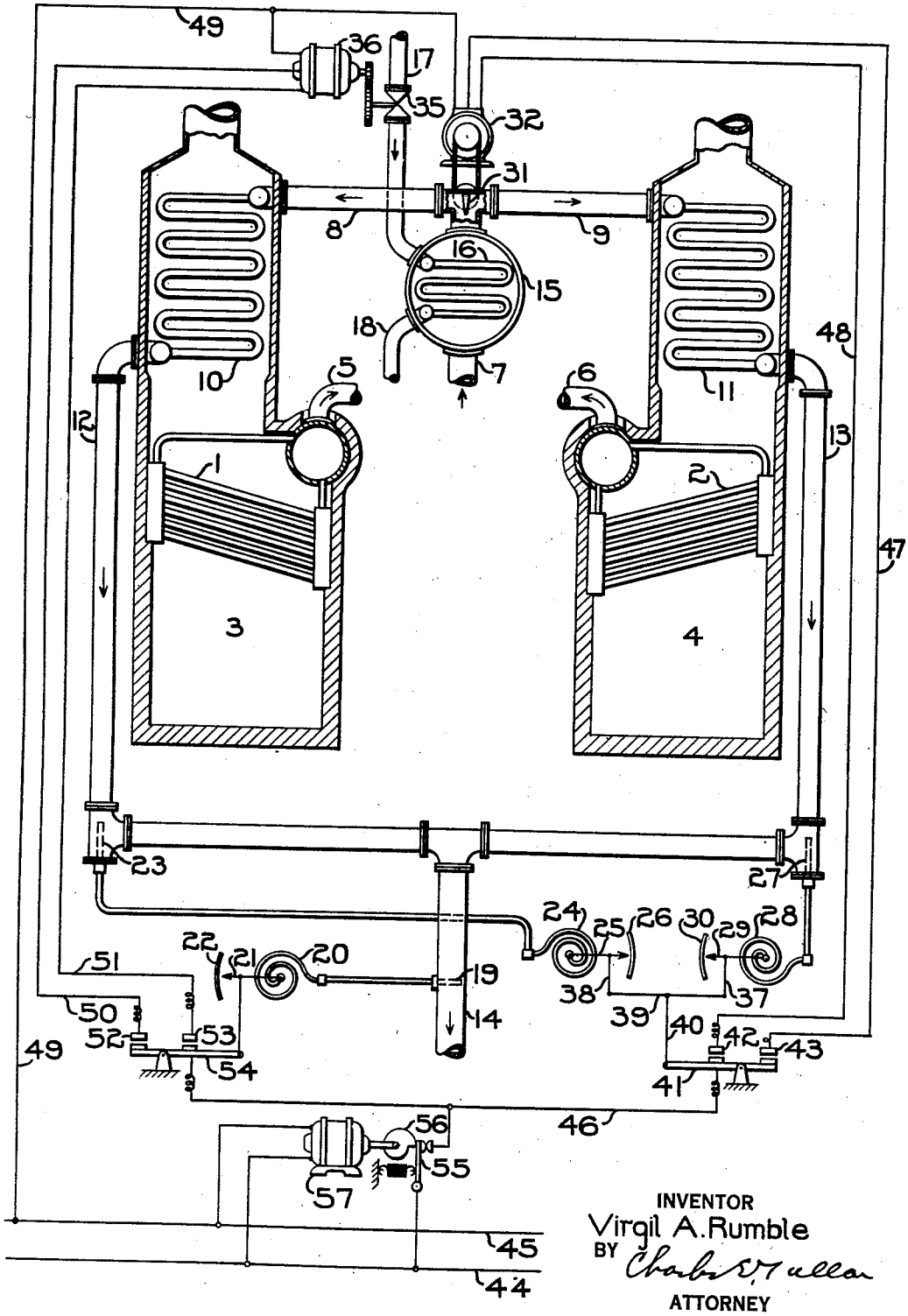
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METHOD OF AND APPARATUS FOR HEATING FLOWING FLUIDS

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INVENTOR
Virgil A. Rumble
BY Charles V. Mullen
ATTORNEY

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METHOD OF AND APPARATUS FOR HEATING FLOWING FLUIDS

Virgil A. Rumble, San Francisco, Calif., assignor to Bailey Meter Company, a corporation of Delaware

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This invention relates to the heating of a flowing fluid and in particular to the proportioning of the fluid through and in accordance with the available heat of a plurality of heaters. It is further concerned with a control of additional heating in the event that the available heat of the first mentioned heaters is insufficient to raise the fluid to a desired temperature.

The primary object of the invention is to provide a method and an apparatus for distributing or proportioning a flowing fluid through a number of heaters in accordance with the available heat supplied the heaters.

A further object is to maintain as nearly as possible a constant final temperature of the fluid being heated.

Still another object is to so distribute the fluid to be heated between the heaters that sufficient cooling of the heaters will result to prevent damage to them.

I have found that when a fluid is passed through several heaters, the temperature of the fluid at the outlet of the different heaters is a good indication of the effectiveness of the heating, and from the several temperatures and the relationship between the temperatures, I control the distribution of the flowing fluid as well as the amount of additional heating.

In order to make clear my invention, I have chosen to illustrate and will describe a preferred embodiment in connection with the reheating of steam after it has passed through a relatively high pressure turbine and prior to passing through a relatively lower pressure turbine. I preferably cause the steam to flow through heat exchangers heated by the gaseous products of combustion of steam generating boilers, and wherein the amount and heat content of the gases for heating may vary with the operation of the boilers. I proportion the flow of steam through these heaters in accordance with the available heat, utilizing a relation between the temperatures of the separate streams of heated fluid leaving the heaters as an indication of the effectiveness of the heating. I then bring the separate streams of heated fluid together to form a mixture, and utilize the temperature of the mixture as an indication of the need for additional heating, which is accomplished by controlling the supply of high heat content steam to another heater through which all of the steam to be heated passes.

In the drawing, which is a diagrammatic representation of apparatus embodying the invention, I have illustrated two steam generating boilers, 1 and 2, heated by the combustion of a suitable fuel in the furnaces 3 and 4 respectively, discharging steam through the pipes 5 and 6. The waste gaseous products of combustion leaving the boilers are used as a heating means for steam to be heated supplied through the conduit 7, and proportioned through the pipes 8 and 9 for heating in the heaters 10 and 11.

From the heaters 10 and 11, the steam passes through the conduits 12 and 13 to join and mix in a conduit 14. I have shown positioned in the conduit 7, ahead of the branches 8 and 9, a live steam reheater or heat exchanger 15, having a coiled section 16 to which high heat content steam is admitted through a conduit 17 and from which the condensate is drained through a pipe 18.

I desire to indicate the temperature of the steam after it has passed through the heater 10, and do this by means of a bulb 23 located in the conduit 12 and forming part of a gas filled thermometer system of which 24 indicates a Bourdon tube carrying a pointer 25 relatively over an index 26. Similarly, I desirably indicate the temperature of steam leaving the heater 11 by means of a bulb 27 of a gas filled thermometer system of which 28 indicates a Bourdon tube carrying a pointer 29 over an index 30.

To divide the steam flowing through the conduit 7 to the branches 8 and 9, I have shown a valve means 31 positioned by a reversible means, shown as a reversing motor 32, in a manner such that for different positions of the valve means 31, different proportionality of flow of steam will occur through the branches 8 and 9.

In the operation of the boilers, heated gaseous products of combustion will pass through the heaters 10 and 11 on their way to the stack, and the heat available in such gases will depend upon the rate of heat liberation in the respective furnaces, the heat absorption by the boilers and other variables. It is desirable to make the best possible usage of the available heat through convection and conduction to the steam flowing through the heaters, and if the rate of steam flow through the two heaters is not in proportion to the available heat, then relatively too great a flow of hot gas will pass one of the heaters as compared to that passing the other heater and correspondingly, the steam passing through the one heater will be heated to a greater extent than that passing through the other heater as will be reflected by the temperature indications on the indexes 26 and 30. Furthermore, the heat balance of the unit is badly disarranged for there will be a wastage of heat in the gases leaving one of the heaters and an insufficient absorption of

heat by the steam in the other heater. Also, the steam flow through one of the heaters, relative to the available heat in the waste gases passing the heater, may be so low that the tubes of the heater are not sufficiently cooled and the heater will burn or be damaged.

I find that the temperature of the steam leaving each of the heaters is a satisfactory indication of the amount of available heat leaving the boiler and the amount absorbed by the steam in its passage through the heater. By determining the ratio between the temperatures at the exit of the two heaters and comparing the actual instantaneous ratio with a predetermined ratio, I have a value or indication of the correctness of the distribution of the steam through the two heaters and from this relation, I divide the steam in a manner such that the predetermined ratio of temperatures is obtained. This is accomplished through the positioning of a contactor, by the temperature responsive devices, to energize the reversing motor 32. From the pointer 29 is suspended a link 37 while from the pointer 25 is suspended a similar link 38. The lower ends of the links are joined by a floating bar 39, which carries intermediate its ends a link 40, in turn connected to one end of a pivoted contacting bar 41, arranged to co-act with a contact 42 or a contact 43, when the bar 41 is positioned, from a predetermined position, around its pivot. The contact bar 41 is shown as connected to the main power line 44 by a conductor 46. Conductors 47 and 48 join the contacts 43 and 42 respectively to the motor 32, from which a return conductor 49 joins the main power line 45.

Interposed in the conductor 46 between the contactor 41 and the power line 44 is shown an interrupting finger 55, spring urged against a cam 56 continuously rotated by a motor 57 which is energized directly from the power lines. This provides a means for intermittently energizing the contactor, allowing when needed the energization of the motor 32 for increments of time depending upon the shape of the cam 56 and its frequency of rotation. This intermittent correction serves effectively to reduce overtravel and hunting, and allow the effect of a certain correction in the position of the valve 31 to be felt before further correction is made.

When the flows are correctly proportioned to the available heat, the relation of temperatures of the steam leaving the heaters will be most nearly unity. Should the flow of steam through one of the heaters vary relative to that through the other while the available heat at the two heaters remains the same, or should the relationship between the amounts of available heat vary while the distribution of steam to be heated remains the same, or should both the available heat and the flow of heat absorbing fluid vary from the desired proportionality, then the temperatures indicated at 26 and 30 may vary from the desired values or relation, and according to my invention initiate a correction to the distribution of flow.

If for example, the flow of steam through the heater 10 increases, the temperature at the bulb 23 will indicate lower, and conversely the temperature at the bulb 27 will indicate higher. Bourdon tube 24 will tend to close in a clockwise direction, moving the pointer 25 downward across the index 26, while at the same time the Bourdon tube 28 tends to open up in a counter-clockwise direction, moving its pointer 29 downwardly over the index 30 and the result is a downward positioning of the connecting bar 39, the link 40 and a counter-clockwise movement of the contacting bar 41 around its fulcrum, to the end that circuit is closed with the contactor 43. As the cam 56 is periodically rotated, the circuit is completed for the motor 32 to position the valve 31 in a clockwise direction, referring to the drawing, so that the flow of steam through the conduit 8 and heater 10 will be diminished and that through the conduit 9 and heater 11 be increased. This adjustment of the valve 31 by increments allows a change in the temperature of the steam leaving the heaters, due to a change in the rate of flow through the heaters, to be felt at the temperature bulbs and correspondingly through the ratio linkage upon the contactor 41 before making additional corrections and prevents overtravel or hunting of the valve. Such correction is intermittently effected until the relation of temperatures is again as desired.

It will be seen that regardless of the nature of the unbalance between the two boilers or the two heaters, any such unbalance in relation between the heat available and the rate of flow of steam to be heated, is immediately reflected in the temperatures at the outlets of the two heaters, and this in turn will position the contactor arm 41 to cause a correction in the proportionality of the rates of flow through moving the valve 31. Such a correction of the rates of flow to the amount of available heat through the heaters serves a further purpose in that it prevents the rate of flow of steam through one of the heaters ever decreasing to an amount relative to the available heat such that the heater tubes would be burned and damaged.

While the operation of my invention as just described insures the maintenance of equal temperatures of the steam leaving the two heaters, it does not necessarily follow that the resulting average temperature of the mixture will be the desired temperature to which the steam is to be heated. This is due to the fact that such heaters as are illustrated at 10 and 11 have an operating characteristic wherein at different rates of operation, different rates of heat transfer exist, and correspondingly different exit temperatures of the heated fluid.

I have shown at 15 a supplemental heater positioned in the conduit 7, to make up for a possible deficiency in the heating by the heaters 10 and 11 at the lower rates of output, to the end that the temperature of the steam leaving through the conduit 14 will tend to remain constant regardless of the rate of flow. The temperature of the steam in the conduit 14 is indicated by a bulb 19 forming a part of a gas filled thermometer system of which 20 indicates a Bourdon tube having a pointer 21 co-operating with an index 22, and for positioning the contactor 54 relative to contacts 52 and 53. These contacts are respectively connected through the conductors 50 and 51 to a motor 36 for positioning a valve 35, to control the flow of high heat content steam through a conduit 17 to the heater 15. A variation in the temperature of the steam leaving through the conduit 14, effective upon the bulb 19, from a predetermined value results in the positioning of the contactor 54 to close circuit with contact 52 or the contact 53 for energizing the motor 36 to result in a positioning of the valve means 35.

If the total heat liberation in the furnaces 3 and 4 is relatively low, then correspondingly the temperature of the steam leaving the conduit 14 will be lower than desired and the Bourdon tube 20

will tend to close up in a counter-clockwise direction, moving the pointer 21 downward over the index 22 and positioning the contact 54 in a clockwise direction to complete circuit to the contact 52. This will result in an energizing of the motor 36, to position the valve 35 in an opening direction, whereby an increased flow of steam will occur through the coils 16, resulting in an increase in temperature of the total volume of steam passing through the heaters 10 and 11.

As I have illustrated in the drawing, I desirably pass the high heat content steam from the conduit 17 and which is to be used for heating the low heat content steam from the conduit 7 in contraflow relation thereto through the heater 15. That is, in the drawing the heating fluid from the conduit 17 passes downwardly through the coils 16, while the fluid to be heated from the conduit 7 passes upwardly around the coils 16. Such contraflow relation between heating fluid and fluid to be heated is desirable, for with contraflow relation the leaving temperature of the fluid to be heated approaches as a limit the entering temperature of the heating fluid; whereas with parallel relation the leaving temperature of the fluid to be heated can only approach as a maximum the leaving temperature of the heating fluid. It will be observed that I employ contraflow relation in the waste heat exchangers 10 and 11 as well as in the controllable heat exchanger 15. By parallel relation or flow I mean that the fluid to be heated as well as the heating fluid flow in the same general direction and that their heat levels are parallel; namely, that the high heat level of one is near the high heat level of the other.

In illustrating and describing my invention in connection with steam generating boilers, waste gas heaters and live steam heaters, I am using as an illustration one embodiment of my invention and I desire it to be understood that I am not limited thereby. The invention may equally well be applied to other arrangements of apparatus wherein other fluids are heated, it only being essential to the working of my invention that a flow of fluid to be heated, be divided proportionally through two or more heaters in accordance with the available heat at those heaters, and where necessary to obtain a final desired temperature of the fluid being heated, to control the addition of supplemental heating.

Furthermore, it is not necessary to have a single swinging gate valve such as I have illustrated at 31 for so proportioning the flowing fluid, for I might have any valve means through whose agency the flow of the fluid through the conduit 7 is divided to the conduits 8 and 9 in desired proportionality.

Any type of throttling or regulating valve may be used at 35 and it is not necessary that electric motors be used to position the valves indicated at 31 and 35 for they may be positioned by other means, such as hydraulic. In showing the type of electric contactors, interrupting means, and so forth that are contained in the drawing, I mean these to indicate one way of accomplishing the desired results and wish it to be understood that while illustrating and describing a preferred embodiment of my invention, I do not expect to be limited thereby other than by what I claim in view of prior art.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The method of heating a flowing fluid which is passed through a plurality of waste heat exchangers, which includes proportioning the fluid through the exchangers in accordance with a comparison of the temperatures of the fluid leaving said exchangers.

2. The method of heating a flowing fluid, which includes, dividing the fluid into a plurality of streams, heating each stream, and maintaining the ratio between the rates of flow of the streams in accordance with the ratio between the temperatures of the streams after having been heated.

3. The method of heating a flowing fluid which is passed through a plurality of heat exchangers, at least one of which is of controllable heat admission and the remainder of waste heat type, which includes proportioning the fluid through the waste heat exchangers in accordance with a comparison of the temperatures of the fluid leaving said exchangers.

4. The method of controlling the heating of a flowing fluid, which includes, dividing the fluid into a plurality of streams, heating each stream, and automatically maintaining the ratio between the rates of flow of the streams in accordance with the ratio between the temperatures of the streams after having been heated.

5. The method of proportioning the flows of a plurality of streams of a fluid to be heated in accordance with the available heat supplied to heaters through which the streams of fluid are separately passed, which consists in measuring the temperature of each stream after it has passed through a heater, determining the ratio of said measures, and subjecting the streams to rate control in accordance with the departure of said ratio from a predetermined value.

6. The method of heating a flowing fluid which is passed through a plurality of heat exchangers, at least one of which is of the controllable heat admission type and the remainder of waste heat type, which includes, proportioning the fluid through the waste type exchangers by the ratio of the heat added in each of the waste type exchangers, and controlling the heat admission to the controllable heat exchanger from an indication of the final temperature of the heated fluid.

7. The method of increasing the heat content per unit weight of a flowing fluid which is passed through a controllable heat exchanger, is divided into a plurality of streams and each stream passed through a waste heat exchanger, and then rejoined to form a final flow, which includes, proportioning the fluid to the waste heat exchangers by the ratio of the heat added per unit weight of the flowing fluid in each of said waste heat exchangers and controlling the controllable heat exchanger from an indication of the temperature of the final flow.

8. The method of increasing the heat content per unit weight of flowing steam which is passed through a steam reheater to which higher heat content steam is applied, divided into a plurality of streams and each stream passed through a waste gas reheater, and then rejoined to form a final flow; which includes, proportioning the steam to the waste gas reheaters by the ratio of the heat added by each of said waste gas heaters per unit weight of steam flowing therethrough, and controlling the supply of higher heat content steam to the steam reheater from an indication of temperature of the final flow.

9. The method of increasing the heat content per unit weight of flowing steam which is passed through a steam reheater to which higher heat content steam is supplied, divided into a plurality of streams and each stream passed through

a waste gas reheater, and then rejoined to form a final total flow, which comprises, proportioning the steam through the waste gas reheaters by the ratio of the heat available to each of the waste gas reheaters, and controlling the supply of higher heat content steam to the steam reheaters from an indication of temperature of the final flow.

10. The method of controlling the heating of a fluid which after flowing through a controllable heat exchanger to which is supplied a heating medium divides to form a plurality of streams with each stream flowing through a waste heat exchanger to rejoin and form a final total flow, which comprises, indicating the temperature of the fluid at the outlet of each waste heat exchanger, comparing said indications and from the comparison controlling the dividing of the fluid to maintain a constant relation between said outlet temperatures, obtaining an indication of the temperature of the final flow, and from said last-named indication controlling the supply of the heating medium to the controllable heat exchanger.

11. The method of proportioning the flows of a plurality of streams of a fluid to be heated in accordance with the available heat supplied to heaters through which the streams of fluid are separately passed, which consists in indicating the temperature of each stream after it has passed through a heater, determining the ratio of said temperatures, and subjecting the streams to rate control in accordance with the departure of said ratio from a predetermined value.

12. The method of controlling the temperature of a fluid flowing through a plurality of heat exchangers, at least one of which has controllable heat admission and the remainder of which utilize waste heat which comprises, dividing the fluid through the waste heat exchangers in accordance with a comparison of the temperatures of the fluid leaving said exchangers, and controlling the heat admission to the controllable heat exchanger from an indication of the final temperature of the heated fluid.

13. Apparatus for heating a flowing fluid, comprising in combination, a plurality of waste heat exchangers, proportioning means for dividing the flowing fluid through the exchangers, thermo-responsive means for measuring the temperature of the fluid as it leaves the individual exchangers, and control means actuated by the thermo-responsive means and adapted to position the proportioning means.

14. In a mechanism for heating a flowing fluid, in combination, a plurality of heat exchangers through which the fluid passes, thermo-responsive means for indicating the temperatures of said fluid leaving the individual heaters, means positioned in accordance with the relation between said indications, and means actuated by said last-named means for proportioning the flow of the fluid through said heat exchangers.

15. In a mechanism for heating a flowing fluid, in combination, a plurality of heat exchangers through which the fluid passes, thermo-responsive means for indicating the temperatures of said fluid leaving the individual heaters, means positioned in accordance with the relation between said indications, means actuated by said last-named means for proportioning the flow of the fluid through said heat exchangers, a controllable heat exchanger through which all of the fluid passes, thermo-responsive means for indicating the temperature of the fluid leaving the controllable heat exchanger, and means actuated upon a departure of said indications from a predetermined value for controlling said controllable heat exchanger.

16. Apparatus for proportioning the flows of a plurality of streams of a fluid to be heated, comprising in combination, a waste heat exchanger for each stream, a conduit through which the fluid flows and having branches each connecting said conduit to one exchanger, valve means in said conduit for distributing the fluid to said branches, reversible means for positioning the valve means, means for indicating the temperature of the fluid at the exit of each exchanger, means for comparing said temperature indications, and means responsive to a departure of said indications from a predetermined ratio for actuating said reversible means.

17. In combination, a conduit for the flow of a fluid to be heated, a heat exchanger positioned in said conduit and through which the fluid flows in heat-absorbing relation to a fluid of higher heat content, valve means for controlling the supply of higher heat content fluid, branches to said conduit for joining the conduit to a plurality of waste heat exchangers, said waste heat exchangers each having available the heat contained in the gaseous products of combustion leaving a vapor-generating boiler, valve means for proportioning the distribution of said fluid from the conduit to said branches, means for indicating the temperature of the fluid leaving the waste heat exchangers, ratio determining means of said temperatures, means actuated upon a departure of said ratio from a predetermined value for positioning said last-named valve means, means for indicating the temperature of the fluid after it has left all of the heaters, and means responsive to a departure of said last-named indication from a predetermined value for positioning said first-named valve means.

18. Apparatus for controlling to a predetermined value the temperature of a flowing fluid, comprising in combination, a conduit through which said fluid flows and having branches, valve means in said conduit for proportioning the flow of fluid to said branches, reversible means for said valve means, a controllable heat exchanger located in heat-conducting relation in said conduit in advance of said valve means, valve means for controlling the supply of heat to said heat exchanger, reversible means for said last-named valve means, a plurality of waste heat exchangers to each of which one of said branches leads, means for indicating the temperature of the fluid leaving each waste heat exchanger, ratio determining means of said temperatures, means actuated upon a departure of said ratio from a predetermined value for actuating said first-named reversible means, means for indicating the final temperature of the fluid after it leaves all of said heat exchangers, and means responsive to a departure of said final temperature from a predetermined value for actuating said second-named reversible means.

19. In combination, a conduit for the flow of a fluid to be heated, a heat exchanger positioned in said conduit and through which the fluid flows in heat-absorbing relation with a fluid of higher heat content, valve means for controlling the supply of higher heat content fluid, branches to said conduit for joining the conduit to a plurality of waste heat exchangers, said waste heat exchangers each having available the heat contained in the gaseous products of combustion leaving a vapor-generating boiler, valve means for proportioning the distri-

bution of said fluid from the conduit to said branches, means for indicating the temperature of the fluid leaving the waste heat exchangers, ratio determining means of said temperatures, electric means actuated upon a departure of said ratio from a predetermined value for positioning said last-named valve means, means for indicating the temperature of the fluid after it has left all of the heaters, electric means actuated upon a departure of said last-named indication from a predetermined value for positioning said first-named valve means, and means for intermittently making effective said electric means.

VIRGIL A. RUMBLE.