Jan. 22, 1957 C. H. WOOLLEY ET AL 2,778,346

METHOD OF AND APPARATUS FOR CONTROLLING VAPOR SUPERHEAT TEMPERATURES

Filed May 16, 1950 3 Sheets-Sheet 1

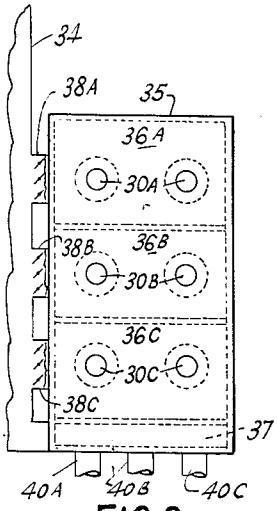


FIG. 2

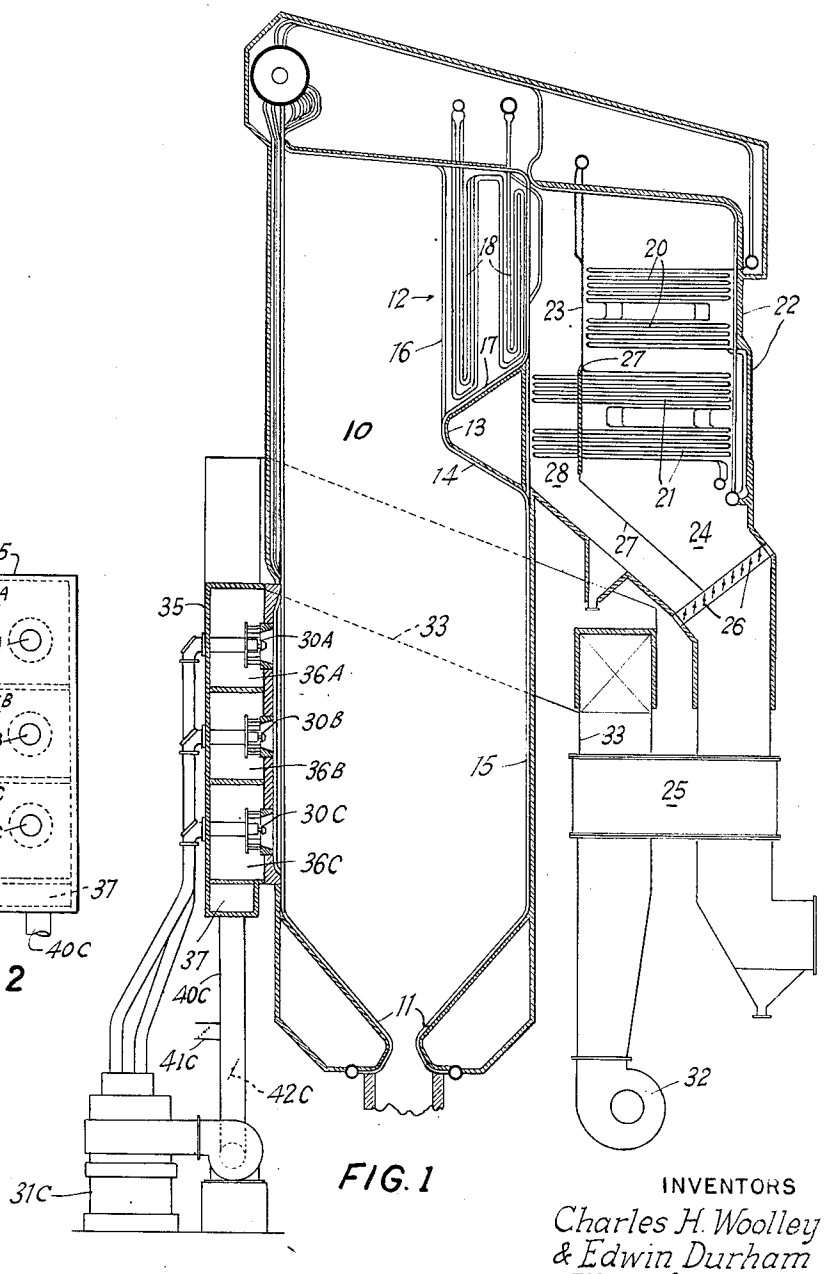


FIG. 1

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Filed May 16, 1950 3 Sheets-Sheet 2

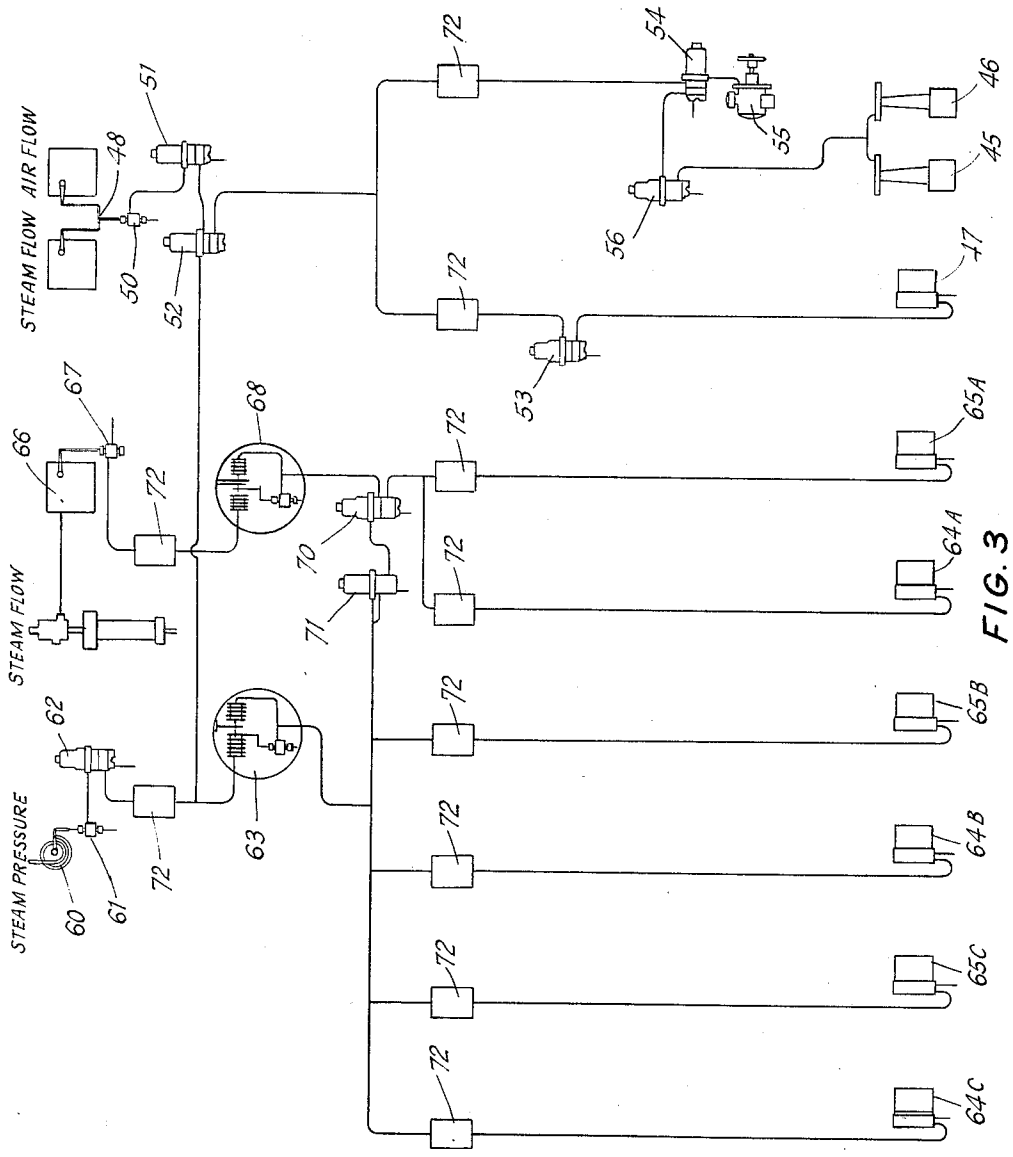


FIG. 3

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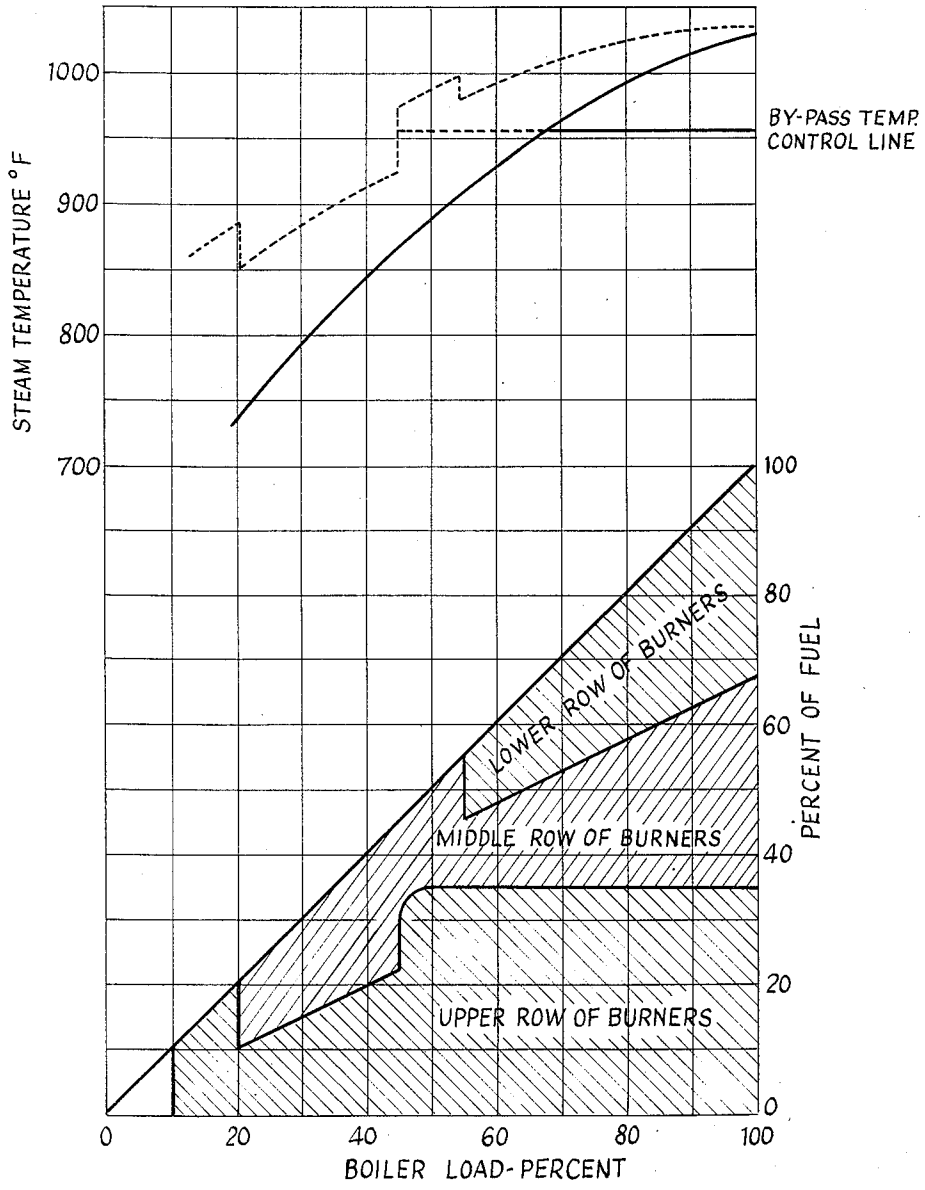


FIG. 4

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2,778,346

METHOD OF AND APPARATUS FOR CONTROLLING VAPOR SUPERHEAT TEMPERATURES

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Application May 16, 1950, Serial No. 162,168

7 Claims. (Cl. 122—479)

The present invention relates to the regulation of superheated vapor temperatures delivered by a vapor generating and superheating unit, and more particularly to an improved method of and apparatus for maintaining the vapor superheat temperature substantially uniform over a wide range of vapor output capacities.

In many vapor generating units it is desirable to maintain the temperature of the superheated vapor substantially uniform over a wide range of vapor output capacities. Superheat temperature control is particularly desirable in the generation of steam for the production of electrical energy in large central station power plants. In such plants, the upper limit of superheat temperature is governed by the materials and construction of the turbine served by the steam. In the interests of turbine efficiency the temperature of the steam delivered to the turbine should be maintained within close optimum limits throughout a wide range of capacities.

In the generation of and the superheating of the steam, a change in the steam output requirements, with an accompanying change in heat input to the water cooled furnace, will also change the temperature and volume of the furnace gases used in superheating the steam. In recent years superheat steam temperatures have been closely regulated by means of a gas by-pass arranged to divert heating gases around portions of the superheaters, or by attemperation of the superheated steam with steam condensate or boiler feed water, or by use of a closed type heat exchanger arranged in the boiler circuit, such as a lower drum attemperator.

When utilizing steam attemperation or a gas by-pass the superheater is ordinarily selected with sufficient heat exchange surface to produce the desired steam superheat temperature at an output capacity somewhat less than the maximum unit flow capacity, for example at 70 to 75% rating. Under such conditions the superheated steam temperature is then maintained at a uniform value between 75 and 100% of unit rating by means of the attemperator, or the heating gas by-pass. Ordinarily it is impractical to provide attemperation or by-pass facilities for superheat temperature regulation for more than the approximate range of capacities indicated.

In accordance with the present invention an elongated vapor generating furnace having a convection type superheater adjacent the gas outlet end of the furnace is provided with a plurality of fuel inlets or burners spaced at different positions from the superheater. The fuel input to one portion of the furnace is maintained substantially uniform over an upper range of vapor flow rates from the unit while the fuel input to the remaining portion of the furnace is varied substantially in proportion to the actual flow rate from the unit. In the preferred embodiment of the invention hereinafter disclosed at least one fuel inlet or a row of inlets positioned closest to the furnace outlet is fired at a substantially uniform rate throughout a major portion of the operating capacity range of the vapor generator. Other fuel inlets spaced further from the furnace outlet are fired at rates corresponding with changes in the vapor generator capacity. As a result the superheat temperature of the vapor generated is maintained at a more uniform value over a greater range of output capacities than would be possible with a variation in all fuel inlet firing rates commensurate with the vapor generating load range. The operation of the vapor generating unit can be manually accomplished in accordance with the method of the invention, or the regulation of the fuel input to the furnace can be attained by means of automatic controls hereinafter described.

The various features of novelty which characterize our 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 we have illustrated and described our invention.

Of the drawings:

Fig. 1 is an elevation side view, partly in section, of a vapor generating unit constructed and arranged in accordance with the invention;

Fig. 2 is a partial front view of the burner portion of the generating unit shown in Fig. 1;

Fig. 3 is a schematic drawing of a control system suitable for the operation of the unit shown in Fig. 1; and

Fig. 4 is a diagrammatic illustration of the operating results attained by the present invention.

In the illustrated embodiment of the invention shown in Fig. 1, the steam generating and superheating unit includes a vertically elongated furnace 10 having a hopper bottom 11 and a heating gas outlet 12 in the upper portion thereof. The furnace is enclosed by fluid-cooled walls containing vapor generating tubes, where the tubes are connected into the circulatory system of the steam generating portion of the unit. The arch 13 below the gas outlet 12 is formed by a row of tubes 14 bent out of the plane of the furnace rear wall 15, with some of those tubes extended upwardly as a widely spaced row 16 to the furnace roof, while the remaining tubes 17 in the arch row are inclined rearwardly to merge into and extend upwardly in the plane of the furnace rear wall 15. The tubes in the row 16 extend across the furnace gas outlet 12 in front of superheating elements 18, which are positioned in the space between the tube row 16 and the tube extensions of the furnace rear wall 15.

Combustion gases are generated within the furnace 10 by the combustion of fuel, as hereinafter described, and pass through the furnace outlet 12 and thence over the superheater elements 18. The gases in leaving the superheating elements 18 pass downwardly over additional banks of tubes of a superheater 20 and through the tubular elements of an economizer 21. The tubes of the superheater 20 and the economizer 21 extend horizontally, with the economizer extending from the outer side of the furnace rear wall 15 to the outer wall 22 of the steam generator. The economizer outlet conduits 23 extend upwardly in a vertical plane outwardly spaced from the furnace rear wall 15 with the superheater 20 positioned between the conduits 23 and the wall 22. The gas leaving the lower bank of the economizer is passed through a duct 24 to an air heater 25 before the gas is discharged through an induced draft fan (not shown) to the atmosphere. The duct 24 is formed with an inclined bottom and is provided with a plurality of gas flow control dampers 26 controlling the flow of gas between the superheater elements 18 and the air heater. The tubes 23 form part of a partition wall 27 extending from the level of the upper end of the superheater 20 to the dampers 26. With this construction, the amount of gas flow through the superheater 20 can be regulated, and

thus the temperature of the superheated steam delivered by the unit. Some of the heat in the gases passed through the by-pass path 28 defined between the partition wall 27 and the rear wall 15 of the furnace, will be absorbed by the portions of the economizer 21 extending across the by-pass path.

Fuel is supplied to the furnace 10 through burners 30 installed in the front wall thereof. As shown in Figs. 1 and 2, the burners are arranged in three rows, the lower row 30C positioned superadjacent the furnace hopper bottom 11, while the intermediate and upper burner rows, B and A respectively, are vertically spaced therefrom. Any number of spaced rows of burners, i. e. two or more, may be used in accordance with the present invention. As shown in Fig. 2, each burner row consists of 2 burners, although any number of burners may be installed in each row, depending upon the width of the furnace 10 and the amount of fuel to be delivered thereto. Each row of burners is supplied with pulverized coal from an individual coal pulverizer 31, with each pulverizer connected to burners of a corresponding burner row by separate burner lines. Pulverizer 31C is shown in Fig. 1 with its air inlet duct, and burner line connections with the burner row 30C. Pulverizers 31A and 31B (not shown) are the same size and capacity as pulverizer 31C, are provided with similar air inlet ducts, and are connected with the burner rows 30A and 30B, respectively.

A forced draft fan 32 is arranged to deliver a controlled amount of air, at the desired pressure, to the air heater 25 with the preheated combination air therefrom passing into a duct 33. The duct 33 is conveniently arranged along one side of the furnace and is provided with an upright extension 34 located adjacent a casing 35 enclosing the burners 30. The casing 35 is provided with vertically spaced horizontal partitions separating the casing into a plurality of air chambers 36A, 36B, 36C and 37. The chambers 36A, 36B and 36C enclose and open to the burner rows 30A, 30B and 30C respectively, and are each in communication with the air duct extension 34 through a dampered conduit connection 38A, 38B and 38C, respectively. The lower end of the air duct extension 34 opens into the chamber 37 at the lower end of the casing 35, from which individual primary air ducts 40A, 40B and 40C lead to the fan inlet connection of each of the pulverizers 31A, 31B and 31C respectively. Each of the primary air ducts is provided with a dampered tempering air inlet connection, such as 41C, and a primary air flow control damper, such as 42C. With the described pulverizer air flow connections, the temperature and amount of air delivered to each pulverizer can be regulated to control the pulverized coal output of the pulverizer and the amount of fuel delivered to each row of burners. The control of pulverized coal flow from a unit pulverizer by means of a regulation of the primary air flow thereto is well known in the art. Thus, regulation of primary air flow accomplishes a corresponding regulation of fuel flow to the burners. The flow of secondary combustion air to each burner row can also be regulated for optimum combustion conditions.

In the control diagram shown in Fig. 3, the forced draft fan 32 (Fig. 1) is controlled to provide an optimum amount of combustion air to the burners 30 for the combustion of fuel within the furnace 10. The fan 32 is provided with both speed control and damper regulations (not shown), both of which are actuated in response to a steam flow-air flow type of control system. The fan speed is regulated by flow of fluid through the valves 45 and 46 to a hydraulic coupling (not shown) on the fan drive. Since fan speed changes will not only change the volume of air delivered, but also the air pressure, the extent of air flow regulation by fan speed is limited. Any increase or decrease in fan air flow, beyond that obtainable by changes in fan speed, is obtained by the use of vanes in the fan inlet, as positioned by a power piston 47. This type of control system is well known and consists of a steam flow-air flow ratio controller 48, where a change in the steam flow from the steam generating unit causes a proportional change in the position of a pneumatic pilot valve 50. The valve transmits an impulse through a Standatrol 51 and an averaging relay 52 to both the piston 47 which positions the vanes in the fan inlet, and to the control valves 45 and 46 regulating the flow of fluid through the variable speed hydraulic fan coupling. The cilibrating relay 53 regulates the transmittal of control impulse to the power piston, while the valves 45 and 46 regulate fan speed through a range of fan speeds in accordance with the adjustment of a differential relay 54 correlated with a hydraulic tachometer 55 and acting through an accelerating relay 56, so that the piston 47 will become operative below the selected fan speed operating range. The regulation of the fan 32 in accordance with the steam flow-air flow controller 48 controls the total amount of combustion air delivered, with the fuel, to the furnace 10, with the exception of a minor amount of tempering air introduced into the primary air stream entering the pulverizers through the connections 41.

The firing rate of the furnace 10 is regulated by the operation of the pulverizers and the air flow to each row of burners. As shown, the pressure of the steam generated within the boiler is measured by a Bourdon tube 60, with changes in pressure transmitted mechanically to an air pilot valve 61 where such changes are transmitted as control impulses through a Standatrol 62 and ratio controller 63 to the power pistons 64 and 65. The power pistons 64 are mechanically arranged to position the valves in the ducts 38. Thus, the piston 64A positions the valves in duct 38A, the piston 64B positions the valves in duct 38B, and the piston 64C positions the valves in duct 38C. In a similar manner the power pistons 65A, 65B and 65C are mechanically arranged to position the valves 42A, 42B and 42C, respectively, of the pulverizers. It will be appreciated that the flow of fuel to the burners is regulated in proportion to the flow of primary air to the pulverizers. As is well known in the art, this is accomplished by a differential ratio control actuated by a measurement of the air flow to the pulverizer compared with a measurement of the air flow through the pulverizer. It will also be understood that the power pistons 65, or their equivalent can also be used to regulate the opening of a valve to control the flow of a liquid or gaseous fuel to the burners 30. The control impulse from the air pilot valve 61 is also transmitted, as a modifying element, to the averaging relay 52 of the forced draft fan control.

A separate control system is interposed to regulate the operation of the pulverizer 31A and the burners 30A over a selected range of steam generating and superheating unit capacities. This system includes a controller 66 actuated by a measurement of the steam flow leaving the generating unit. The control impulse from the controller 66 is passed to a pilot valve 67, which may be cam actuated to obtain desirable control characteristics, and thence to a ratio controller 68 and an averaging relay 70 where it is joined by the control impulse originating from the Bourdon tube 60, after passing through a calibrating relay 71. The control impulse thereafter is transmitted to the power pistons 64A and 65A.

In the operation of the controls, the steam flow-air flow controller 48 regulates the operation of the forced draft fan 32 through the positioning of piston 47, and valves 45 and 46 so as to supply the proper amount of total air to the furnace 10, as required for the combustion of sufficient fuel to generate the steam discharged from the boiler. This control system is modified by a superimposed control impulse produced by the Bourdon tube 60 and Standatrol 62 so as to insure immediate control re-

sponse to a change in boiler operating conditions. The change in boiler operating conditions created by a change in steam pressure actuates the ratio controller 63, while a change in boiler operating conditions created by a change in steam flow actuates the ratio controller 68. The steam pressure actuated ratio controller 63 creates a change in the position of the primary air control dampers of pulverizers 31B and 31C, as well as the corresponding secondary air dampers for the burners 30B and 30C. However, in accordance with the method of the present invention, the control impulse from the controller 63 will be ineffective over a selected operating capacity range of the steam generating unit, in altering the damper positions of pulverizer air control valve 42A and secondary air flow to the burners 30A. This is accomplished by adjustment of the calibrating relay 71 and the averaging relay 70. When the steam flow rate from the boiler unit is below a predetermined value, the pulverizer and burner power pistons 64A and 65A are regulated in parallel with pistons 64B, 64C, 65B and 65C in accordance with the control impulses from the ratio controller 63. Thus, the burners 30A are supplied with a substantially uniform supply of fuel and combustion air in an upper range of steam generating and superheating capacity, while the burners 30B and 30C are operated in parallel at rates necessary to maintain the steam pressure requirements of the unit. Below the selected range of unit output capacity, the burners 30A, 30B and 30C are operated in parallel in response to steam pressure through the controller 63. To avoid an abrupt changeover in the operation of the burners 30A at the lower end of their operation at a substantially uniform fuel input, the relays 70 and 71 are adjusted to permit a gradual or smooth changeover from a predominantly steam flow regulation to a predominantly steam pressure regulation of the fuel and air supplied through the burners 30A. If desired, a cam actuated pilot 67 can be used to accentuate or diminish the controlling impulse obtained from steam flow. In accordance with the usual control practice, selector valves 72 are provided in the control circuits to permit selective manual or automatic operation of the control elements.

By way of example, Fig. 4 diagrammatically illustrates the operation of a steam generating and superheating unit of the type shown in Fig. 1, in accordance with the present invention and the effect of this operation on the superheated steam temperature. As shown in the lower portion of Fig. 4, full load on the steam generating unit is carried by the operation of all three rows of burners, with each row supplying approximately one-third of the total fuel requirement of this load. Also, at maximum capacity of the steam generating unit, each row of burners is operated substantially at its full design capacity. As the capacity of the unit is reduced, the upper row of burners (30A) continues to supply substantially its rated capacity of fuel, while the reduction in furnace fuel requirements is obtained by a reduction in the amount of fuel delivered by the lower and middle rows of burners (30C and 30B). For example, at 70% capacity of the steam generating unit, the burner row 30A continues to supply substantially its full rated capacity of fuel, while the remaining fuel requirements are supplied by the burner rows 30B and 30C. At this steam output capacity, approximately one-half of the total fuel is supplied by burner row 30A, while the burner rows 30B and 30C each supply approximately one-fourth of the total fuel requirement. A further reduction in the steam output capacity requires a corresponding reduction in the fuel delivered to the furnace by the burner rows 30B and 30C, until the fuel input to those burners reaches a minimum preferred capacity. This condition is shown in Fig. 4, at approximately 55% of boiler load, where one row of burners, namely 30C, is removed from service and the input from the burners 30B is correspondingly increased. Between a boiler load of approximately 55 and 45 percent, fuel is supplied to the furnace 10 at the same base rate by burners 30A, while burners 30B are operated at a rate sufficient to make up the difference in fuel requirements. Below 45% of boiler load burner rows 30A and 30B are operated in parallel with each providing approximately an equal share of the fuel requirements. The transition to parallel operation of burner rows 30A and 30B is illustrated by the curved line separating the representation of "upper" and "middle" (or "intermediate") burner inputs occurring between approximately 45 and 50 percent of boiler load. At 20 percent of boiler load, burner row 30B is removed from service and all of the fuel requirements are supplied by burner row 30A, to its minimum operating capacity. The removal of any pulverizer from service, or its restarting, is accomplished manually in accordance with usual operating practice.

In the operations described and illustrated in Fig. 4, the minimum operating capacity rate of each row of burners has been shown as illustrative of a furnace supplied with pulverized coal from a plurality of direct firing pulverizers. The operating range of each pulverizer and row of burners supplied thereby is generally typical of a practical operating range with this type of equipment, where the range may be limited by burner velocity considerations, flame stability or pulverizer operations. Other minimum capacity values may be used, whether the source of fuel may be pulverized coal from a storage or unit system, liquid or gaseous.

The upper portion of Fig. 4 illustrates the effect upon steam superheat temperatures with furnace fuel deliveries according to the present invention as compared with superheat temperatures when operating all burners in parallel. As shown, the dotted line illustrates superheat temperatures when the controlled firing technique of the present invention is utilized, while the solid line represents superheat temperatures, in the same unit, when the burners are operated in parallel according to furnace fuel requirements, as in the usual "balanced" mode of burner operations. The dotted temperature line is considerably flatter than the solid line, and while both lines have substantially the same temperature value at rated boiler load, i. e. 100% capacity, the dotted line crosses the "bypass temperature control line" at approximately 45% of boiler load. Thus, burner operation according to the present invention permits the maintenance of substantially uniform superheat output temperature from the unit between a load of 45% to 100% while using a conventional, and economical, gas by-pass arrangement for superheat temperature control. In addition, the drop in superheat temperatures at ratings below 45% of boiler load is considerably less than with conventional firing methods.

It will be noted the present invention provides for the operation of a steam generating unit through a wide range of operating capacities while maintaining a substantially uniform temperature of the superheated steam produced. This is accomplished by the provision of a conventional superheater gas by-pass, or alternately with a steam attemperator, in conjunction with a novel regulation of the fuel input to the boiler furnace. Fuel is delivered at vertically spaced positions into a vertically elongated furnace enclosed by fluid cooled walls and having a convection type superheater positioned closely adjacent or within an upper furnace outlet. The fuel delivered to the upper portion of the furnace is maintained at a substantially uniform input rate throughout a major portion of the upper load range of the steam generating unit, while variations in fuel input to the furnace are obtained by changes in the amount of fuel delivered to the lower portion of the furnace. In this manner the wall cooling effect of the lower portion of the furnace will have less effect upon the temperature of the combustion gases leaving the furnace outlet and passing to the superheat elements.

The invention has been illustrated by the use of pulver-

ized coal as a fuel in generating and superheating steam, and a simple and efficient control system for attaining the superheat temperature control of the invention has been shown. However, it will be understood that the objectives of the present invention can be attained by manual regulation of furnace fuel inputs, and that liquid or gaseous fluids can also be used to accomplish the advantageous superheat temperature regulation of the invention.

While in accordance with the provisions of the statutes we have illustrated and described herein the best form of the invention now known to us, 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 our claims, and that certain features of our invention may sometimes be used to advantage without a corresponding use of other features.

We claim:

1. In a vapor generating and superheating unit of the type having an elongated fluid-cooled combustion zone with a heating gas outlet in one end portion thereof and having convection vapor superheater elements positioned beyond said combustion zone outlet in the path of heating gas flow, the method of operation which comprises introducing fuel and air for combustion into the opposite end and intermediate portions of said zone, said introduction of combustion fuel and air comprising introducing a substantially uniform flow of fuel and air into the intermediate portion of said zone throughout a selected upper range of vapor generating capacity requirement while varying the fuel and air introduced into said opposite end portion in accordance with a change of vapor generating capacity requirement, and directly varying the fuel and air introduced to both of said opposite end and intermediate portions of said combustion zone equally in accordance with vapor generating requirements below said selected upper range of vapor generating capacity.

2. The method of maintaining a substantially uniform superheated vapor temperature over an extended operating capacity range of a vapor generator having an elongated fluid-cooled furnace with a heating gas outlet in one end portion thereof and convection vapor superheater elements positioned beyond said fluid-cooled furnace outlet in the path of heating gas flow which comprises, introducing fuel and air for combustion into the opposite end and intermediate portions of said furnace, said introduction of combustion fuel and air comprising introducing a substantially uniform flow of fuel and air into the intermediate portion of said furnace throughout a selected upper range of vapor generating rates while varying the fuel and air introduced into said opposite end portion in accordance with the actual change of vapor generating rates, directly varying the fuel and air introduced to both of said opposite end and intermediate portions of said furnace equally in accordance with vapor generating rates below said selected upper range of vapor generating rates, and by-passing at least a portion of the heating gases leaving said furnace around a portion of said vapor superheater elements at the upper vapor generating rates to lower vapor superheat temperatures.

3. The method of maintaining a substantially uniform superheated vapor temperature over an extended operating capacity range of a vapor generator having an elongated fluid-cooled furnace with a heating gas outlet in one end portion thereof and convection vapor superheater elements positioned beyond said fluid-cooled furnace outlet in the path of heating gas flow which comprises, separately introducing air and fuel for combustion into the opposite end and intermediate portions of said furnace, said introduction of combustion fuel and air comprising introducing a substantially uniform flow of fuel and air into the intermediate portion of said furnace throughout a selected upper range of vapor generating capacity while varying the fuel and air introduced into said opposite end portion in accordance with a change of vapor pressure, directly varying the fuel and air introduced to both of said opposite end and intermediate portions of said furnace equally in accordance with generated vapor pressure below said selected upper range of vapor generating capacity, and attemperating said superheated vapor to maintain a substantially uniform temperature over at least a portion of the capacity range of said substantially uniform fuel and air introduced into the intermediate portion of said furnace.

4. The method of regulating superheated vapor temperature over an extended operating capacity range of a vapor generator having an elongated fluid-cooled furnace with a heating gas outlet in one end portion thereof and a convection vapor superheater positioned beyond said fluid-cooled furnace outlet in the path of the heating gas flow which comprises, introducing fuel and air for combustion into the opposite end and intermediate portions of said furnace, said introduction of combustion fuel and air comprising introducing a substantially uniform flow of fuel and air into the intermediate portion of said furnace throughout a selected upper range of vapor generating capacity while varying the fuel and air introduced into said opposite furnace end portion in accordance with a change of vapor generating load as measured by a variation in vapor pressure, directly varying the fuel and air introduced to both of said opposite end and intermediate portions of said furnace equally in accordance with vapor pressure below said selected upper range of vapor generating load, in a manner to obtain a substantially uniform ratio of air and fuel delivered to both portions of said furnace.

5. Apparatus for generating and superheating vapor comprising, in combination, walls lined by spaced vapor generating tubes defining an upright elongated furnace having a heating gas outlet in one portion thereof, a convection superheater positioned adjacent said furnace gas outlet in the path of gas flow leaving said furnace, a plurality of fixed position fuel burners opening to said furnace and spaced at different positions from said furnace outlet, means for delivering a substantially uinform fuel and air input to a portion of said furnace in an upper range of vapor generating flow rates while varying the fuel and air input to another portion of said furnace in accordance with the actual pressure requirement of the vapor generating rate, and means for delivering substantially equal amounts of fuel and air into both portions of said furnace at required vapor generating rates less than the lower limit of said upper range of required vapor generating rates.

6. Apparatus for generating and superheating vapor comprising, in combination, walls lined by spaced vapor generating tubes defining an upright elongated furnace having a heating gas outlet in one portion thereof, a convection superheater positioned adjacent said furnace gas outlet in the path of gas flow leaving said furnace, a plurality of rows of fuel burners opening to said furnace with each burner row spaced at a different position from said furnace outlet, a controllable source of fuel for each row of burners, a controllable source of preheated secondary combustion air for each row of burners, control means responsive to vapor pressure for regulating the amount of fuel and air delivered to each row of burners, and a separate control means responsive to vapor flow for maintaining a substantially uniform delivery of fuel and secondary air to the row of burners closest to said superheater throughout an upper range of vapor generating rates, said separate control means overriding said vapor pressure responsive control means in said upper range of vapor generating rates and becoming ineffective below said upper rate range.

7. Apparatus for generating and superheating vapor comprising, in combination, walls lined by spaced vapor generating tubes defining a vertically elongated furnace

having a heating gas outlet in the upper portion thereof, a convection superheater positioned adjacent said furnace gas outlet in the path of gas flow leaving said furnace, a plurality of rows of fuel burners opening to said furnace and vertically spaced at different positions from said furnace outlet, a pulverizer connected with each row of said fuel burners, a control responsive to vapor pressure for regulating the fuel input to each row of said burners from each pulverizer in accordance with the output rating of said vapor generator, and a separate control responsive to vapor flow for maintaining a substantially uniform fuel input to the uppermost row of burners from the connected pulverizer to said furnace throughout an upper range of vapor generating rates, said separate control overriding said vapor pressure responsive control in said upper range of vapor generating rates and becoming ineffective below said upper rate range, and means for maintaining a substantially uniform ratio of secondary combustion air and pulverized fuel delivered to each row of said burners.

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