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APPARATUS FOR REGULATING THE RECIRCULATION OF WORKING MEDIUM IN A ONCE-THROUGH FORCE-FLOW STEAM GENERATOR

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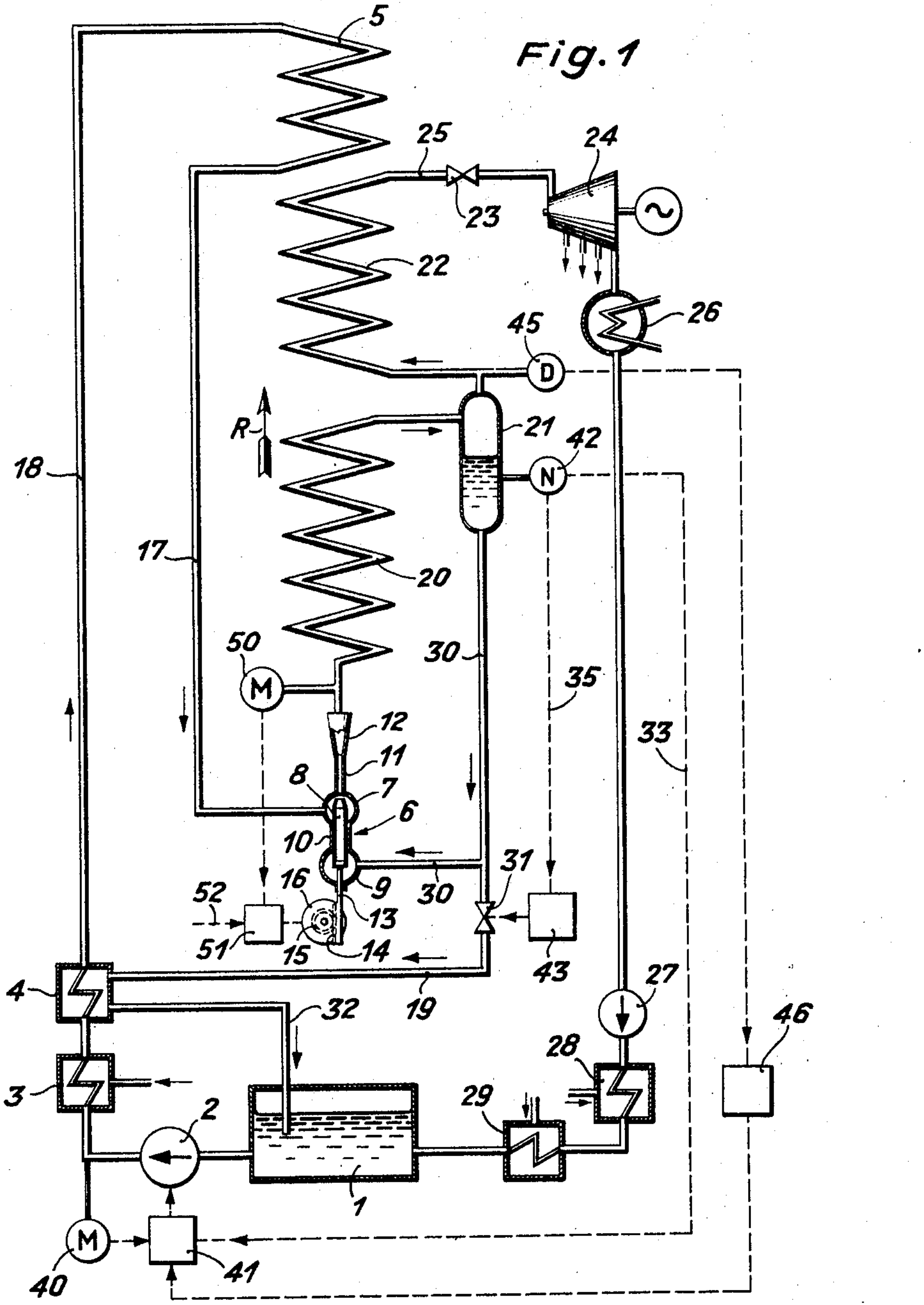

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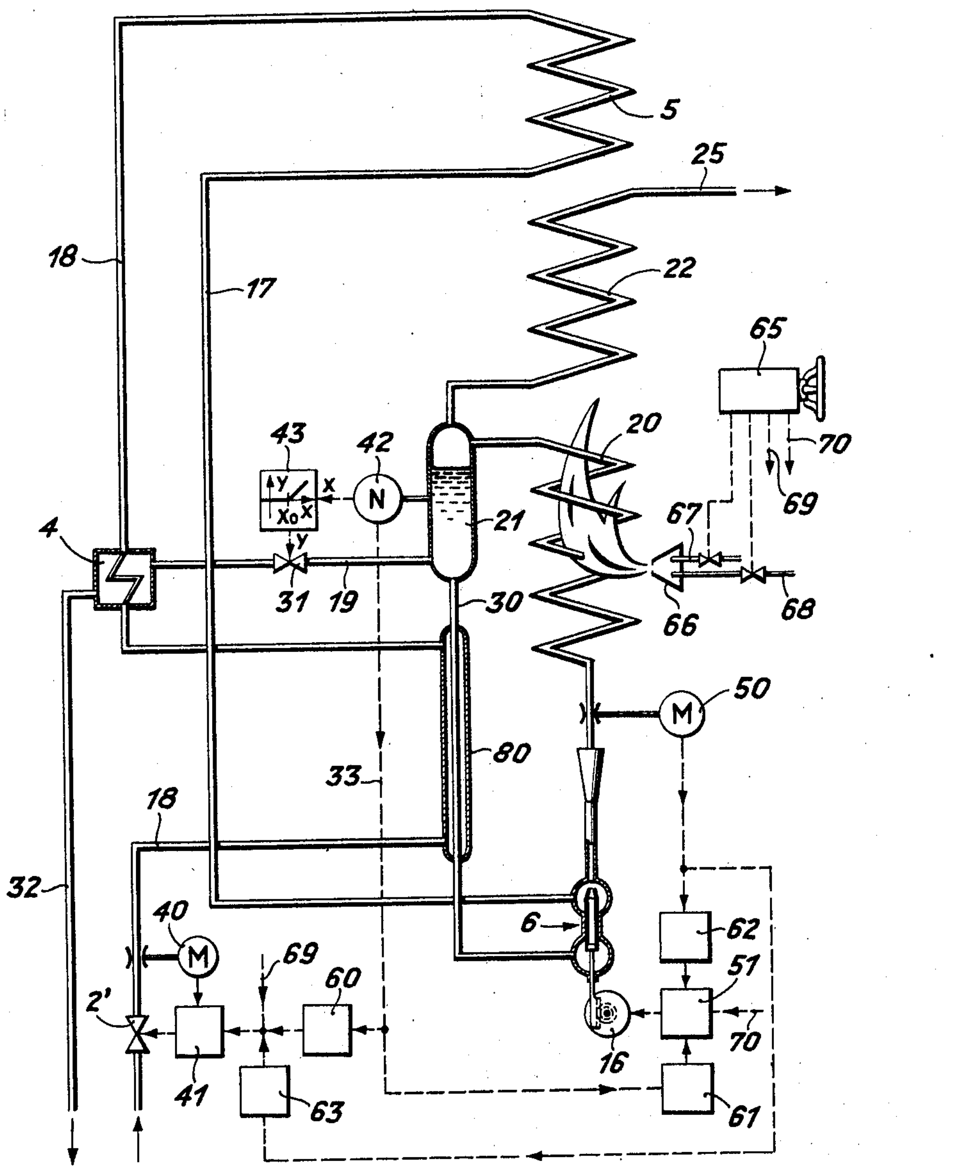
Fig. 2



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APPARATUS FOR REGULATING THE RECIRCULATION OF WORKING MEDIUM IN A ONCE-THROUGH FORCE-FLOW STEAM GENERATOR

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ABSTRACT OF THE DISCLOSURE

An ejector is positioned in the feedwater line downstream of the economiser and includes a hollow tubular needle which communicates with the recirculated working medium. The needle is slidably adjustable in response to the load to vary the flow cross-section of the feedwater so as to effect a variance in the amount of recirculated working medium drawn through the needle and mixed into the feedwater.

This invention relates to an apparatus for regulating the recirculation of working medium in a once-through force-flow steam generator. Still more particularly, this invention relates to an apparatus for ejecting recirculated working medium into an entrainment flow of feedwater to a heating surface of a steam generator.

It has been known to incorporate various types of ejector devices into the circuit of a once-through force-flow steam generator in order to eject a recirculated flow of working medium into the feedwater line downstream of a heating surface. Usually, the ejector device has been sub-divided into two stages for separately directing the flow of recirculating working medium and has been provided with entrainment nozzles in each stage which connect to the feedwater line via a branch line. In addition, an on-off valve has been included in the branch lines to control the flow of working medium into the feedwater line. The two stages of the ejector device have been dimensioned so as to be placed in operation either singly or together. Generally, such an ejector has satisfied the requirement of maintaining an adequate flow of working medium in the combustion chamber heating surface when the steam generator is started and shut down. However, in changing over from one stage to the other, adding the second stage, or shutting down one or both stages disadvantageous regulation disturbances have been transmitted into the steam generator such as to cause the operating characteristics of the steam generator to become substantially impaired.

Accordingly it is an object of the invention to provide a once-through force-flow steam generator with an ejector apparatus which does not result in regulation disturbances in the operating characteristics of the steam generator.

It is another object of the invention to adjust the flow of recirculated working medium by varying the flow cross-section of the entraining feedwater at a mixing position.

It is another object of the invention to avoid the use of valves in an ejector apparatus for ejecting recirculating working medium into the feedwater line.

Briefly, the invention provides an ejector apparatus for a once-through force-flow steam generator which includes a slidably mounted component for regulating the flow cross-section of the entrainment flow of feedwater to a heating surface of the steam generator. The component further communicates with a flow of working medium

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which is drawn off downstream of the heating surface to deliver the drawn off flow into the entrainment flow of feedwater at a mixing position for recirculation through the heating surface. The position of the component relative to the feedwater flow is varied according to the load of the steam generator so that the feedwater flow cross-section can be varied at the mixing position.

The entire feedwater flow passes through the ejector apparatus over the entire load range and the recirculated flow of working medium is adjusted in a simple manner by the slidably mounted component. Because of this, regulation disturbances are prevented from affecting the steam generator. The steam generator is thus able to exhibit good operating characteristics over the entire load range. Further, by being able to vary the flow cross-section of the entrainment flow of feedwater in dependence upon the load, the ejector apparatus component provides for optimum adaptation of the recirculated working medium to the load, that is, unnecessary power expenditure for the feedwater feed pump is avoided. Moreover, due to the absence of on-off valves, none of the disadvantages of such valves, for example, leakage and erosion of the valve spindle, can occur.

Preferably, the ejector apparatus component for varying the feedwater flow cross-section is constructed as a tubular member. In addition, the tubular member is mounted in the ejector apparatus in a longitudinally slidable manner and is connected to the line which conducts the recirculated working medium.

These and other objects and advantages of the invention will become more apparent from the following detailed description and appended claims taken in conjunction with the accompanying drawings in which:

FIG. 1 illustrates a schematic view of a steam generator plant incorporating an ejector apparatus of the invention therein; and

FIG. 2 illustrates a schematic view of a modified steam generator plant incorporating the ejector apparatus of the invention therein.

Referring to FIG. 1, the once-through force-flow steam generator substantially comprises an economiser heating surface **5**, an evaporator surface **20** which is highly stressed by the incident heat, and a superheater surface **22**. These heating surfaces are serially disposed in the flow of working medium. The firing system, not shown, of the steam generator is disposed in the zone of the heating surface **20** and delivers a flow of combustion gases in the direction of the arrow R along the superheater surface **22** and the economiser heating surface **5**. An ejector apparatus **6** is connected between the economiser heating surface **5** and the evaporator heating surface **20**.

The ejector apparatus **6** includes a housing which substantially defines an entrainment chamber **7**, a supply chamber **9**, and a cylindrical portion **10** which joins the entrainment and supply chamber **7**, **9** to each other. The economiser heating surface **5** communicates with the entrainment chamber **7** through a line **17** to deliver a flow of feedwater into the entrainment chamber **7** while the evaporator surface **20** communicates via a water separator **21** between the evaporator surface **20** and superheater surface **22** with the supply chamber **9** through a line **30** to deliver a flow of working medium for recirculation into the supply chamber **9**. In addition, the ejector apparatus **6** includes a hollow tubular nozzle needle **8** which is mounted, in a guided manner within the cylindrical portion **10** of the housing. The nozzle needle **8** is coupled to a rod **13** which has a plurality of teeth **14** at one end which cooperates with a pinion **15** of a servomotor **16**. The servomotor **16** is operated to cause the nozzle needle **8** to be axially moved within the cylindrical portion **10** and entrainment chamber **7** to vary the flow cross-section of the feedwater flowing through the entrainment chamber **7**.

The housing of the ejector apparatus 6 also defines a mixer tube 11 and a flow diffuser 12 connected downstream of the entrainment chamber 7 for mixing of the feedwater which acts as an entrainment medium and the recirculated working medium. In order to regulate the operation of the servomotor 16, a flow rate measuring element 50 is connected between the diffuser 12 and the evaporator heating surface 20 to measure the flow rate of the mixed entrainment medium and working medium. The flow rate measuring element 50 is operatively connected via a regulator 51 to the servomotor 16 to deliver a signal to the servomotor 16 in response to the measured flow rate. In addition, a set value signal obtained from a load control apparatus, not shown, is supplied to the regulator 51 via a signal line 52 for comparison with the measured signal from the flow rate measuring element 50 so that the servomotor 16 is actuated in response to the compared signals.

The feedwater is supplied to the economiser heating surface 5 from a feedwater tank 1 via a feed pump 2, steam-heated preheater 3 and a cooler 4 in a feedwater line 18. The cooler 4 is connected on the primary side via a line 19 to the recirculating line 30 and via a line 32 to the feedwater tank 1. The superheater surface 22 connects via a live steam line 25 containing a valve 23 to a turbine 24 whose exit extends to a condenser 26. The condenser 26 is connected via a condensate pump 27 and a pair of preheaters 28, 29 with the feedwater tank 1.

A flow rate measuring element 40, which acts on the feed pump 2 via a feedwater regulator 41, is provided in the feedwater line 18 downstream of the feed pump 2 to measure the flow in the line 18 and regulate the pump 2 in response thereto. The regulator 41 is also provided with a reference value in the form of a signal which depends on the level in the water separator; the signal being transmitted by a level measuring element 42 via a signal line 33. The regulator 41 is also provided with a steam flow rate signal tapped off by means of a steam flow rate measuring element 45 downstream of the water separator 21 and fed via a regulator 46 into the circuit in the form of a disturbance value. The level measuring element 42 also biases, via a signal line 35 and a regulator 43, a valve 31 in the line 19 which extends to the cooler 4.

When the steam generator is in operation, feedwater is supplied from the tank 1 by means of the feed pump 2 via the feedwater line 18 to the economiser heating surface 5 from which it is transferred to the evaporator heating surface 20 via the line 17, the entrainment chamber 7, the mixing tube 11 and the diffuser 12. The working medium, which will have been largely evaporated, then the steam trap 21 from which the vaporized part of the medium flows into the superheater surface 22 and thereafter via the live steam line 25 to perform work in the turbine 24. The steam expanded in the turbine 24 is then condensed in the condenser 26 and delivered by means of the condensate pump 27 into the feedwater tank 1. The quantity of feedwater supplied to the steam generator is measured by the measuring element 40 and regulated by the feedwater regulator 41 by varying the speed of the feed pump 2.

The liquid separated from the steam in the steam trap 21 is fed back via the recirculating line 30 into the evaporator heating surface 20 by being drawn up by the feedwater which flows through the entrainment chamber 7 so that after flowing through the supply chamber 9 and the tubular nozzle needle 8 the liquid is mixed in the mixing tube 11 with the entrainment medium. The working medium which flows through the evaporator heating surface 20 is measured by the measuring element 50 and a measured value signal corresponding to the flow is supplied to the regulator 51 in which the measured value is compared with the set value. The servomotor 16 is driven on the basis of the comparison to axially displace the tubular needle 8, to vary the flow cross-section of the entrainment medium at the mixing position. This causes an adjustment in the working medium flow returned from the water separator 21.

If the amount of fuel supplied to the system is reduced, starting from full load conditions of the steam generator, the level in the water separator 21 will rise so that the amount of feedwater is reduced via the signal line 33, the regulator 41 and the feed pump 2. This in turn results in a reduced flow through the evaporator heating surface 20 so that the signal supplied by the measuring element 50 becomes smaller. By virtue of this aforementioned signal the regulator 51 biases the servomotor 16 in the sense that the servomotor moves the tubular nozzle needle 8 slightly in the upward direction (as viewed in FIG. 1). The needle 8 thus reduces the flow cross-section of the entrainment medium and increases the pressure thereof in the entrainment chamber 7 so that the exit velocity of the entrainment medium into the mixing tube 11 is also increased. This in turn results in an increase of the amount of liquid drawn up from the supply chamber 9 and recirculated from the water separator 21 so that the total amount of water supplied to the evaporator heating surface 20 once again corresponds to the set value supplied via the line 52.

It is a condition for the operator of the steam generator that the amount of water delivered by the feed pump 2 is a minimum and that the delivery must not drop below the minimum, for example, 15% of the working medium, under full load conditions. This is achieved with known means not shown in this context. For example, if the boiler load drops below the load corresponding to the minimum amount of water, the level in the water separator 21 will rise to a limiting value to trigger a limiting value signal in the regulator 43 which, in this case, is constructed as a limiting regulator so that the valve 31 is opened. Thus, at minimum load, part of the water separated in the water separator 21, will be returned via the line 19, the cooler 4 and the line 32 into the feedwater tank 1. The desired amount of water is therefore introduced into the evaporator heating surface 20 even at minimum loads without the feedwater pump pressure having to be increased beyond permissible limits.

It is also possible to omit the measuring element 50 in accordance with an embodiment of the invention which is not shown. In such an embodiment, the tubular nozzle needle 8 is directly adjusted via the regulator 51 and/or servomotor 16 by a load governor which supplies the final control signal instead of the signal being supplied by a set value of the flow rate. This is possible because the position of the tubular nozzle needle depends substantially only on the load.

It is furthermore possible to allow the measuring signals of the measuring elements 50 and 42 to act in an interchanged manner relative to the arrangement illustrated in FIG. 1, that is, the signal in the line 33 acts upon the regulator 51 while the signal of the flow-measuring element 50 is applied to the feedwater regulator 41.

In an exemplified embodiment illustrated in FIG. 2, the construction of the steam generator is substantially the same as that of FIG. 1 as indicated by like reference characters but incorporates process control refinements which are obtained by the combination of regulating signals. Referring to FIG. 2 the measuring signal of the level measuring element 42 acts via the line 33 on a feedwater regulator 41 which adjusts the feedwater regulating valve 2′ as well as on the tubular needle regulator 51 with a regulator 60, 61 respectively preceding the regulators 41, 51 in both cases. The measuring signal of the flow rate measuring element 50 acts in analogous manner both on the tubular needle regulator 51 as well as on the feedwater regulator 41; a regulator 62, 63 respectively being similarly disposed upstream of the two regulators 41, 51. In addition, a load governor 65 which adjusts the amount of air or fuel supplied to a burner 66 via lines 67 and 68 supplies reference values via signal lines 69 and 70 to the regulators 41, 51 respectively. The level measuring element **42** also sends a signal x to the regulator **43** which controls the valve **31** in order to adjust the amount of excess water returned to the feedwater tank when the load drops below the minimum value. The transfer characteristics of the regulator **43**, as shown, are such that if the input quantity x rises above a limiting value of x_0, the output quantity y begins to rise linearly, that is, when x is smaller than x_0, $y=0$ and the valve **31** is closed. If x is larger than x_0, y is greater than 0 and the valve **31** opens progressively.

Finally, a tubular cooler **80** is disposed about the recirculating line **30** to cool the water returned from the water separator **21** with the aid of feedwater prior to entry of the recirculated water into the ejector apparatus **6**.

The invention thus provides an ejector apparatus which is void of any valves and which is able to adjust the flow of a recirculated medium by varying the flow of the entraining feedwater medium. Further, the invention provides an ejector apparatus which is controlled in relation to the load of the steam generator incorporating the ejector apparatus therein.

What is claimed is:

1. In combination with a once-through force-flow steam generator having a heating surface therein, first means at a first point for delivering feedwater into said heating surface, and second means downstream of said first means for withdrawing a portion of the heated feedwater from said heating surface, said second means being connected to said first means at said first point to recirculate the withdrawn portion of heated feedwater into said heating surface; an ejector apparatus at said first point for receiving and mixing the delivered feedwater of said first means and the withdrawn portion of heated feedwater of said second means for delivery into said heating surface, said ejector apparatus including means for varying the flow cross-section of the feedwater of said first means in response to the load of said steam generator.

2. The combination as set forth in claim **1** wherein said ejector apparatus further includes a housing having an entrainment chamber connected to said first means to receive the feedwater, a supply chamber connected to said second means to receive the withdrawn portion of heated feedwater and a portion joining said entrainment and supply chambers and slidably mounting said means for varying the flow cross-section of the feedwater therein.

3. The combination as set forth in claim **2** wherein said means for varying the flow cross-section comprises a tubular component, said tubular component projecting into said entrainment chamber and communicating said supply chamber and second means with said entrainment chamber.

4. The combination as set forth in claim **1** which further includes a flow rate measuring element connected to said heating surface to measure the flow of feedwater therethrough and a servomotor connected between said element and said means for varying the flow cross-section, said servomotor actuating said means in response to the measured flow.

5. The combination as set forth in claim **1** wherein said second means includes a water separator for collecting water therein, a measuring element connected to said water separator for measuring the level of collected water therein, and a servomotor connected between said element and said means for varying the flow cross-section, said servomotor actuating said means in response to the measured level.

6. The combination as set forth in claim **1** wherein said means for varying the flow cross-section includes a needle nozzle disposed in the feedwater flow of said first means and in communication with said second means for drawing the heated feedwater from said second means into the feedwater flow of said first means under the suction force of the feedwater flow of said first means passing into said heating surface.

7. The combination as set forth in claim **1** wherein said means for varying the flow cross-section is a hollow tubular nozzle needle.

8. The combination as set forth in claim **7** wherein said ejector apparatus further includes a means connected to said nozzle needle for axially moving said nozzle needle into and out of the flow of feedwater of said first means to vary the flow cross-section thereof in response to the load of said steam generator.

9. The combination as set forth in claim **8** wherein said means connected to said nozzle needle is actuated in response to the flow of feedwater passing through said heating surface.

10. The combination as set forth in claim **8** which further includes a steam trap in said second means for collecting water therein and wherein said means connected to said nozzle needle is actuated in response to the level of water in said steam trap and the flow of feedwater passing through said heating surface.

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