 and 39 may be rotated by an automatically acting device. The transmission of pulses from the cams to the automatic controls of the individual regulating devices may be effected hydraulically, pneumatically, or electrically by conventional means, not shown, without departing from the scope of the present invention.

The new system which may be termed step pressure and temperature control system combines the advantages of the conventional constant pressure and temperature method during starting of the plant and changes of load with the advantages of the sliding pressure or temperature method which produces an improved thermodynamic efficiency during steady load conditions.

I claim:

1. In combination with a forced flow vapor generator, means for supplying fuel and air as elements of combustion and an operating fluid in liquid state to the generator, a pipe receiving the vapor produced by the generator, first regulating means connected to said means for supplying fuel and air and an operating fluid to the generator for simultaneously and interdependently changing the amounts of fuel, air and operating fluid supplied to the generator for changing the vapor output of the generator, a pressure regulating valve interposed in said pipe, automatic control means connected to said pipe upstream of said valve and responsive to the vapor pressure in said pipe and connected to said valve for actuating said valve to maintain a predetermined pressure in said pipe, and second regulating means separate from and independent of said first regulating means and connected to said automatic control means for changing the set point of said automatic control means for altering the vapor pressure to which said automatic control means is responsive and the pressure maintained in said pipe.

2. In combination with a forced flow vapor generator, a tube system including vaporizing tubes and superheating tubes, means for supplying fuel and air as elements of combustion to the generator, means for supplying an operating fluid in liquid state to said vaporizing tubes, a pipe connected to said superheating tubes for receiving

the vapor produced by the generator, first regulating means connected to said means for supplying fuel and air to the generator and to said means for supplying an operating fluid to said vaporizing tubes for interdependently changing the amounts of fuel and air supplied to the generator and of operating fluid supplied to said vaporizing tubes for changing the vapor output of the generator, a vapor temperature control device connected to said tube system, automatic control means connected to said tube system downstream of said temperature control device and responsive to the temperature of the vapor in said tube system and connected to said temperature control device for actuating the latter to maintain a predetermined temperature in said tube system, and second regulating means separate from and independent of said first regulating means and connected to said automatic control means for changing the set point of said automatic control means for altering the vapor temperature to which said automatic control means is responsive and the temperature maintained in said tube system.

3. In combination with a forced flow vapor generator, a vapor reheater, means for supplying fuel and air as elements of combustion and an operating fluid in liquid state to the generator, first regulating means connected to said means for supplying fuel and air and an operating fluid to the generator for simultaneously and interdependently changing the amount of fuel, air and operating fluid supplied to the generator for changing the vapor output of the generator, a vapor temperature control device connected to said reheater, automatic control means connected to said reheater downstream of said temperature control device and responsive to the temperature of the reheated vapor and connected to said temperature control device for actuating the latter to maintain a predetermined reheat temperature, and second regulating means separate from and independent of said first regulating means and connected to said automatic control means for changing the set point of said automatic control means for altering the temperature to which said automatic control means is responsive and the temperature maintained in said reheater.

4. In combination with a forced flow vapor generator, means for supplying fuel and air as elements of combustion and an operating fluid in liquid state to the generator, a pipe receiving the vapor produced by the generator, a vapor turbine, conduit means interconnecting said turbine and said pipe to direct a portion of the vapor flowing in said pipe to said turbine, a valve interposed in said conduit means for controlling the supply of vapor to said turbine, first regulating means connected to said means for supplying fuel and air and an operating fluid to the generator for simultaneously and interdependently changing the amounts of fuel, air and operating fluid supplied to the generator for changing the vapor output of the generator, automatic control means connected to said pipe and responsive to the vapor pressure in said pipe and connected to said valve for actuating said valve, and second regulating means separate from and independent of said first regulating means and connected to said automatic control means for changing the set point of said automatic control means for altering the vapor pressure to which said automatic control means is responsive and the vapor supplied to said turbine.

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