July 26, 1966 J. P. SMITH ET AL 3,262,394

BOILER FEED PUMP CONTROL SYSTEM

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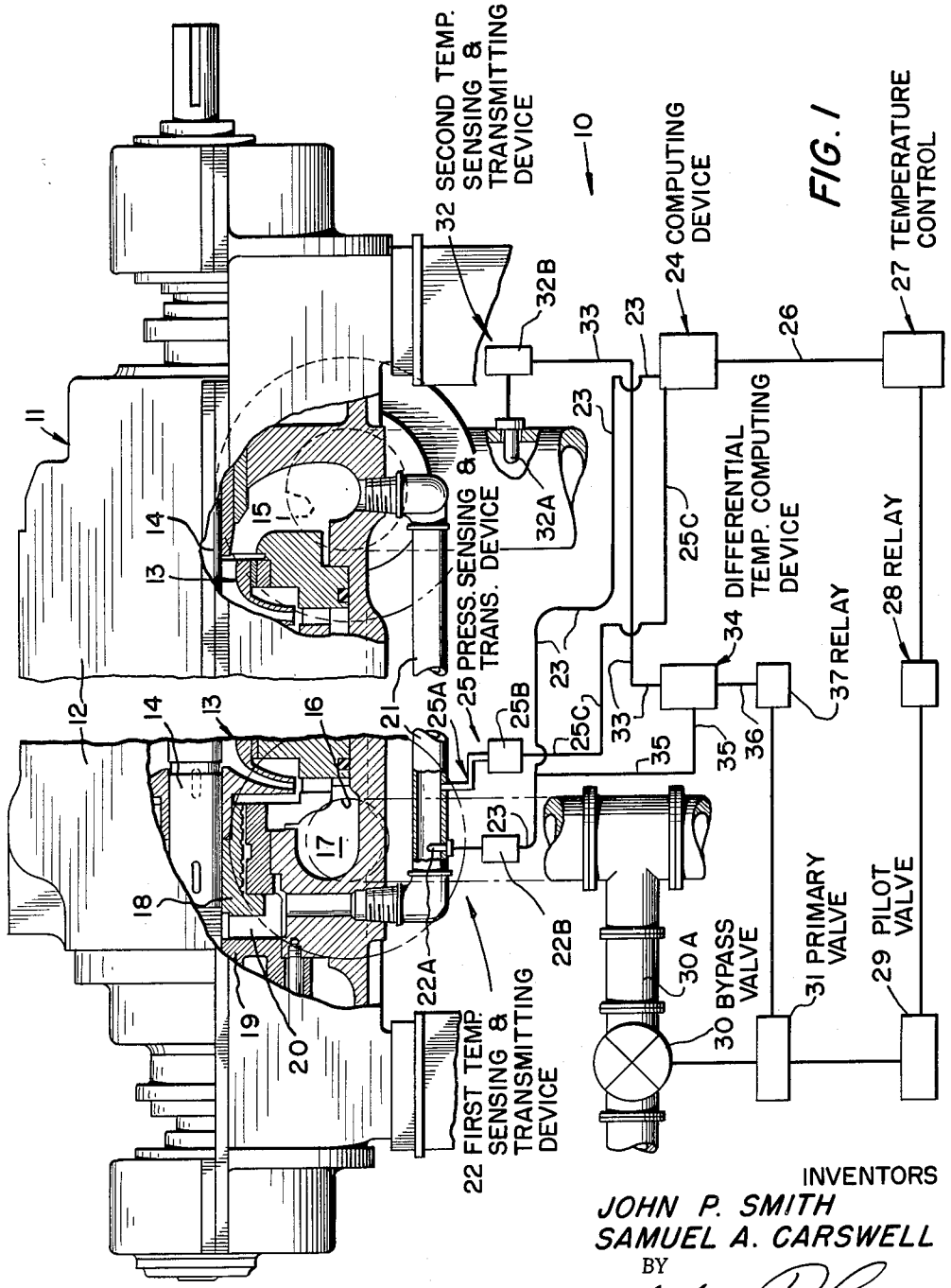


FIG. 1

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FIG. 3

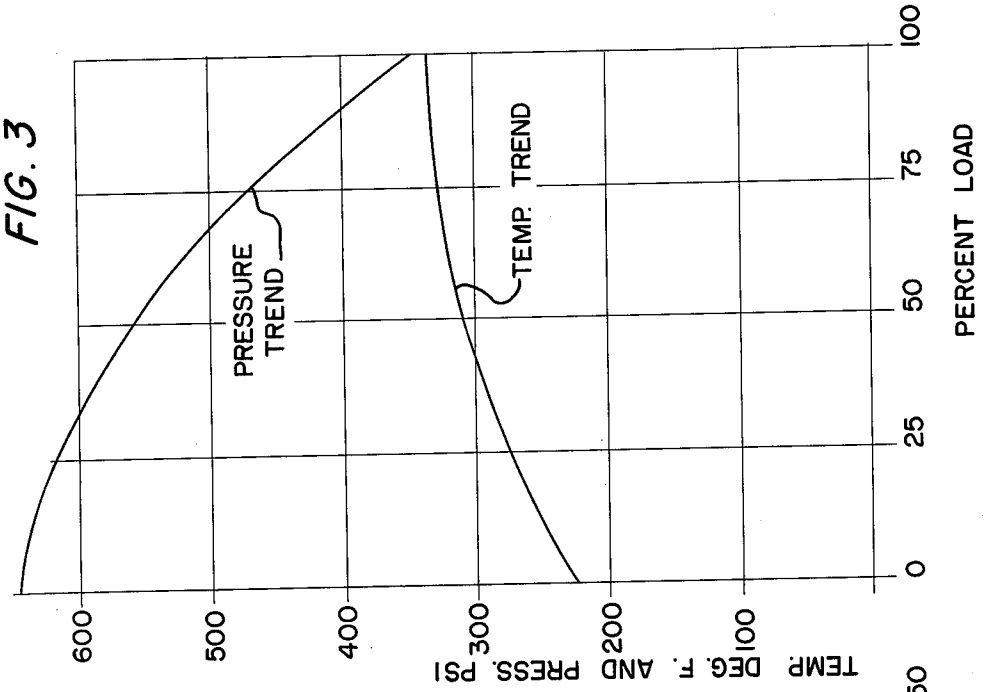
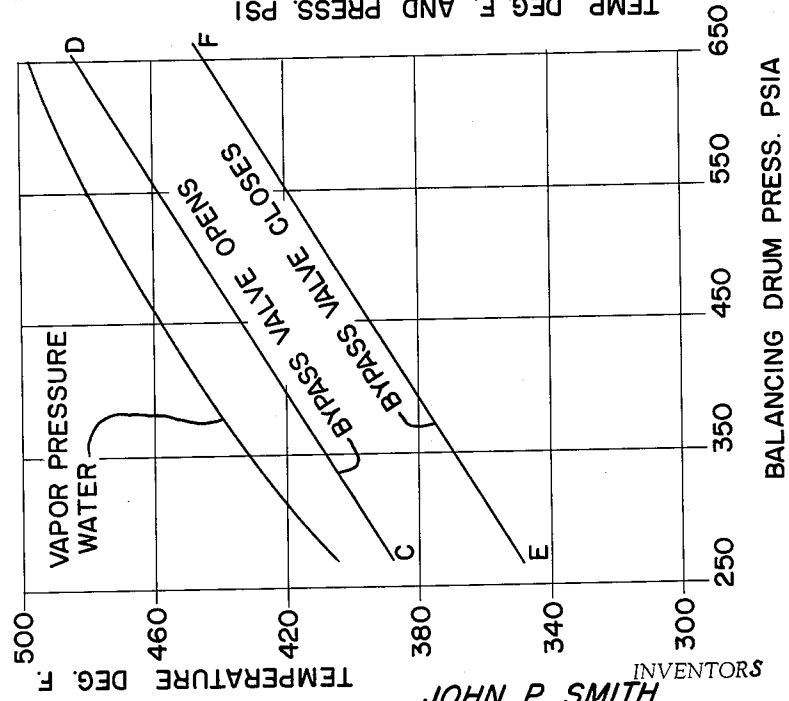


FIG. 2



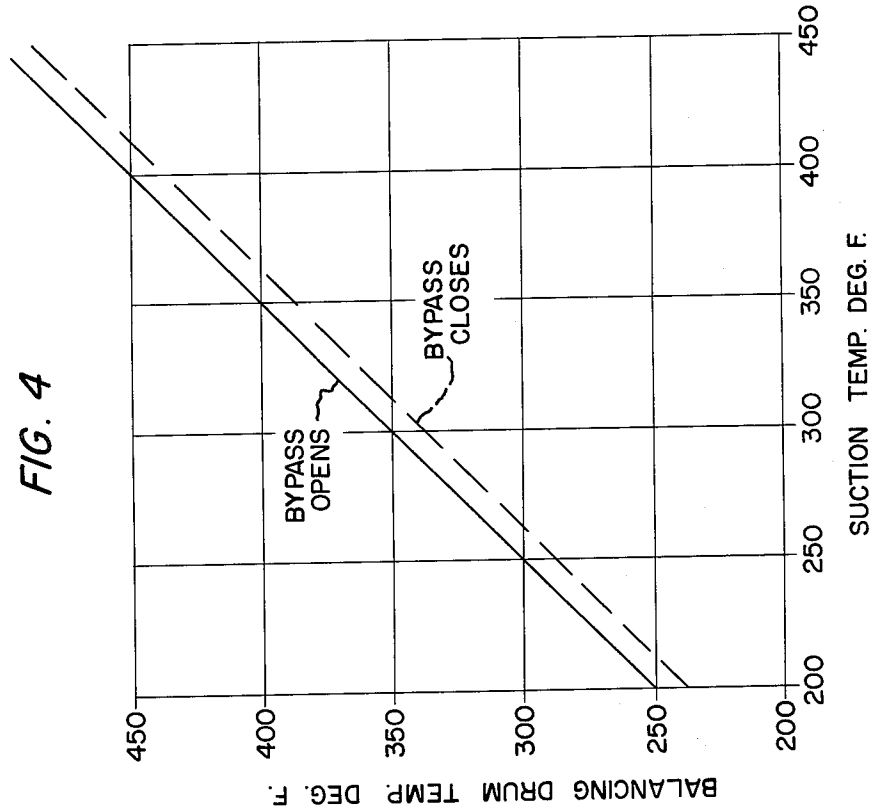
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FIG. 4



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BOILER FEED PUMP CONTROL SYSTEM

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8 Claims. (Cl. 103—41)

This invention relates to boiler feed pumps having a balancing drum or disc at the discharge end of the pump, which drum forms with the other pump components a balancing drum chamber connected to the suction side of the pump so as to hydraulic balance the hydraulic thrust generated by the pump impellers. More specifically, the invention relates to a boiler feed pump control system operative to prevent the flashing of water into vapor in the balancing drum chamber under low-load or no-load operation of the feed pump.

In conventional systems for preventing the flashing of water into vapor in the balancing drum chamber of a boiler feed pump, provision is made for the by-passing of water discharged from the pump to the condenser or the deaerator to thereby limit the water temperature rise in the balancing chamber to a value below its saturation temperature. This control of recycled or by-passed pump discharge water is achieved either by sensing the quantity of water flow at the intake of the pump or by sensing and measuring the temperature difference between the water entering the pump and the water discharging from the pump. In these conventional systems no consideration is given to the actual temperature and pressure of the water in the balancing chamber of the pump, which conditions are variable factors and essential to insure non-flashing of water in the balancing drum chamber.

Accordingly, it is an object of this invention to provide a boiler feed pump control system wherein the vaporization of water in the balancing drum chamber of the pump is prevented by controlling the amount of recycled pump discharge water in response to substantially the actual temperature and pressure of the water in the balancing drum chamber of the pump.

It is another object of the present invention to provide a boiler feed pump control system wherein the vaporization of water in the balancing drum chamber of the pump is prevented by the operation of recycle control valve in response to a temperature value near the vaporization temperature of the water under the prevailing pressure in the balancing drum.

A still further object of this invention is to provide, in a boiler feed pump control system for preventing the vaporization of water in the balancing drum chamber of the pump, an overriding control which functions to recycle pump discharge water when the temperature differential across the pump reaches a predetermined value.

It is, therefore, contemplated by the present invention to provide a boiler feed pump control system comprising a temperature sensing and transmitting means and a pressure sensing and transmitting means in communication with the balancing drum chamber of the boiler feed pump to sense substantially the actual temperature and pressure of the water in the balancing drum and transmit an appropriate signal to a computing device. The computing device correlates the temperature signal and the pressure signal in relation to an experimental constant factor so that, when the pressure of the water in the balancing drum chamber reaches a predetermined maximum value, a controller connected to the computing device operates to open a by-pass valve in the discharge line of the boiler feed pump. The controller also functions to close the by-pass valve when the pressure of the water in the balancing drum chamber reaches a predetermined minimum value at which the temperature of the water can be sustained

without the vaporization of the water, the predetermined temperature and pressure values being computed by the computing device from signals transmitted thereto by the temperature sensing and transmitting means and the pressure sensing and transmitting means.

To maintain the maximum water temperature rise across the boiler feed pump at a satisfactory level, a supplemental control is provided in the control system. The supplemental control consists of a second temperature sensing and transmitting means which is disposed to measure the temperature of the water at the inlet of the boiler feed pump. The temperature signal is transmitted to a second computing device which also receives the balancing drum chamber temperature signal from the first temperature sensing and transmitting means. The second computing device calculates the temperature difference between the two signals; and, if the temperature differential is at a predetermined value—for example, 50° F.—the computing device actuates the by-pass valve to an open position regardless of the action of the controller. In other words, the supplemental control mechanism overrides the primary control mechanism. The second computing device is preset to function and close by the by-pass valve when the temperature differential falls to a predetermined value, for example, 40° F.

The control system according to this invention also provides for the second computing device to effect the actuation of the by-pass valve to an open position when the temperature of the water in the balancing drum chamber of the pump reaches a predetermined maximum temperature value, for example, 350° F.

In the aforedescribed control system, it is within the scope and spirit of the present invention that the components of the system can be constructed of electrical, pneumatic, hydraulic, or mechanical elements, or combinations thereof, wherein an appropriate temperature and pressure signal is converted into mechanical, electrical, or fluid energy of such magnitude as to effect the actuation of the motor means for operating the by-pass valve. It is, therefore, to be understood that the present invention is not limited to the precise components shown in the drawing and it is to be limited only by the scope of the claims.

The invention will be more fully understood from the following description when considered in connection with the accompanying drawings in which:

FIG. 1 is a diagrammatic showing of the boiler feed pump control system according to this invention;

FIG. 2 is a graph showing the relationship of the temperature in Fahrenheit degrees and the pressure of water in the balancing drum of the boiler feed pump in pressure-per-square-inch absolute;

FIG. 3 is a graph showing the relationship of the water pressure relative to the percent of the total load and the water temperature in Fahrenheit degrees in relation to the percent of the total load; and

FIG. 4 is a graph showing the relation of the inlet temperature of the water and the temperature of the water in the balancing drum to override the control of the by-pass valve based on the temperature rise across the pump.

Now referring to the drawing and more particularly to FIG. 1, **10** generally designates the entire boiler feed pump control system according to this invention, while reference number **11** designates a boiler feed pump of the multi-stage type. Although boiler feed pump **11** is illustrated as a multi-stage type, it is to be understood that the invention is not limited to such a pump or to a pump of any particular design, except that the pump must have a balancing drum chamber.

The boiler feed pump shown comprises a casing **12** surrounding a plurality of series-connected impeller-stator assemblies **13**, the impellers being mounted for rotation on a drive shaft **14**. The pump is provided with an inlet

connection 15 which is in communication at one end with a source of water, such as a deaerator or condenser (not shown), and at the other end with a first impeller-stator assembly 13. An outlet connection 16 is provided at the other end portion of the pump, which connection communicates with the last of the plurality of impeller-stator assemblies 13 to receive the pumped water from the latter. Adjacent outlet connection 16 and outlet chamber 17, a balancing drum 18 is mounted on shaft 14. The balancing drum 18 defines with the casing 12 and a stuffing box connection 19 a balancing drum chamber 20 which receives water at substantially inlet or suction temperature and pressure through an equalizer line 21.

Control system 10 for preventing the vaporization of water in balancing drum chamber 20 comprises a first temperature sensing and transmitting device 22, such as a thermocouple 22A and an amplifier unit 22B, connected to equalizer line 21 nearest the drum chamber 20. A suitable temperature sensing and transmitting device 22 is presently manufactured by Moore Products Company of Spring House, Pennsylvania, and is designated Model B. The temperature sensing and transmitting device 22 supplies a signal which is conveyed by a line 23 to a computing device 24. A pressure sensing and tranmsitting device 25, comprising a sensing line 25A and an amplifier unit 25B, is connected to equalizer line 21 adjacent thermocouple 22A to receive and sense the pressure of the water in line 21, which water is at substantially the temperature and pressure as the water temperature and pressure in balancing drum chamber 20. The amplifier unit 25B transmits a signal, corresponding to the pressure being sensed, through a line 25C to computing device 24. While thermocouple 22A and sensing line 25A are shown connected to equalizer line 21, it is within the scope and spirit of this invention to position the thermocouple and the sensing line on the pump so as to communicate directly with the interior of balancing drum chamber 20.

A suitable pressure sensing and transmitting device 25 is presently manufactured by Moore Products Company and is designated Model 173S.

The computing device 24 is of any suitable construction well known to those skilled in the instrumentation art, is so connected to receive the temperature and pressure signals—voltage, hydraulic, or other type of signal—from the first temperature sensing and transmitting device 22 and the pressure sensing and transmitting device 25, and operates to correlate the pressure signal and the temperature signal in relation to an experimental constant to produce a resultant signal. The resultant or computed signal is transmitted by a line 26 to a temperature controller 27. The computing device 24 solves the following equation:

$$P_1=P_2-K_1P_3$$

When:

P_1 represents the resultant or computed signal;

P_2 represents the temperature signal input received from the temperature sensing and transmitting device 22;

P_3 represents the pressure signal input received from the pressure sensing and transmitting device 25; and

K_1 represents a constant factor which is a linearized "slope" of vapor pressure relative to a temperature curve C–D and E–F as shown in FIG. 2.

A suitable computing device 24 is a temperature compensating relay manufactured by Moore Products Company, designated Model 65, and sold under the trademark "Xtractor," while a suitable temperature controller 27 is also manufactured by Moore Products Company and designated Model 50MW.

The controller 27, in response to the signal P_1 received from computing device 24, effects the operation of a relay 28. Relay 28 is connected to a pilot relay 29 which, in turn, causes the actuation of a by-pass valve 30 disposed in a recirculation or by-pass line 30A, the latter communicating with outlet connection 16 and a deaerator or condenser (not shown). By-pass valve 30 may be of any suitable automatic valve construction; for example, a valve of the type manufactured by Black, Sivalls and Bryson, Incorporated, of Kansas City, Missouri, and designated as type 70–19 high pressure angle valve. Pilot relay 29 is connected to by-pass valve 30 through a primary or main pilot relay 31 so that the latter is capable of overriding the action of pilot relay 29. Pilot relay 31 forms a part of a primary or main control system or means which includes a second temperature sensing and transmitting device 32 disposed to pick up and transmit the temperature of the fluid in the pump inlet connection 15. Each of the pilot relays 29 and 31 may be of the Hunt 3-way valve type presently manufactured by Valvair Company. The second temperature sensing and transmitting device 32 may consist of a thermocouple 32A and an amplifier unit 32B, the latter being connected through a line 33 to a differential temperature computing device 34 to transmit a signal thereto.

The differential temperature computing device 34 receives a voltage signal from the first temperature sensing and transmitting device 22 through a line 35. Device 34 is constructed and arranged to compute the temperature differential between the fluid at the inlet connection 15 and at the balancing drum chamber 20. The device is preset to provide an output signal when the temperature differential reaches a predetermined value; for example, 50° F. Differential temperature computing device 34 may be of the type manufactured by Moore Products Company and designated Model 10B80. The output signal is communicated through a line 36 to a relay 37 which actuates pilot relay 31 to a position to cause by-pass valve 30 to open regardless of the position of pilot relay 29. The device 34 is also pre-adjusted to transmit an output signal, when the temperature differential is reduced to a level—for example, 40° F.—to effect the closing of by-pass valve 30 and the resetting of device 34.

The device 22 is also adjusted to effect the opening of by-pass valve 30 when the fluid temperature in the balancing drum chamber reaches a predetermined maximum amount; as, for example, 350° F.

In FIG. 2 is shown the relationship of the balancing drum temperature and pressure to effect the opening of by-pass valve 30 and the re-closing of the by-pass valve, while in FIG. 3 is shown the normal relation of the condensate water pressure and temperature in a pumped-through system.

In the operation of control system 10, to prevent the vaporization of the water in balancing drum chamber 20 at low-load or no-load condition of operation of boiler feed pump 11, the by-pass valve 30 permits the recirculation of water from the pump discharge side thereof to the deaerator or condenser (not shown) in response to the temperature and pressure conditions in the balancing drum chamber, the differential temperature value between the water in the balancing drum chamber 20 and the water at the pump inlet, and when the temperature of the water reaches a maximum temperature value in the balancing drum chamber.

As previously described, substantially the actual temperature and pressure of the water in balancing drum chamber 20 are measured by temperature sensing and transmitting device 22 and pressure sensing and transmitting device 25; and such temperature and pressure measurements are converted to signals, such as voltage signals, which are correlated in accordance with the formula $P_1=P_2-K_1P_3$ by computing device 34. When the computing device emits to the temperature controller 27 a resultant signal or impulse P_1 of a present value which is near but below the vaporization point of the water, as determined from the relationship of the temperature and pressure as shown in FIGS. 2 and 3, pilot relay 29 is activated to open by-pass valve 30. When the resultant signal or impulse P_1 falls below a second preset value,

which value corresponds to the water temperature that can be maintained in the balancing drum chamber **20** without vaporization of the water, the temperature controller **27** causes pilot relay **29** to close by-pass valve **30**.

A supplemental control system of control system **10** functions to measure the temperature differential between the water inlet temperature and the temperature of the water in the balancing drum chamber as computed by computing device **34** from temperature signals received from temperature sensing and transmitting devices **22** and **32**. When the computing device transmits to the pilot relay **31** a resultant signal according to a predetermined temperature differential value—for example, 50° F.—by-pass valve **30** is actuated to an open position. This signal overrides the P_1 signal and operation of pilot relay **29**. When the temperature differential is reduced to a preset level—for example, 40° F.—computing device **34** activates pilot relay **31** so as to effect the closing of by-pass valve **30**. This supplemental control limits the maximum temperature rise across the boiler feed pump to an acceptable level below which the water in balancing drum chamber **20** will not vaporize (see the graph shown in FIG. 4).

Each of the relays **28** and **37** may be of the type presently manufactured by Moore Products Company and designated as precision relay Model 67.

When the water temperature at the pump inlet attains a maximum temperature level—for example, 350° F.—as measured by temperature sensing and transmitting device **32** and communicated to computing device **34**, by-pass valve **30** is opened through the activation of pilot relay **31** which is controlled by computing device **34**.

It is believed now readily apparent that a control system has been provided to prevent the vaporization of the water in the balancing drum chamber of a boiler feed pump by measuring and reacting to open a by-pass or recirculation valve in the pump discharge line when the water temperature and pressure relationship in the balancing drum chamber nears the vaporization point of the water, when the temperatures of the water at the inlet and in the balancing drum chamber reach a predetermined maximum difference, and when the water inlet temperature attains a predetermined maximum value. The control system insures that the water in the balancing drum chamber will not vaporize under all the varying pressure and temperature factors which effect the vaporization of water.

We claim:

1. A method of preventing the vaporization of water in a balancing drum chamber of a boiler feed pump comprising the steps of:

(a) sensing the temperature and pressure of the water in the balancing drum chamber of the boiler feed pump,

(b) transmitting a signal commensurate with the temperature and pressure sensed to a computing device,

(c) correlating the temperature and pressure signals into a resultant signal in accordance with the formula $P_1=P_2-K_1P_3$ wherein:

P_1 represents the resultant or computed signal

P_2 represents the temperature signal

P_3 represents the pressure signal, and

K_1 represents a constant factor which is a linearized "slope" of vapor pressure relative to a temperature curve,

(d) recirculating the fluid discharged from the pump when the value of P_1 reaches a predetermined value near the point at which the water in the balancing drum chamber will vaporize under the existing pressure therein.

2. The method of claim **1** including the steps of:

(a) measuring the temperatures of the water entering the pump and the water in the balancing drum chamber, and

(b) recirculating the fluid discharged from the pump when the temperature differential between the water entering the pump and the water in the balancing drum chamber reaches a predetermined value.

3. The method of claim **1** including the steps of:

(a) measuring the temperature of the water entering the pump, and

(b) recirculating the fluid discharged from the pump when the temperature of the water reaches a predetermined maximum value.

4. A method of preventing the vaporization of water in a balancing drum chamber of a boiler feed pump comprising the steps of:

(a) sensing the temperature and pressure of the water in the balancing drum chamber of the boiler feed pump,

(b) calculating the relationship of the water temperature to the pressure in accordance with the following formula $P_1=P_2-K_1P_3$ wherein:

P_1 represents the resultant relationship between the temperature and the pressure

P_2 represents the temperature measured

P_3 represents the pressure measured

K_1 represents a constant factor which is a linearized "slope" of vapor pressure with respect to a temperature curve,

(c) recirculating the water discharged from the boiler feed pump through the pump when the value of P_1 nears the point at which the water in the balancing drum approaches the point of vaporization relative to the pressure therein.

5. The method of claim **4** including the steps of:

(a) measuring the temperatures of the water entering the pump and the water in the balancing drum chamber,

(b) recirculating the fluid discharged from the pump when the temperature differential between the water entering the pump and the water in the balancing drum chamber reaches a predetermined upper value, and

(c) ceasing to recirculate the discharged water from the pump when the temperature differential value between the water at the inlet of the pump and the water in the balancing drum chamber reaches a predetermined lower value at which water vaporization will not occur in the balancing drum chamber.

6. The method of claim **4** wherein the water is recirculated through the pump when the temperature of the water reaches a predetermined maximum value.

7. A control system in combination with a boiler feed pump having a balancing drum and a balancing drum chamber therein for receiving the water at substantially inlet water temperature and pressure, the control system comprising:

(a) a computing device,

(b) a first temperature sensing and transmitting means for measuring the temperature of the water in the balancing drum chamber and transmitting a signal commensurate with the temperature measurement to said computing device,

(c) pressure sensing and transmitting means for measuring the pressure of the water in the balancing drum chamber and transmitting a signal commensurate with the pressure measurement to said computing device,

(d) said computing device being constructed and arranged to calculate the relationship of the temperature and pressure as conveyed by said temperature and pressure signals and transmitting a resultant signal,

(e) a recirculation line communicating with the discharge of the boiler feed pump,

(f) a by-pass valve in said recirculation line,

(g) operating means connected to said computing device and said by-pass valve for opening the by-pass valve at a predetermined resultant signal and for closing the by-pass valve at another predetermined resultant signal, and

a second temperature sensing and transmitting means for measuring the temperature of the water entering the boiler feed pump and transmitting a signal, a second computing device connected to said first-mentioned temperature sensing and transmitting means and said second temperature sensing and transmitting means to receive the temperature signals therefrom and compute the temperature differential between the water entering said feed pump and the water in the balancing drum chamber, and second operating means overriding said first-mentioned operating means to open said by-pass valve upon a predetermined maximum temperature differential and to close said by-pass valve upon a predetermined minimum temperature differential.

8. The system of claim 7 wherein said second computing device is constructed and arranged to cause the second operating means to open the by-pass valve upon a predetermined maximum temperature of the water entering the pump.

References Cited by the Examiner

UNITED STATES PATENTS

1,485,504	3/1924	Hollander	103—112
2,062,925	12/1936	Ofeldt	122—448
2,593,058	4/1952	Schlieder	103—41
2,672,820	3/1954	Hillier	103—41
2,985,107	5/1961	Anderson	103—41
3,180,266	4/1965	Smith	103—41

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