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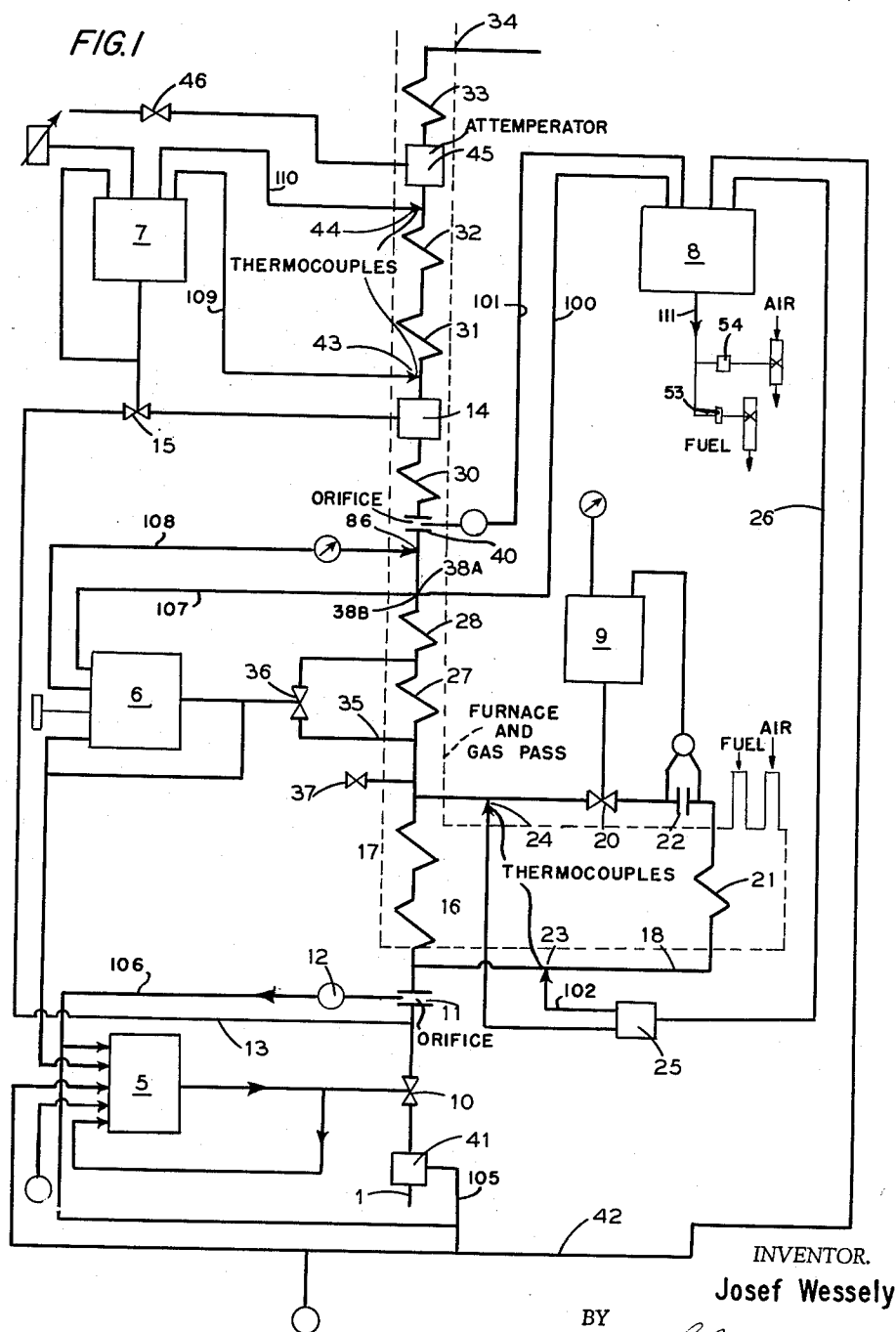
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3,133,529

CONTROL OF BENSON BOILERS AND SIMILAR HIGH PRESSURE BOILERS

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2 Sheets-Sheet 1



INVENTOR.

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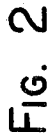
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2 Sheets-Sheet 2



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BY

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CONTROL OF BENSON BOILERS AND SIMILAR HIGH PRESSURE BOILERS

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2 Claims. (Cl. 122-479)

The present invention relates to high pressure, high temperature vapor generating and superheating units of the once-through type, and more particularly to a method of and apparatus for controlling the operation of such units. This application is a continuation-in-part of my application Serial No. 716,938 filed February 24, 1958.

In once-through boilers as, for example, the Benson boilers, the problem of compensating for load swings in the systems has not been satisfactorily solved. The principal difficulty in the control of such boilers is due to the small storage capacity of the once-through type of boiler as compared to either natural circulation or forced flow circulation of drum type boilers. With the small storage capacity of the boilers, an excessive time lag occurs for the change of fuel to water ratio during load swings. In addition, during such load swings, the normal transition point or zone in the boiler changes, changing the effective length of the superheating surfaces of the unit.

Attempts have been made to overcome these difficulties by means of a system of controls involving recirculation of water in the unit. Unfortunately, the amount of steam delivered by the unit can never be more than the amount of steam generated by heat exchange in the unit. Under these conditions, it has been impossible, as a practical matter, to maintain a correct ratio of feed water delivery to heat input to the system. It is, of course, possible to measure the exact quantity of feed water delivered to the unit. However, the heat input to the unit can be only measured indirectly in the systems heretofore in use. The measurement of the heat input to the unit has been obtained by the use of a portion of the heating surfaces in the unit where such portion has been used for control purposes. The inlet and outlet connections of this control portion of the unit have heretofore been located on opposite sides of a flow resistance in the piping system of the unit so that the water flow through the control portion is proportional to the total flow through the entire unit. Thus, the heat absorption of the control surface is proportional to the total heat absorption of the boiler. Thus, at any load, the temperature difference between the inlet and outlet connections of the control surfaces should remain the same. However, this does not occur in actual operation and it has been absolutely necessary to use spray attemperation for control of steam temperature of the steam discharged to the steam user. The principal purpose of the attemperator spray control is, of course, to eliminate variations in final steam temperatures as caused by irregularities in the rate of steam input to the system, and in this sense, spray attemperation is utilized only to overcome an inadequate control system.

The known methods for controlling once-through boilers has not been satisfactory with the increased requirements of compensating for load swings in the operation of the units. Essentially, the performance of the known control systems have been inadequate because the measurements obtained from the control portion of the heat exchange elements are influenced in opposite directions by two changing components, namely water flow rate and heat input as measured by fuel weight.

The present invention is intended to overcome the difficulties encountered in the operational control of once-

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through boilers, particularly of the Benson type. This is accomplished by obtaining controlled impulses, with or without secondary impulses for control purposes, from temperature measurements of a section of the heating surface in the unit. The control section, or surface, may be installed in the gas passes and/or in the walls of the furnaces exposed to radiant heat. A constant or uniform flow of vaporizable fluid, such as water, is passed through the control section or surface of the unit. Under these conditions, control impulses can be obtained from temperature measurements only. Such temperature measurements are taken from the inlet and outlet connections to the control section where such temperature differences will be indicative of the heat input to the unit. In addition, impulses are used in the control system where such impulses originate in measurements of the pressure and temperature of the steam as obtained in any portion of the superheating section of the unit. Preferably, such pressure and temperature measurements are taken closely adjacent the transition point or zone on the vapor side of the unit.

In addition, the present invention involves a system for maintaining the transition point or zone where the water is evaporated to steam at a substantially fixed point. This is accomplished by introducing additional water or, if necessary, by withdrawing water from the system closely adjacent the normal transition point or zone so as to attain a substantially constant transition point in the evaporator section of the unit. In addition, according to the present invention, several groups of heating surfaces, connected in series, are each independently controlled by the use of spray attemperators to control the steam temperature in separate sections of the superheating portion of the unit.

Advantageously, the control system of the present invention drastically reduces the time lag of control response and difficulties resulting from a variation in the effective length of the superheater elements.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of the invention.

Of the drawings:

FIG. 1 is a diagrammatic illustration of the invention; and

FIG. 2 is a schematic illustration, in greater detail, of the control system shown in FIG. 1.

As shown in the drawing, a once-through boiler, for example, of the Benson type, is illustrated by a single line designated with the numeral 1. Feed water is delivered to the boiler from a feed water source (not shown) through a control valve 10 which is regulated, as hereinafter described, by a conventional feed water regulator. The water entering the boiler passes through the valve to an orifice 11 which is provided with a differential pressure measuring device 12 of conventional design which in turn is connected with the feed water controller 5. Between the control valve 10 and the orifice 11, a branch pipe 13 connects with a spray type attemperator 14 positioned downstream of the once-through boiler. As hereinafter described, the flow of water through the pipe 13 is controlled by a conventional control valve 15 in response to the operation of a controller 7. Essentially, the flow of water through the line 13 to the attemperator 14 is responsive to temperature measurements taken in the superheating portion of the once-through boiler. The feed water passing through the orifice 11 is directed through water heating surfaces indicated at 16 and 17 on

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the drawing. The surfaces 16 and 17 may be heated by radiant heat or by convection heat transfer.

In accordance with the present invention, a section 18 of the water heating portion of the unit is provided with a flow control device 9 which actuates a control valve 20 positioned in the section 18. As indicated on the drawing, the heating surfaces of the section 18 is schematically indicated by the numeral 21. The control device 9 is operated in response to a measurement of the differential pressure obtained by flow through an orifice 22 which is located upstream of the control valve 20. As indicated, the valve 20 is operable to maintain a substantially uniform flow of water through the pipe 18 and the heating surfaces 21. As shown in the drawing, heat responsive means designated 23 and 24 are located in the inlet and outlet portions of the section 18 to measure the temperature of the water before and after it is passed through the heating surfaces 21. The impulses from the temperature measuring means, which may be thermocouples of known characteristics, are transmitted to a controller 25 which in turn passes the differential temperature impulses through a line 26 to a fuel feeder controller 8. The combined flow of water passed through the heating surfaces 16, 17 and 21 is discharged to heating surfaces 27 which represents the normal transition zone of the once-through boiler. In the transition zone 27, the water is converted to steam with the steam thereafter passed through a series of steam superheating surfaces indicated by the numerals 28, 30, 31, 32 and 33. The flow through the superheating surfaces is in series with the superheated steam delivered through the pipe 34 to points of use (not shown).

In accordance with another feature of my invention, I provide a bypass pipe 35 connected to opposite sides of the transition zone 27. The flow of water through the bypass pipe 35 is controlled by the valve 36 which is actuated by a controller 6. Thus, with the arrangement described, water may be bypassed through the pipe 35 to control the transition point, or zone, of the unit. As indicated at 37, a valved inlet is provided for the addition of water to the system to control the location of the transition point or zone when the addition of water is necessary for this purpose.

The fuel feed control 8 is provided with control impulses obtained from a pressure sensitive device indicated at 38 and control impulses from a flow device indicated at 40. Such impulses are transmitted to the feeder controller 8 with the overall operations of the feeder controller modified by the flow of water to the system, as determined from the differential pressure or flow recording device 12, and the temperature of the water as determined by the device 41.

The flow of attemperating water to the spray attemperator 14 is regulated by measurements of the steam temperature obtained by impulses from the temperature sensitive devices 43 and 44 positioned on opposite sides of the heating surfaces 31 and 32. Such impulses transmitted to the controller 7 regulate the flow of the spray attemperating water.

As indicated on the drawing, the temperature of the superheated steam passing through the surfaces 33 can be regulated by the use of a spray attemperator 45 which may be actuated by a control valve 46 which is operable in response to the final steam temperature passed through the pipe 34.

In accordance with the present invention, I not only provide an accurate and effective source of control impulses for regulating the heat input to the once-through boiler, but I also provide a system for maintaining the transition point or zone in the unit substantially constant. The disclosed invention is effective in overcoming the difficulties heretofore encountered in the operational control of a once-through boiler of the Benson type.

Referring now to FIG. 2, I therein show one form, incorporating pneumatic instrumentalities, which the con-

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trol system illustrated in FIG. 1 may take. It will become apparent as the description proceeds that the control system may incorporate hydraulic or electrical instrumentalities as well. In FIG. 2, I have shown the components of the control in logical arrangement and have referenced into FIG. 1 the sensing devices and final control elements.

Referring first to the fuel and air control generally identified by the reference 8 in FIG. 1, a transmitter 50 translates the pressure at 38A through line 100 into a corresponding pneumatic loading pressure which is transmitted to the B bellows of a relay 51. The relay 51 provides proportional and reset actions and may take any one of a variety of forms as will be readily appreciated by those skilled in the art. For purposes of specific illustration, however, I have chosen to show the type of relay illustrated and described in U.S. Patent 2,805,678 to Michael Panich to which reference may be made for a detailed description. Briefly, variations in loading pressure at B are translated into immediate and proportional changes at output port D of opposite sense. So long as the loading pressure at B is at other than the set point value, a continuous relatively slow change in pressure at D occurs in a direction to cause a corrective action to restore the loading pressure at B to the set point value. Such action is obtained by virtue of the adjustable restriction 52 between the D and C chambers of the relay. The proportional change at D for a given change at B may be manually adjusted by the so-called proportional band adjustment 51A. The set point may be adjusted by varying the tension on spring 51B. The proportional band and the restriction 52 are adjusted in accordance with the time constant of the controlled unit, in this case the vapor generator 1.

The relay such as shown at 51 is a universally adaptable unit and may be used to obtain a wide variety of control actions. By introducing the loading pressure into the A chamber in place of the B chamber, for example, a direct action may be obtained in place of an inverse action. By introducing loading pressure into both the A and B chambers and opening the C chamber to atmosphere, a pressure at D proportional to the difference between the loading pressures introduced at A and B may be obtained, or a pressure at D may be obtained proportional to the sum of the pressures introduced into C and A. In the embodiment of my invention shown in FIG. 2, I utilize the relay, such as shown at 51, to obtain various of these control actions. For the sake of brevity, I have for the most part shown the relays in block form for, as previously mentioned, reference may be made to U.S. Patent 2,805,678 for a complete description.

The loading pressure is introduced into the B chamber to obtain inverse changes in the pressure at D so that increases in vapor pressure at 38A will cause positioning of fuel valves 53A and 53B and of a combustion air control drive 54 in a closing direction. Thus a change in vapor pressure will effect an immediate and proportionate change in fuel and air of opposite sense and a slow continuing change until the vapor pressure is restored to the set point value.

As I have previously explained, as part of the fuel and air control I provide a control section 18 through which a constant fluid flow is maintained. In FIG. 2, I show a typical constant flow control incorporating a transmitter 55 responsive to the differential pressure produced by orifice 22 and passed through line 104 and thereby establishing a pneumatic loading pressure transmitted to a relay 56 through a pipe 57. Relay 56 is similar to relay 51 providing proportional and reset actions. Thus an increase in rate of flow, for example, through control section 18 will result in an immediate and proportional closing of valve 20 and thereafter a slow continuing closing until the flow is restored to the set point value. A selector station such as shown at 58 may be incorporated in the system to facilitate transfer of the constant flow control from "Automatic" to "Man-

ual" and vice versa. Reference may be made to U.S. Patent 2,747,595 to Paul S. Dickey for a description of one type of selector station suitable for inclusion in the control. As described in this patent, the station 53 may, if desired, be provided with a hand adjustable knob 53A for establishing the set point loading pressure which is transmitted through a pipe 59 to the A chamber of relay 56.

The control impulse produced by relay 51 is modified in accordance with the temperature differential across the control section 18 as determined by temperature responsive devices 23 and 24. Devices 23 and 24 establish pneumatic loading pressures through lines 102 and 103, respectively, and the agency of transmitters 60 and 61, respectively, proportional to the fluid temperatures at the entrance and exit of control section 18. A control impulse proportional to the difference between the loading pressures and hence proportional to the difference in temperature is produced by a relay 62 (the equivalent of controller 25 of FIG. 1). This relay is similar to the relay 51, except it will be noted that the C chamber is open to atmosphere in place of being connected to the D chamber through a bleed connection. Thus the pressure at D of relay 62 corresponds to the difference in loading pressures at A and B.

As a constant flow is maintained through control section 18 the temperature rise therethrough which the control maintains should be a function of load. That is to say the correct temperature rise will usually be at a minimum at minimum load and progressively increase with load and be a maximum at maximum load. A linear function may exist between load and desired temperature or a non-linear functional relationship depending among other factors upon the location of control section 18 relative to the parallel generator sections. Such action I obtain in the control system by modifying the loading pressure established at D of relay 62 in a relay 63 in accordance with the rate of flow through the generator as determined by flow restriction 40. A transmitter 64 is connected through line 101 with restriction 40 and establishes a loading pressure corresponding to the rate of flow which is transmitted through pipe 65 to the B chamber of relay 63. So long as the pressure at A is equal to the pressure at B no change in the pressure produced at D of relay 63 will occur. That is to say, so long as the temperature differential across control section 18 corresponds to the scheduled temperature no corrective impulse will be transmitted to the fuel and air; however, an increase above the scheduled temperature differential for the then existing load will cause a corresponding decrease in fuel and air and vice versa. The loading pressure produced by the relay 51 is introduced into relay 63 by way of chamber C so that the loading pressure generated in relay 51 is modified in accordance with deviations in the temperature differential from the desired differential as scheduled from load.

As I have further described with reference to FIG. 1, the heat supply to the generator 1 is preferably varied inversely with the product of the temperature and flow entering the fluid. More precisely it may be said that the heat supply, that is the rate of firing, is preferably varied inversely with the total B.t.u. in the fluid entering the generator 1. A sufficiently accurate measure of the B.t.u. so supplied may usually be obtained by multiplying the temperature of the entering fluid by the rate of flow thereof. If, however, a higher degree of accuracy is desired the control may be arranged to produce from a temperature sensing device an effect varying directly with the B.t.u. content of the entering fluid and such effect then multiplied by the rate of flow as will be readily appreciated by those familiar with the art.

In FIG. 2, a transmitter 69 responsive to the differential pressure across flow restriction 11 through line 106 generates a loading pressure proportional to the rate of flow of fluid to the generator. This loading pressure is trans-

mitted by pipe 70 to the E chamber of a computing relay 71 basically similar to the relay 62 but modified in accordance with the teachings of U.S. Patent 2,743,710 to Jack F. Shannon. Into the A chamber of this relay is introduced, through a pipe 72, a loading pressure generated by a transmitter 73 connected by line 105 and responsive to the temperature sensitive device 41. The relay 71 produces at D a loading pressure proportional to the product of the temperature and rate of flow of fluid to the generator 1. This corrective impulse is then transmitted to the B chamber of a relay 74 and thence to a relay 75 for modification of the loading pressure established in relay 63.

The relay 74 serves to generate a loading pressure, which is proportional to the loading pressure established in a master controller 76 modified by the loading pressure from relay 71. I have shown by way of example a manually adjustable master controller whereby an operator by adjusting knob 76A can adjust the firing rate of the generator and hence the vapor output thereof. As apparent to those skilled in the art if desired a master loading pressure may be generated automatically as from a measure of load on the vapor consuming unit supplied by the generator 1. Thus, if the latter is a turbine-generator unit, the electrical load may be used to generate the master loading pressure, or the cam shaft position of the turbine or the like.

Suitable selector stations such as shown at 78, 79 and 80 may be incorporated in the system including branch lines leading from line 111 of the relay 75 to afford a means of partially or wholly transferring the fuel and air control from "Automatic" to "Manual" and vice versa. I have shown two fuel control valves by way of example it being evident that one or more valves may be utilized as required. Likewise valves 53A and 53B are shown as representative of typical final control elements, it being evident that other forms may be substituted as required to be compatible with the type of fuel and fuel burning equipment. Further for illustrative purposes I have shown a so-called parallel control of fuel and air, it being evident that readjustment control of fuel and air can be incorporated to maintain a desired excess air.

The master loading pressure generated by controller 76 also serves to adjust the rate of fluid flow to the generator 1 in parallel with changes in the firing rate. As shown the master loading pressure as modified in a relay 81, later to be described, is introduced into the A chamber of a relay 82 having proportional and reset actions. Into the B chamber of this relay is introduced, by way of a pipe 83, the loading pressure from transmitter 69 corresponding to the rate of fluid flow to the generator 1. The loading pressure generated in chamber D of this relay is transmitted through selector station 84 to the control valve 10. A constant flow control is thus provided, the set point of which is established by the loading pressure introduced into the A chamber of relay 82. This loading pressure in turn is derived from the master controller 76 so that the flow of fluid to the generator 1 will be adjusted in parallel with adjustments in the firing rate.

As explained with reference to FIG. 1, it is highly desirable that the transition point, that is the point where vaporization occurs, is maintained in the transition section 27 under all loads and conditions. This I accomplish by by-passing fluid around the section or adding fluid to the section through valve 37. A sensing device responsive to temperature of the fluid immediately following the transition section is primarily utilized to selectively control the by-passing and addition of fluid. In FIG. 2, the control is shown in greater detail. Therein the transmitter 85 is shown as establishing a loading pressure corresponding to the vapor temperature leaving the transition section as determined by a temperature sensitive device 86 and connected therewith by line 105. This loading pressure is transmitted to a relay 87 having proportional and reset actions. The output thereof is trans-

mitted by way of a selector station 89 to valve 36. As I have shown in FIG. 2, the loading pressure to valve 36 may also be used to operate the valve 37.

In operation, as the temperature at 86 increases above the desired value, for example, valve 36 is positioned in an opening direction causing a smaller proportion of the fluid to pass through transition section 27 and accordingly less heat to be added to the fluid. Conversely upon a decrease in temperature at 86 from the desired value, valve 36 is caused to move in a closing direction thereby increasing the flow through the transition section. Preferably, valves 36 and 37 are adjusted for sequential operation with a slight overlap so that valve 36 is substantially wide open before valve 37 starts to open and conversely valve 37 is substantially closed before valve 36 starts to close.

The transition point control so far described operates to maintain a constant temperature at the location of sensitive device 86. Under fluctuating vapor pressure such a control may not operate to maintain as constant a superheat as desired. Accordingly, the temperature maintained is preferably adjusted from vapor pressure so that a substantially constant superheat is maintained at point 86 regardless of fluctuations in vapor pressure. Such a secondary control has the further advantage in that it serves to anticipate changes in temperature caused by changes in vapor pressure. In FIG. 2, I adjust the temperature set point by means of a transmitter 90 generating a loading pressure proportional to the vapor pressure at 38B as transmitted through the line 107 which is in turn transmitted to the B chamber of relay 87 through a pipe 91. Variations in this loading pressure adjust the set point of relay 87, that is, the temperature the control maintains at responsive device 86.

As fluid is introduced through valve 37, or transition section 27 is by-passed through valve 36, a corresponding adjustment is preferably made in the fluid feed rate to the generator as at optimum condition valves 36 and 37 are closed with all of the fluid entering the generator 1 passing through the transition section 27. Accordingly, I show the loading pressure from selector station 89, representative of the positions of valves 36 and 37 transmitted through a pipe 92 to the B chamber of relay 81 wherein it is effective for modifying the positioning of feed valve 10. The arrangement is such that upon the loading pressures to valves 36 and 37 increasing, valve 10 is adjusted in a closing direction, thereby decreasing the feed rate and assisting in maintaining the transition point within section 27.

The temperature of vapor leaving superheater 32 is controlled by introducing more or less fluid through spray attemperator 14. The temperature of the vapor leaving superheater 33 is controlled by introducing more or less fluid through spray attemperator 45. As the temperature control systems for the attemperators 14 and 15 may be identical I have shown in FIG. 2 a suitable control for the attemperator 14 only, it being understood that a duplicate arrangement may be used for control of attemperator 45.

Transmitter 93 is connected by line 110 and establishes a loading pressure proportional to the temperature sensed by responsive device 44 which is transmitted through a pipe 94 to a relay 95 having proportional and reset actions. The output pressure from relay 95 at chamber D is transmitted through a relay 96 and thence to valve 15 by way of selector station 97. The arrangement is such that an increase in temperature at 44 will cause valve 15 to open introducing fluid at a greater rate into spray attemperator 14. To anticipate changes in temperature at the outlet of superheater 32, valve 15 is also adjusted in accordance with changes in temperature at the entrance to superheater section 31 by means of transmitter 98

connected by line 109 to element 43 and generating a loading pressure which is introduced into the C chamber of relay 96.

In FIG. 1, I have indicated "feedback loops." In FIG. 2, such "feedback loops" are effected by providing valves such as 53A and 53B with opposing springs so that the positions assumed are proportional to the magnitude of the loading pressures impressed. Similarly, the effect of a "feedback loop" is obtained in the drive 54 by providing a positioner such as shown and described in U.S. Patent 2,679,829 to Harvard H. Gorrie. It will be apparent to those skilled in the art that the particular type of "feedback loop" employed will depend upon the type of control system and control components employed, as for example, in an electrically operated control system the feedback loop may be obtained by impressing upon a controller a voltage proportional to the position of the final control element.

While in accordance with the provisions of the statutes I have illustrated and described herein the best form and mode of operation of the invention now known to me, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by my claims, and that certain features of my invention may sometimes be used to advantage without a corresponding use of other features.

What is claimed is:

1. Apparatus for regulating the heat input to a fluid heating and superheating unit of the once-through type which comprises means for passing a controlled variable flow of fluid through said unit, means for measuring the temperature differential in the fluid flow path of a bypass section positioned in parallel to the fluid heating portion of said unit, means for maintaining a substantially constant fluid flow through said bypass section of the fluid heating portion of said unit, means for measuring the flow rate and pressure of the fluid heated in said unit, and control means for regulating the rate of fuel delivery to said unit responsive to the flow rate and pressure of said fluid as modified by said measurement of fluid heating temperature differential.

2. In a high pressure once-through vapor generating and superheating unit the combination including means for supplying fluid to said unit in response to vapor flow requirements from said unit, means for regulating the fuel input to said unit in primary response to the heat requirements of the unit, and means for maintaining the transition point of fluid to vapor in said unit substantially constant over a wide range of vapor generating rates comprising a valved bypass pipe around the normal transition point of said unit, valved pipe means connecting a source of fluid with said unit upstream in a fluid flow sense of said normal transition point, and control means operative to move said bypass valve in an opening direction when the transition point tends to move downstream from its normal position and to move the valve in said fluid source in an opening direction to add fluid when the transition point tends to move upstream from its normal position.

References Cited in the file of this patent

UNITED STATES PATENTS

2,907,305 Profos ----- Oct. 6, 1959

OTHER REFERENCES

German application, 1,055,167, printed April 16, 1959 (Kl. 24m 1/03).

"Combustion" of August 1956, pages 47 to 56, published by Combustion Publishing Co. of New York, New York.