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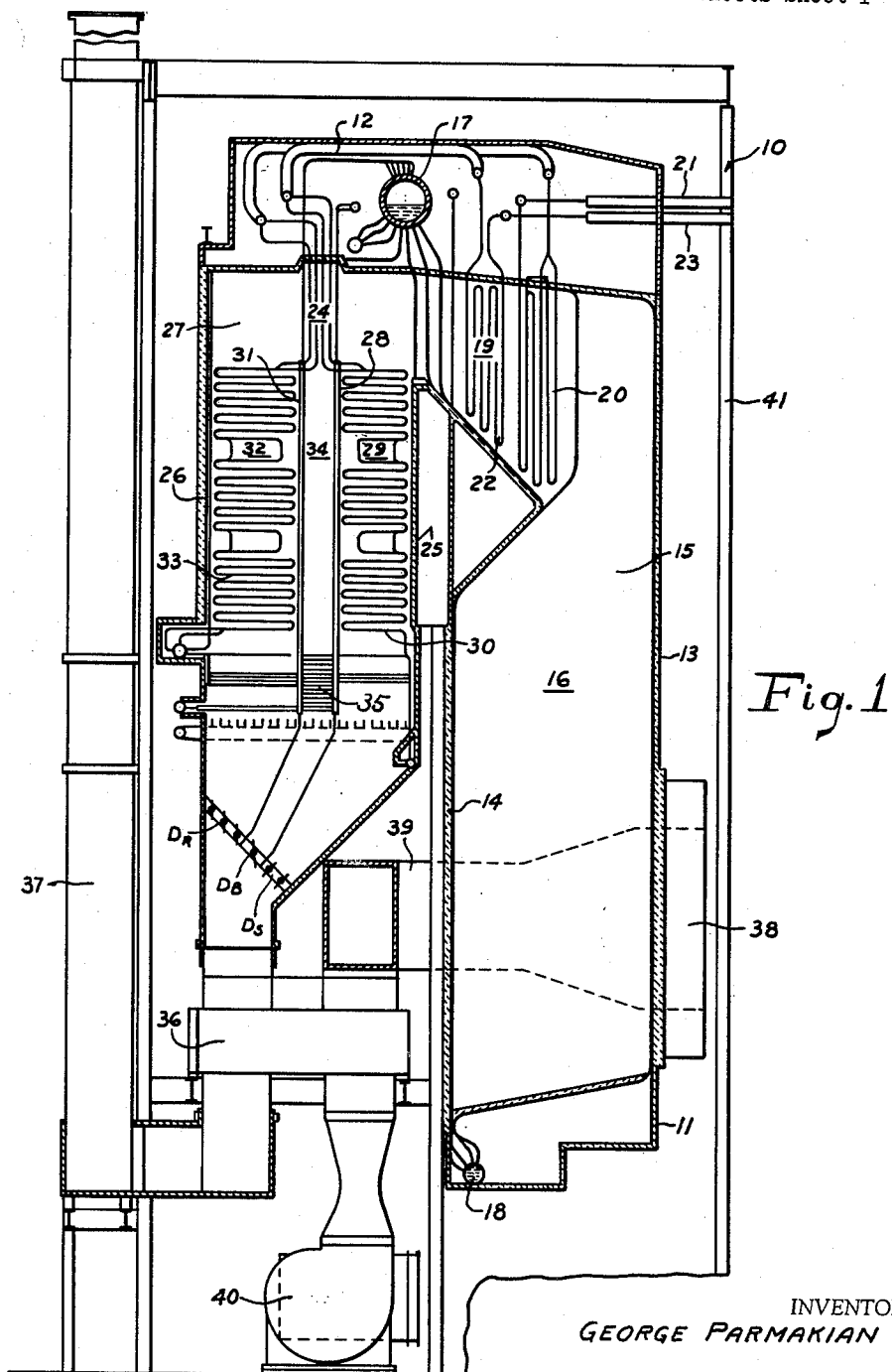
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STEAM TEMPERATURE CONTROL

Original Filed Nov. 30, 1954

2 Sheets-Sheet 1



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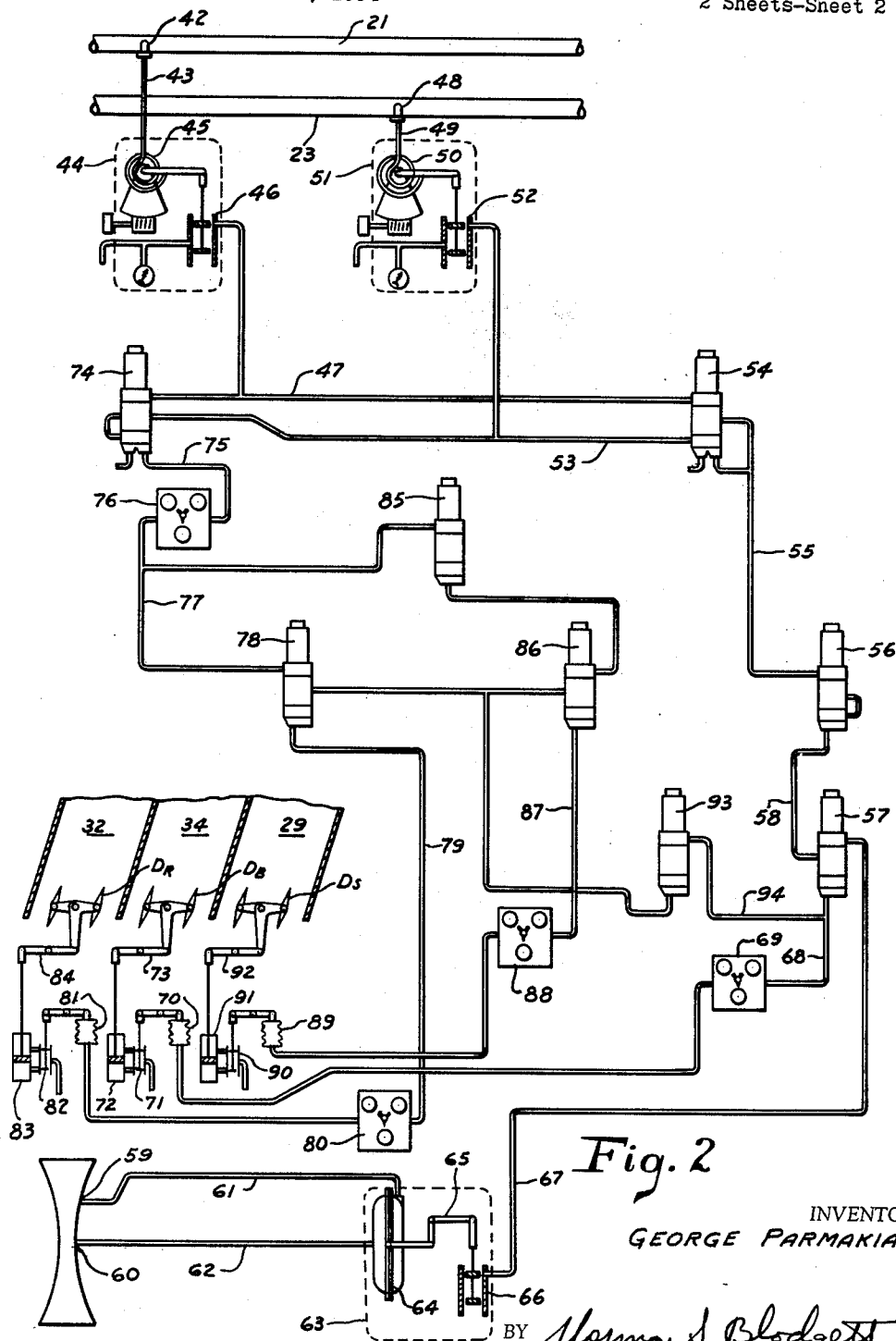


Fig. 2

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STEAM TEMPERATURE CONTROL

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Continuation of application Ser. No. 472,119, Nov. 30, 1954. This application Nov. 13, 1958, Ser. No. 774,074
1 Claim. (Cl. 122—479)

This invention relates to steam temperature control, and more particularly, to a method and apparatus for maintaining the temperature of superheated and reheated steam in a steam generating unit at a constant value over a wide range of loads.

This is a continuation of patent application Serial Number 472,119, filed November 30, 1954, now abandoned.

In the operation of steam generating units of the type where the steam must be superheated and reheated, one of the outstanding problems often encountered is that of maintaining the temperature of the superheated and reheated steam at a constant value. It is desirable to maintain these steam temperatures at constant values because of the fact that the steam turbines are designed for efficient operation at only one temperature. In the past, many ways have been proposed and used for controlling steam temperatures, among them being the use of desuperheaters and the use of tilting burners. However, the method most extensively used is that of the so-called damper control; that is to say, temperature is accurately determined by the control of the flow of gases over the respective superheating and reheating surfaces. However, even this last method of control suffers from many disabilities, due primarily to its sluggish action. The present invention obviates in a novel manner the difficulties experienced in the prior art.

It is, therefore, an outstanding object of the present invention to provide a method and means of controlling superheat and reheat in a steam generating unit so that the superheated and reheated temperature remains constant over a wide range of load.

Another object of the invention is the provision of superheat and reheat control which is simple and fool-proof in that it eliminates the necessity of water sprays, heat exchangers, change in flame direction, and the operating and maintenance problems associated with such systems.

It is a still further object of this invention to provide a steam temperature control in which the exit gases are maintained at a low value irrespective of load.

A still further object of this invention is the provision of a steam temperature control in which complete use is made of the heat available in the combustion gas for reheating and superheating.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the claims appended hereto.

The character of the invention, however, may be best understood by reference to certain of its structural forms as illustrated by the accompanying drawings, in which:

FIG. 1 is a longitudinal sectional view of a steam generating unit embodying the principles of the present invention; and

FIG. 2 is a more or less schematic view of one form of control apparatus for carrying out the present invention.

Referring first to FIG. 1, wherein is best shown the general features of the invention, a steam generating unit, indicated generally by the reference numeral 10, is shown as comprising a furnace 11 and a boiler 12. The furnace 11 is made up of a front wall 13, a rear wall 14, and

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side walls 15 forming a combustion chamber 16. The boiler 12 comprises a steam-and-water drum 17 having a downcomer, not shown, leading to a header 18 in the lower part of the combustion chamber 16 from which tubes radiate and pass upwardly along the furnace walls to the steam-and-water drum 17. Above the combustion chamber 16 resides an upper horizontal pass 19 in which resides a high temperature superheater section 20 discharging into the superheated-steam header 21 and a high-temperature reheat section 22 discharging into a reheated-steam header 23. Rearwardly of the combustion chamber 16 is a vertical back pass 24 having a forward wall 25, a rearward wall 26, and side walls 27. A dividing wall 28 extends transversely of the back pass 24 and forms with the forward wall 25 a first pass 29 in which resides a primary superheater section 30. Another wall 31 extends transversely of the back pass 24 and defines with the rearward wall 26 a second pass 32 in which resides a primary reheat section 33. The dividing walls 28 and 31 define therebetween a by-pass 34 in the lower portion of which resides an economizer 35. Portions of the economizer extend into the first pass 29 and into the second pass 32. The opening at the lower portion of the first pass 29 has residing therein dampers *Ds*. At its lower portion the second pass 32 is provided with dampers *Dr*, while the by-pass 34 is provided with a damper *Db*. The lower portion of the back pass 24 is connected to a regenerative air heater 36 which discharges into a breaching 37. Burners 38 are mounted on the forward wall 13 of the furnace 11 and are supplied with air flowing through a ducting 39 connected to the air exit of the regenerative air heater 36. A fan 40 is connected to the air inlet of the air heater 36. All of the apparatus described above is mounted on a structural steel framework 41 in the usual manner.

Referring next to FIG. 2, wherein is shown a control of the type which may be used in carrying out the principles of the present invention, it may be noted that the gas passes 29, 32, and 34, and the dampers *Ds*, *Db*, and *Dr* are shown more or less schematically. The superheated-steam header 21 and the reheated-steam header 23 are also shown in this view. A temperature-sensing element 42 resides in the superheated-steam header 21 and is connected through a conduit 43 to a master controller 44 wherein a Bourdon tube 45 actuates an air pilot valve 46, thus varying the air pressure in a conduit 47 to which the pilot valve is connected. A similar temperature-sensing element 48 resides in the reheated-steam header 23 and is connected through a tube 49 to a Bourdon tube 50 in a master controller 51, the Bourdon tube serving to actuate a pilot valve 52, thus producing air pressure changes in a conduit 53. Both the conduit 47 and the conduit 53 are connected to an air relay 54 of the type shown and described in the patent to Gorrie, Reissue Patent No. 21,804. In the present case the air relay 54 is used as a totalizing relay and emits an air signal indicative of the sum of the pressures in the conduits 47 and 53. The output of the totalizing relay 54 is connected by a conduit 55 to an air relay 56 which is used as an amplifier. The output of the air relay 56 is connected to an air relay 57 by means of a conduit 58.

A pressure connection 59 is situated at the entrance to a venturi situated in the air duct 39 and a pressure connection 60 is situated in the throat of the same venturi. The connections 59 and 60 are connected by conduits 61 and 62, respectively, to a master controller 63 containing an enclosed diaphragm control element 64. The conduits 61 and 62 are connected to chambers on opposite sides of the diaphragm 64 so that its movement is representative of the differential in the pressures therein and, thus, indicative of a change in boiler load. The controller 63 thus acts to measure changes in load which, of course, influence steam temperature. The diaphragm 64 is connected

through a linkage 65 to an air pilot valve 66, the output of which is connected through a conduit 67 to the air relay 57. The conduits 67 and 58 are connected to the air relay 57 in such a manner that the air relay produces an air pressure in its exit conduit 68 which is indicative of the difference in air pressures in these conduits. The conduit 68 is connected through a selector 69 to a bellows 70 which actuates a hydraulic pilot valve 71 which is connected to actuate a cylinder 72 that is connected through a linkage 73 to the bypass damper Db.

The conduits 47 and 53 are also connected to an air relay 74 in such a manner that the air relay acts as a differential relay and emits a signal into its exit conduit 75 which is indicative of the differences in pressure in the conduits 47 and 53. The conduit 75 is connected to a selector valve 76 the other side of which is connected through a conduit 77 to an air relay 78 which acts as a calibrating relay. The output of the air relay 78 is connected through a conduit 79 and through a selector valve 80 to a bellows 81 which actuates a hydraulic pilot valve 82. The valve 82 is connected to a cylinder 83 which operates the reheat dampers Dr through linkage 84. The output of the differential relay 74 is also connected through the selector valve 76 to a reversing relay 85, the output of which is connected to a calibrating relay 86, the output of which is connected to a conduit 87 through a selector valve 88 to a bellows 89 which actuates a hydraulic pilot valve 90. The pilot valve 90 actuates the cylinder 91 which operates through a linkage 92 to adjust the superheater dampers Ds. The output of the averaging relay 57 is connected to a calibrating relay 93 by a conduit 94. The output of the relay 93 is connected to both calibrating relays 78 and 86.

The operation of the apparatus and the manner of carrying out the method will now be clearly understood from the above description. Water from the steam-and-water drum 17 passes downwardly into the header 18 and is distributed into the waterwalls, eventually returning to the steam-and-water drum 17 in the form of steam. From the steam-and-water 17 the steam passes into the low temperature superheater section 30 and passes from that into the high temperature section 20 from which it enters the superheated-steam header 21 for use in a turbine or the like. The exit steam from the turbine is returned to the steam generating unit and enters the low temperature reheat section 33 after which it flows through the high temperature reheat section 22 before passing into the reheated-steam header 23 from which it is removed for a low pressure turbine. Fuel introduced into the burner 38 is mixed with air originating in the duct 39 and the air and fuel pass into the combustion chamber 16 where they burn. Hot gases originating in the combustion chamber 16 pass upwardly and through the upper pass 19 and then downward into the back pass 24. The gases are divided between the forward pass 29, the bypass 34, and the rear pass 32 according to the setting of the dampers Ds, Db, or Dr. Gases leaving the back pass 24 through the dampers pass through the air heater 36 into the breeching 37 for discharge into a stack or the like. Gases flowing through the first pass 29 pass over the low-temperature superheater section 30 and a small portion of the economizer 35. Gases flowing through the second pass 32 pass over the low-temperature reheater section 33 and a small section of the economizer 35. Gases flowing through the bypass 34 pass only over a large section of the economizer 35. The settings of the dampers Ds, Db, and Dr are controlled in accordance with the temperature of the steam in the superheated-steam header 21 and the reheated-steam header 23, as modified by air flow measurements indicated by the air flow measuring device situated in the furnace and in the air duct, namely, the elements 59 and 60, the difference in these two being indicative of load. The master controller 51 gives a signal indicative of the temperature of reheated steam and passes it into the conduit 53. The master controller 44 gives an output

signal proportional to the temperature in the superheated-steam header 21 and this is transmitted to the conduit 47. These two pressures are added in the totalizing relay 54. This air pressure is amplified in the air relay 56 and it is combined in the air relay 57 with another air signal originating in the master controller 63 which is indicative of load. The signal which is resultant of averaging the signals in the conduits 58 and 67 is used to actuate the bypass dampers Db. The air pressures existing in the conduits 47 and 53 are subtracted in the differential relay 74 and the resultant air pressure is modified in the calibrating relay 78 before being used to actuate the reheat dampers Dr. At the same time, the signal originating in the differential relay 74 is introduced to the reversing relay 85 where a signal is obtained which is the reciprocal of the output signal of the relay 74. This signal is passed through the calibrating relay 86 and is used to actuate the superheater dampers Ds. Furthermore, the output signal of the relay 57, after being somewhat modified in the calibrating relay 93, is introduced to the calibrating relays 78 and 86 to modify their output signals in accordance with the output pressure of the averaging relay 57.

The following is a description of the application of the above-described method and apparatus to a practical steam generating installation. The steam temperature control described herein is designed for use with steam generating units to be fired with natural gas, oil, or pulverized coal which are equipped with high temperature superheaters and reheaters. In a certain installation the superheaters and reheaters would be constructed for delivery of 1,005 degrees F. high pressure steam with the steam reheated to 1,005 degrees F. The design of the steam generating unit and its steam temperature control will be such that the final specified temperature of 1,005 degrees F. will be maintained for both high pressure and reheat steam within a range of steam flow rate of 65% to 100% of design capacity. The high pressure superheater surface consists of a primary section placed in the vertical down pass and a final high temperature section located immediately behind a single row of water screen tubes separating this section from the furnace. The primary section is drainable and the high temperature section consists of vertically hanging loops and is non-drainable. Approximately 76% of the total high pressure superheater surface is represented by the primary horizontal loop surfaces. The reheater surfaces consist of a low temperature section placed in a second vertical gas pass, and a final temperature section located immediately behind the high temperature section of the superheater. The low temperature reheater section is formed by horizontal loops of tubes and is drainable, whereas the final high temperature section is of the vertically-hanging type and is non-drainable. Approximately 86% of the total reheater surface is represented by the horizontal tube drainable section. The primary superheater and low temperature reheater sections are separated by a vertical gas pass which contains economizer surface of sufficient area to cool the combustion gases flowing through the center pass to the same degree as would be accomplished if these gases were passing over the primary superheater and low temperature section of the reheater. Therefore, the exit gas temperature at the outlets of the three gas passes remains essentially the same regardless of the proportion of flue gas flowing through either of these three passes. Each of the three vertical gas passages terminates with a set of gas flow control dampers which are automatically controlled from final steam temperature. The operation of the control is as follows:

(1) Superheater and reheater surfaces and the gas pass areas are so proportioned that the specified final temperature for high pressure and reheat steam is obtained at approximately 65% of designed steam flow rate. Up to this load the combustion gases are divided in direct proportion and the gas flows only through reheated and primary superheater passes with the center bypass damper

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completely closed. At approximately 65% steaming rate, primary superheater and reheater passes are wide open and the center damper closed.

(2) As steam flow rates increase, the steam temperature would rise above the specified limit if there were no control, but the impulse sent to the control dampers starts to open the center pass damper gradually and, thus, permits a certain quantity of combustion gas to spill over through the center pass. The heat contained in this portion of flue gas is not available for the primary superheater. Only sufficient gas will flow through the center pass to keep the superheater and reheater steam temperature at 1,005 degrees F.

(3) The dampers below superheater and reheater passes are then automatically adjusted to divide correctly the remaining combustion gas between the two passes so that high pressure and reheat steam temperature will be maintained at exactly 1,005 degrees F.

(4) As has been stated above, at steam flow rates lower than 65% of design capacity the center pass damper will be completely shut and all available combustion gas will flow over primary superheater and reheater surfaces. The dampers below these two gas passages will be automatically adjusted to proportion the gas quantity flowing over primary superheater and reheater surfaces so that the temperature of superheater and reheater steam will remain exactly qual. For example, if at a steam output rate of 50% of design capacity only sufficient heat is available to produce 950 degrees F., high pressure steam and reheater steam temperature, the dampers of the respective passes are so adjusted that both high pressure and reheat steam will remain at exactly 950 degrees F. In other words high pressure and reheat steam temperatures will be the same for any load between minimum and maximum.

(5) Only one control instrument is required to record the steam temperature and to send the impulses to respective power units operating the three sets of dampers, but to anticipate a change in the performance of superheater and reheater resulting from a change in steam flow rate, an air flow controller is recommended in addition to the steam temperature controller. Each of the three sets of dampers is, of course, operated by its individual power unit; the function of the control instrumentation is as follows:

(A) Temperatures of superheater and reheater steam will be totalized throughout the entire range of operation. The master controller and the totalizing relay obtain the sum of reheat temperature sensing elements in the headers. If the sum of the two temperatures is less than 2,010 degrees F., the impulse sent to the power unit will keep the center bypass damper fully shut; if, with an increase of steam flow rate, the sum of the two temperatures tend to exceed 2,010 degrees F., the impulse sent to the power unit of the center bypass damper will gradually open the damper to permit spillover of gas with its excess heat which thus bypasses superheater and reheater surfaces.

(B) The instrumentation divides the sum of temperatures into two equal parts and the impulse sent to the power units operating the reheater and primary superheater dampers will so adjust these dampers that the gas flowing over the primary superheater and low temperature reheater surfaces is proportioned to produce the exact temperature of 1,005 degrees F. for each as long as the steam flow rate is above approximately 65% of full load.

(C) For lower steam flow rates at which the sum of the high pressure and reheat steam temperatures is less than 2,010 degrees F., the instrument continues to divide the sum into two equal parts and continues to adjust the primary superheater and low temperature reheater dampers so that exactly equal temperatures are obtained for both.

(D) In many cases, it is possible to design the center bypass for low gas flow resistance with a maximum pos-

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sible flow of bypass gas to insure that the full open position of the bypass damper cannot be reached within any point of control range including the control condition necessary with a possible overload of 15% above the design capacity.

(6) The power units of the superheater and reheater control dampers are designed so that one or the other of the two groups of dampers will always be wide open, while the second group of dampers adjusts gas flow by throttling. This is to prevent the possibility of both dampers gradually drifting toward a closed position which would result in an excessive gas flow resistance.

(7) The apparatus is simple and foolproof. It eliminates the necessity of water sprays, heat exchangers, change in flame direction, and the operating and maintenance problems associated with such systems. Because all gas passages extend across the entire width of the boiler, there can be no unequal gas flow rate between one side and the other of the setting which, of course, is vitally important for the maintenance of uniform steam and metal temperatures in superheater and reheater. Complete use is made of the heat available in combustion gas for reheating and superheating because only that portion of heat contained in the bypass gas and which is not required for superheating and reheating is being bypassed.

(8) All control dampers are located in areas of relatively low gas temperatures and can never be heated above 750 degrees F. No special provisions need therefore be made for the cooling of these dampers, nor is it necessary to construct the damper assembly of special heat resisting steels.

The total air flow, which is an index of boiler load, acts through the master controller 63 to open the bypass damper Db as the boiler load increases above approximately 65% by transmitting its air loading pressure through the averaging relay 57 and a selector valve 69. The bypass damper opening is modified as required by the sum of the superheater and reheat temperature control loading pressures which correspond to 2,010 degrees F. transmitted from the totalizing relay 54 to the averaging relay 57 by way of the amplifying relay 56; should the sum of the two temperatures start to increase above 2,010 degrees F. with a wide open bypass damper both the superheat and reheat dampers will be throttled together to force the required additional quantity of gas through the bypass section. This action is accomplished by an increase in control loading pressure transmitted through the calibrating relay 93 and applied to control drive calibrating relays 78 and 86 to control from boiler load as modified by the sum of the two steam temperatures and to maintain the sum of the two temperatures constant at 2,010 degrees F. above approximately 65% boiler load.

When the superheated and reheated steam temperatures are equal and the air relay 54 into which their control pressures terminate is in balance, an increase in reheated steam temperature above superheated steam temperature transmits a change in output of the differential air relay 74 in a direction that throttles the reheat control damper. A decrease in reheated steam temperature below superheated steam temperature reverses the direction of the output of the differential relay 74 and causes the reheat damper to open. Should the reheated steam temperature remain lower than the superheated steam temperature, the differential relay 74 output would continue to change in the same direction and to cause the superheat damper to throttle, thus leaving the reheat damper wide open as required to equalize the two temperatures. The output of the differential relay 74 is applied to the superheat and reheat damper control drives through selector valves and reversing and calibrating relays as indicated in the drawings; thus, the superheat and reheat dampers are positioned to maintain equal superheated and reheated steam temperatures. At boiler loads where the

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sum of these two temperatures of 2,010 degrees is available, each will be controlled at 1,005 degrees F.

It is obvious that minor changes may be made in the form and construction of the invention and in the operation without departing from the materials and spirit thereof. It is not, however, desired to confine the invention to the exact form herein shown and described but it is desired to include all such as properly come within the scope of claim.

The invention having been thus described, what is claimed as new and desired to secure by Letters Patent is:

Apparatus for controlling the operation of a vapor generating and superheating unit of the type having a convection vapor superheater and a convection vapor reheater disposed, respectively, in divided and separate parallel structurally defined gas flow passages from a common combustion space and having a controllable structurally defined gas by-pass around the said parallel heating passages, including in combination, damper throttling means for the superheater passage, damper throttling means for the reheater passage, damper throttling means for the by-pass, means continuously determining superheat final total temperature, means continuously deter-

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mining reheat total temperature, first control means responsive to both the superheat final total temperature, and the reheat final total temperature determining means and producing a control effect representative of the total of the two temperatures, means arranged to position the by-pass damper means responsive to said first control means, a second control means responsive to both the superheat final total temperature and the reheat final total temperature determining means and producing a second control effect representative of the difference of the two temperatures, and means selectively responsive to said second control effect arranged independently and individually to throttle the damper of the superheat passage or of the reheat passage, whichever temperature is higher, while leaving the opposite damper open.

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