

Sept. 10, 1957

R. D. JUNKINS

2,805,653

VAPOR GENERATING AND SUPERHEATING OPERATION

Filed July 5, 1951

8 Sheets-Sheet 1

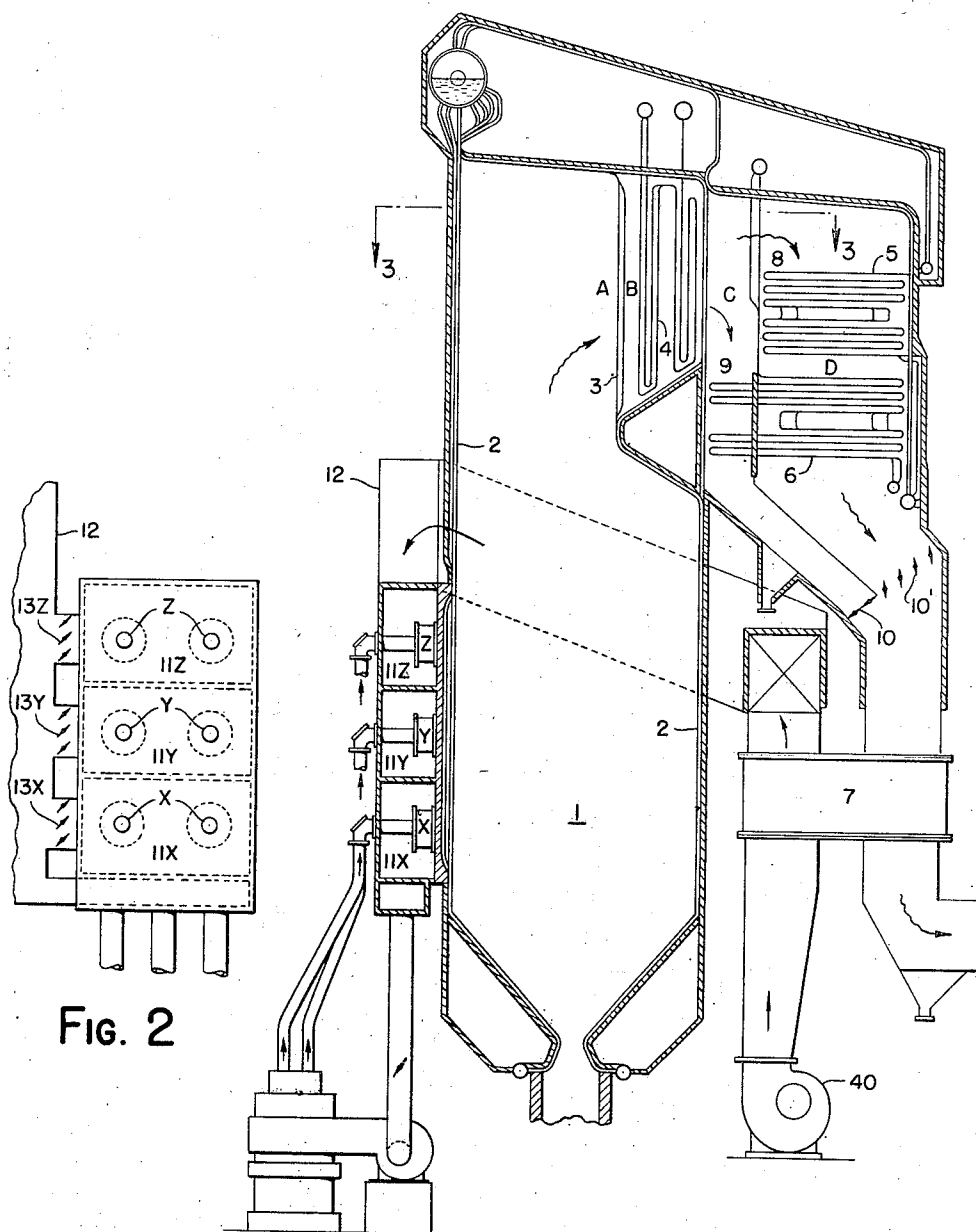


FIG. 1

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Sept. 10, 1957

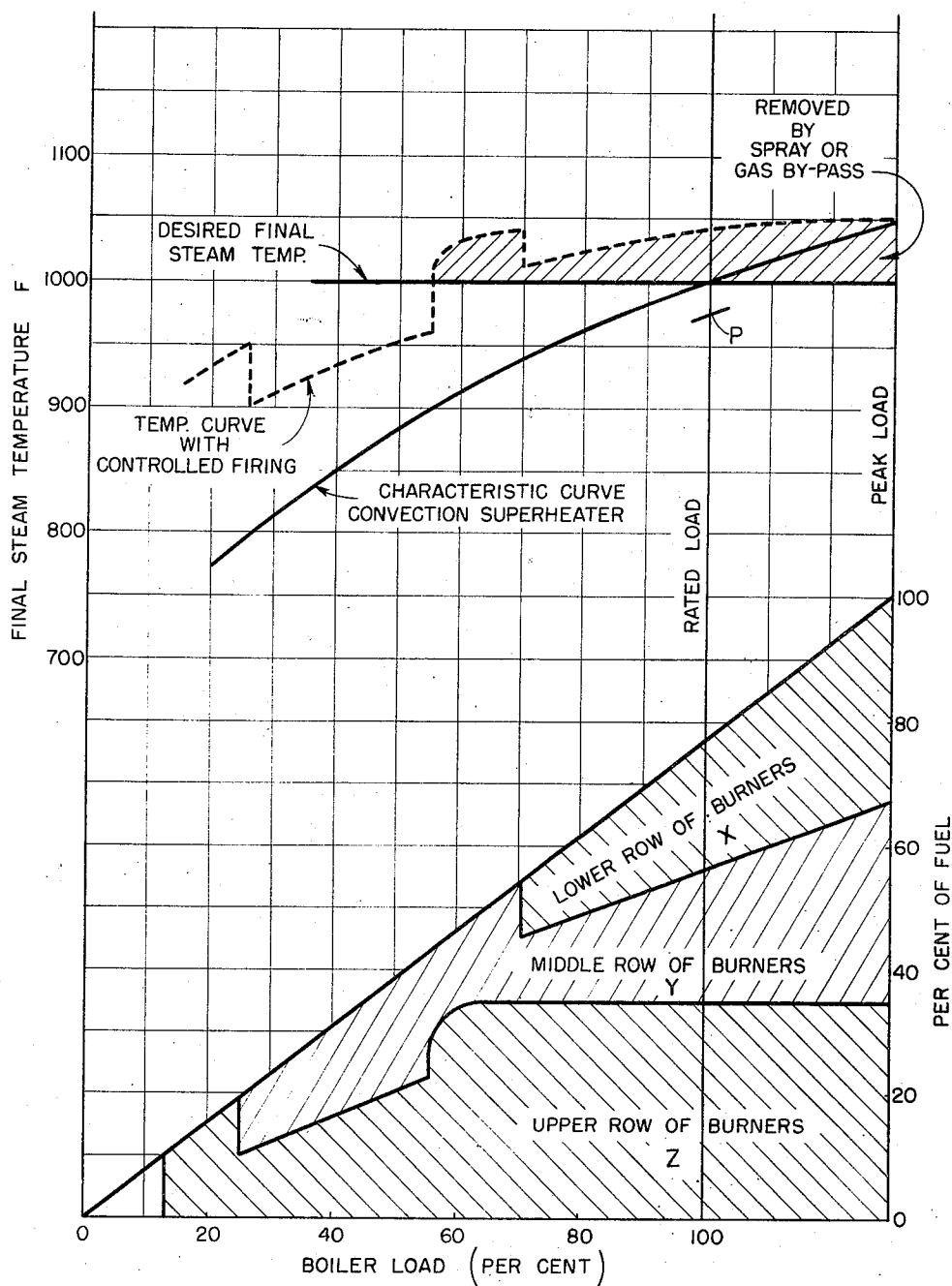
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8 Sheets-Sheet 3



INVENTOR.

FIG. 4

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8 Sheets-Sheet 4

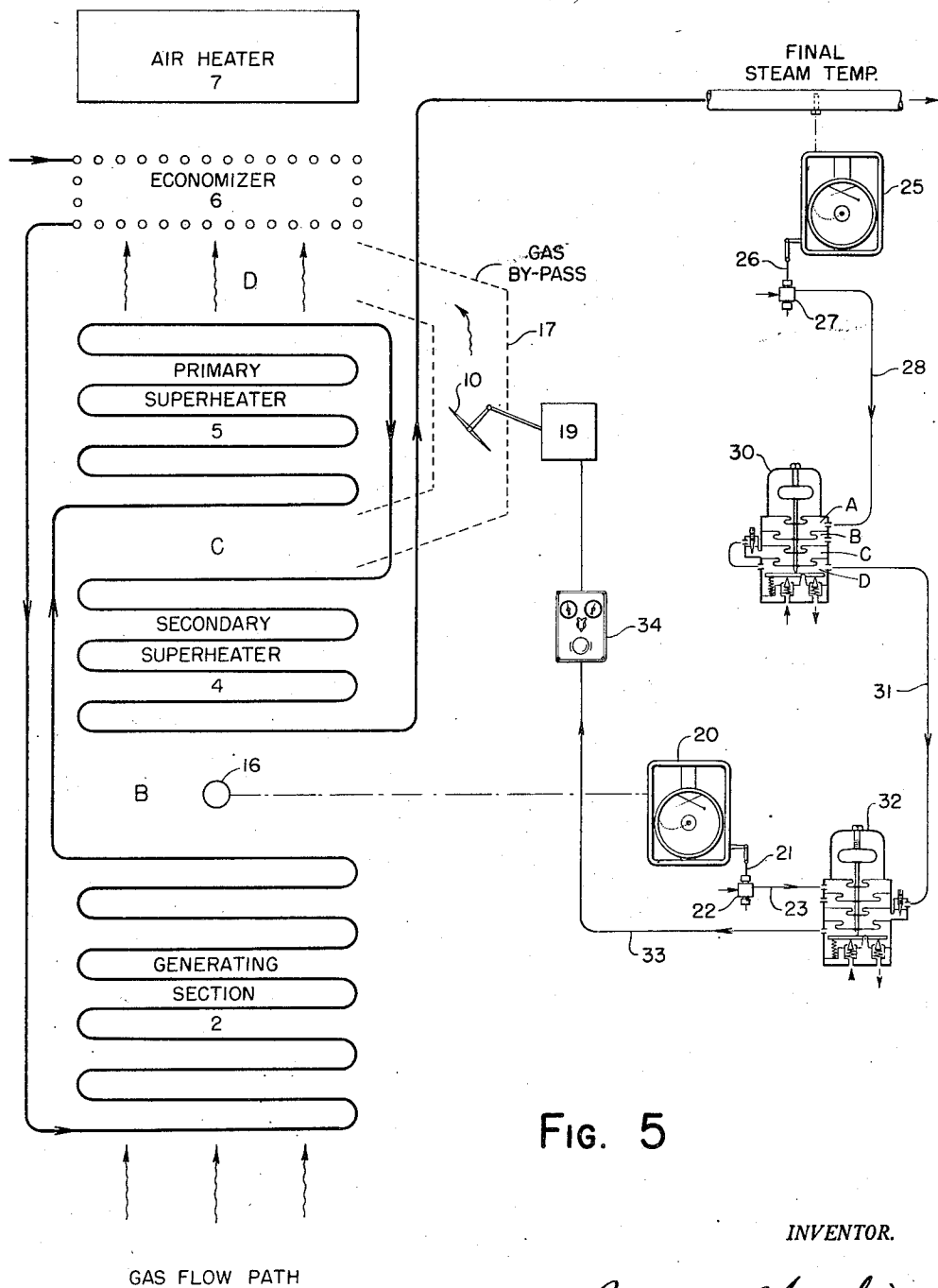


FIG. 5

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VAPOR GENERATING AND SUPERHEATING OPERATION

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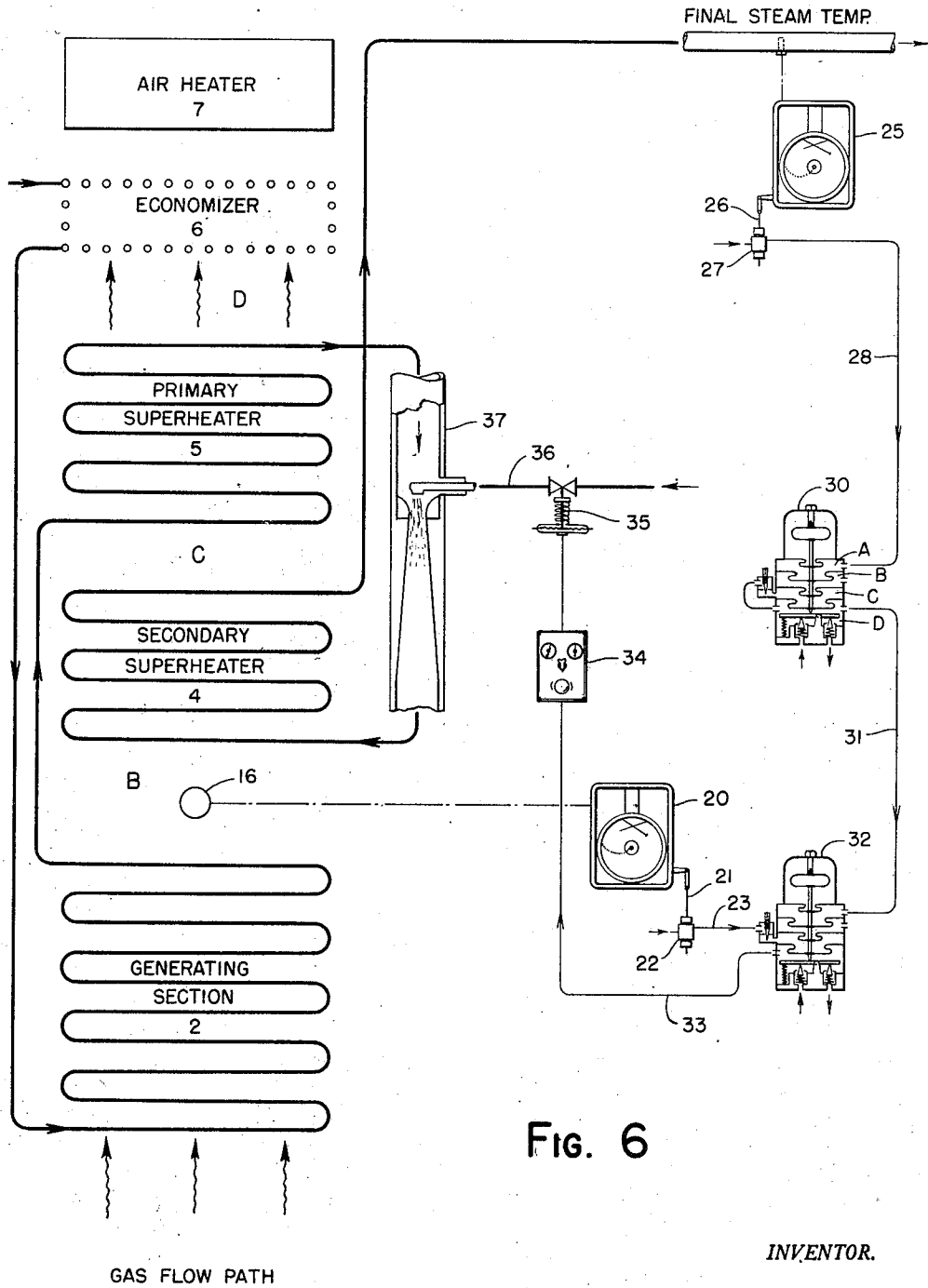


FIG. 6

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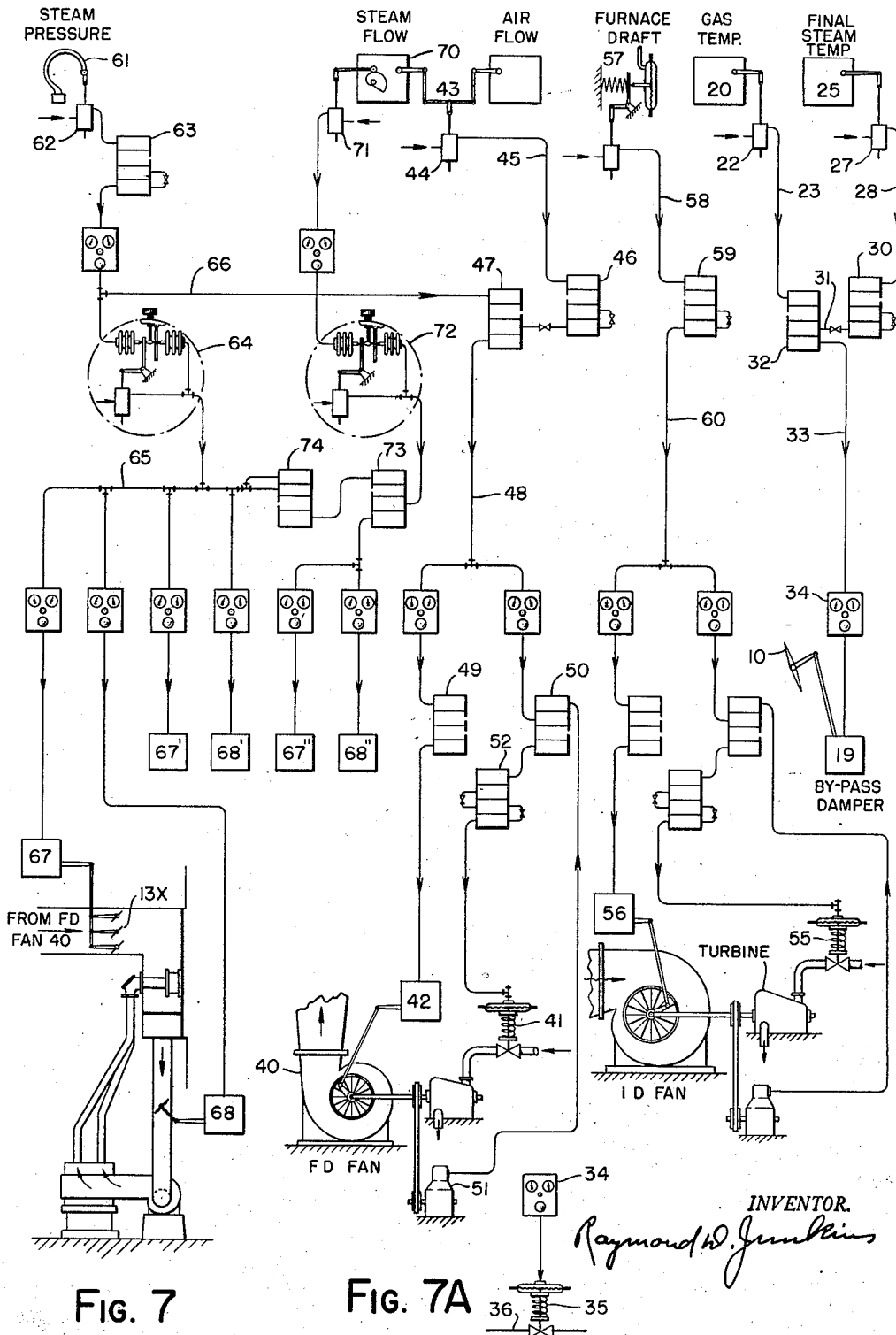
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VAPOR GENERATING AND SUPERHEATING OPERATION

Filed July 5, 1951

8 Sheets-Sheet 6



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VAPOR GENERATING AND SUPERHEATING OPERATION

Filed July 5, 1951

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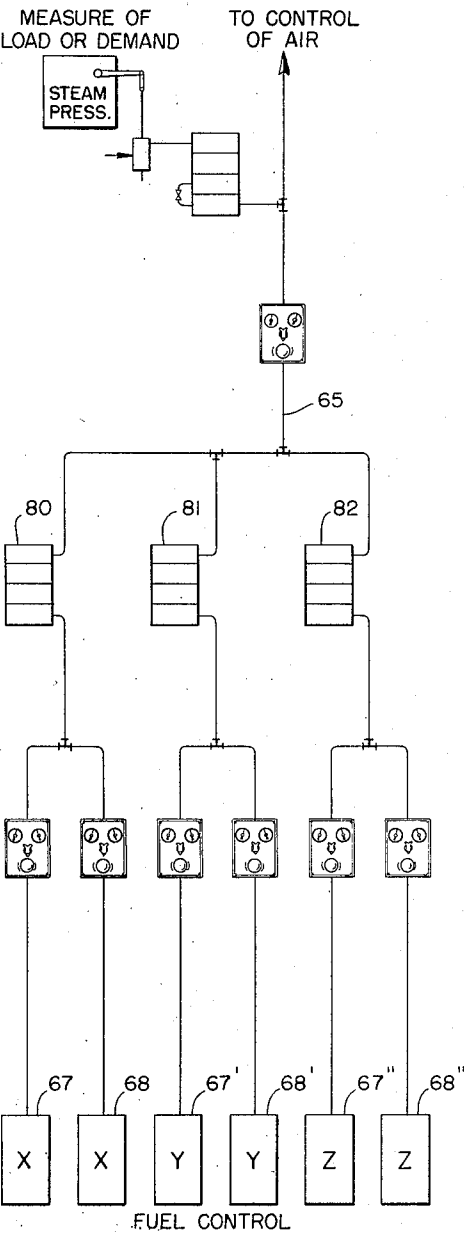


FIG. 8

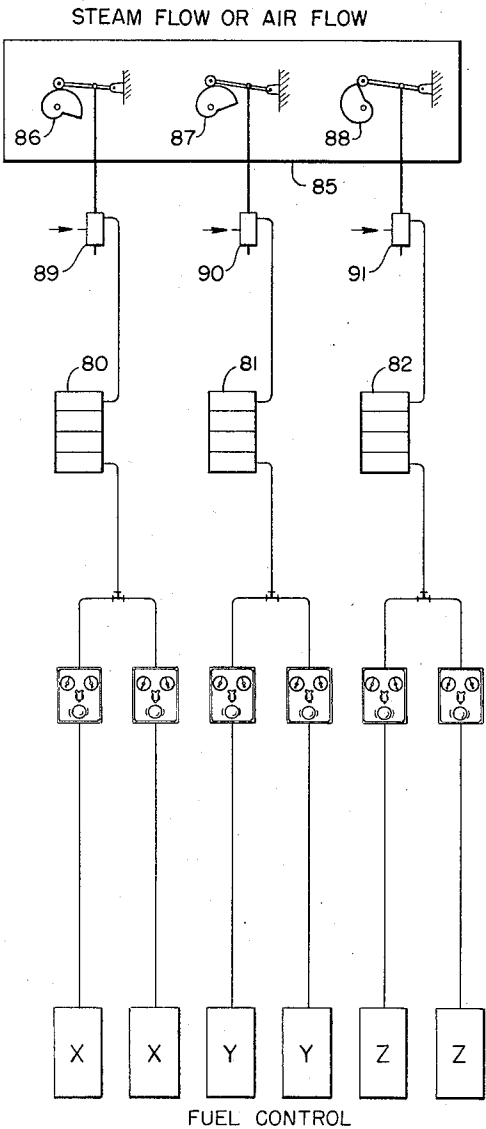


FIG. 9

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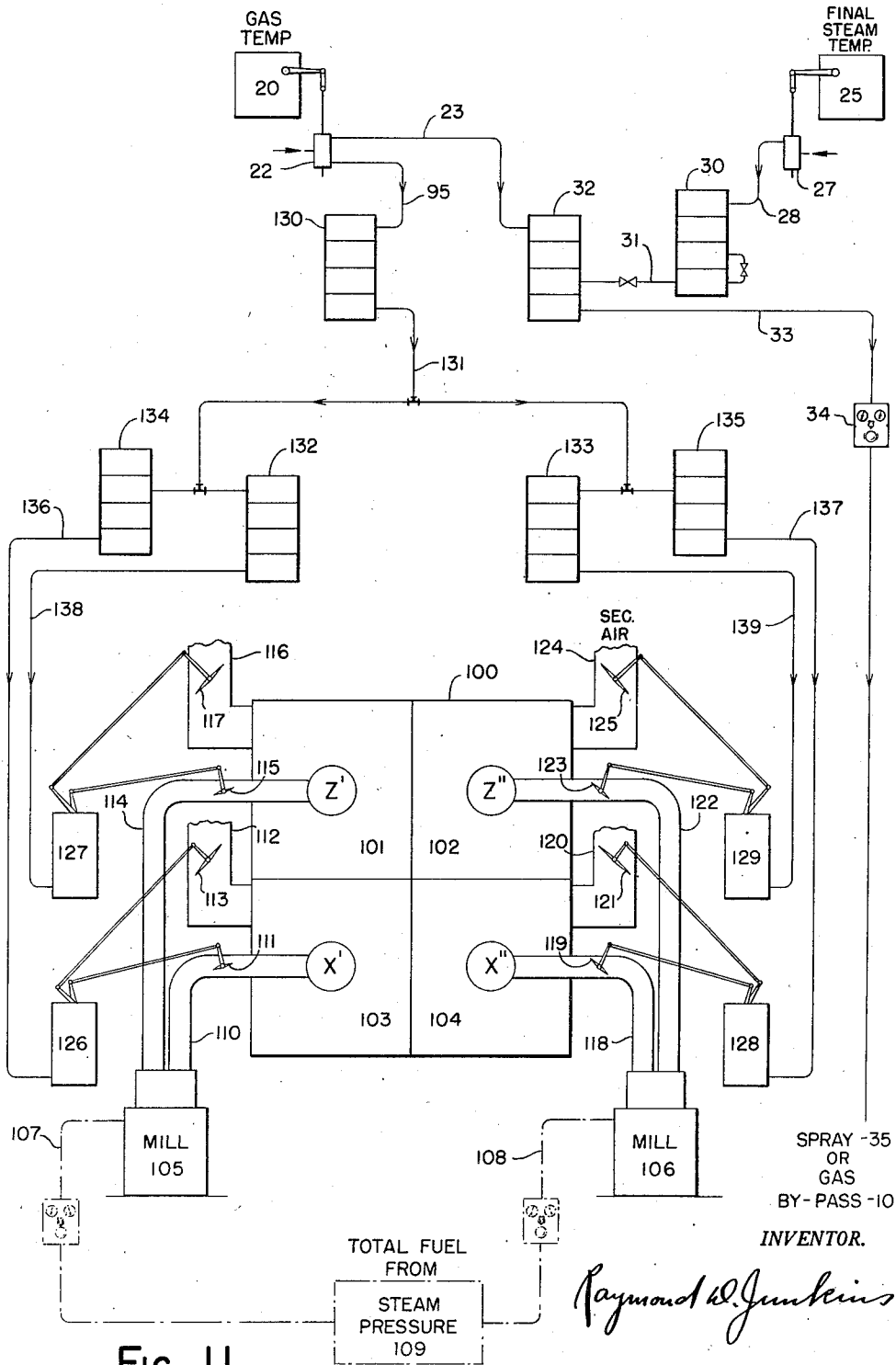
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VAPOR GENERATING AND SUPERHEATING OPERATION

Filed July 5, 1951

8 Sheets-Sheet 8



2,805,653

VAPOR GENERATING AND SUPERHEATING OPERATION

Raymond D. Junkins, Cleveland Heights, Ohio, assignor, by mesne assignments, to The Babcock & Wilcox Company, a corporation of New Jersey

Application July 5, 1951, Serial No. 235,260

23 Claims. (Cl. 122—479)

My invention lies in the field of steam power generation and particularly in the control of steam temperature in connection with present day vapor generators. Practically all central station capacity presently being installed, or on order, in the United States has rated steam conditions above 800 p. s. i. g. and 800 FTT; the highest operating temperature being 1050 FTT at pressures from 1500 p. s. i. g. to 2000 p. s. i. g. and rated load of from 500,000 to 1,000,000 lb. per hr., with a large percentage employing reheat surfaces. The problems involved in the generation and close control of the properties of steam are quite different now than was the case at the time of the inventions in this field which are shown in the prior art.

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 interest 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.

As feed water temperatures progressively increase there is less and less work for the boiler proper, with the result that its convection heat-absorbing surface has disappeared to the point where the modern large utility unit consists of a water-walled furnace, a convection superheater, an economizer and an air heater. Furnace design is now centering around sufficient water cooling surface to absorb the radiant heat and to achieve the required relatively low furnace exit gas temperatures.

With the superheating or resuperheating of the steam in one or more convection type heat exchange surfaces, the size and cost of such surfaces becomes a material factor in the total cost of the unit and any improvement leading to a reduction in the size of superheaters becomes of considerable importance. Usually these surfaces must be made of expensive high-alloy tubing to satisfactorily handle the temperatures and pressures encountered.

It is thus a prime desideratum, in the design of such a unit, to proportion the steam generating surfaces and the steam superheating surfaces to give the desired final steam temperature at "rated load." At "peak load," in excess of the rated load, the final steam temperature will be in excess of that desired and correspondingly at lower ratings the steam temperature will not equal that desired. It is false economy to design the superheater for desired final steam temperature at peak load, for all loads below that value would then produce steam below the desired temperature. On the other hand, the design of the superheater to produce the desired final steam temperature at some rating below "rated load" would require an excessive cost of superheating surface and an excessive final steam temperature throughout the upper ratings, with consequent danger to the turbine or the necessity of extracting some of the surplus heat from the final superheated steam.

Thus, usually the heat exchange surface of the superheater is designed to provide the desired total temperature of the steam at "rated load," and experience has shown that below this load the total temperature of the leaving steam decreases while above this load the total temperature increases. This is because the characteristic curve of a convection superheater is a rising function with load as will be seen in Fig. 4 of the present application.

To reach the desired high superheated steam temperature, but not exceed it, requires exceedingly careful proportioning of the heat absorbing surfaces both for generating steam and for superheating it. But even if the desired superheated steam temperature be just attained initially by very careful designing at "rated load," the superheated steam temperature will vary during operation by reasons of changes in cleanliness of the heat absorbing surfaces. Slag will form and adhere to the heat absorbing surfaces in the furnace thereby reducing the effectiveness of such surfaces and raising the furnace outlet temperature of the products of combustion. Furnace outlet temperature will also change with percentage of excess air supplied for combustion, with the characteristics of the fuel burned, and with the rate of combustion and the corresponding rate of steam generation. All of these things will therefore affect the temperature of the gases leaving the furnace and supplied to the superheater, whether the superheating elements are located in the furnace where they absorb heat by radiation from the burning fuel and products of combustion, or whether they are located beyond the furnace where they absorb heat by convection from the products of combustion only.

With the furnace volume, as well as the vapor generating furnace surface, and the vapor superheating surface, fixed and invariable, the possibility of satisfactorily controlling the final steam temperature lies in controlling the volume and temperature of the gases contacting the superheating surfaces. Fuel and air supply must be varied with rating to provide the desired steam flow rate. The furnace temperature of the flame and products of combustion does not vary greatly with rating. This leaves the controllable variables as the volume and temperature of the gases entering the convection superheating surfaces. The volume or mass flow rate has been controlled in the past by by-passing some of the gas flow around the superheater surface. The temperature of the entering gases may be controlled by selecting the amount of generating surface to be contacted by the gases before they enter the superheater. It is also known to have spray desuperheaters or other heat absorbing means for the excess heat in the final steam before the steam goes to a turbine.

For any given furnace, as load increases, the heat input is increased, but the rate of heat absorption does not increase as rapidly as the rate of heat input; therefore, the furnace leaving temperature will rise. With both the quantity rate and the temperature of the gases leaving the furnace increasing with load, it is apparent that a fixed surface convection superheater will receive a greater heat rate at higher loads than at lower loads and the heat transfer area is usually designed for the volume and temperature of leaving gases at rated load. Any further increase in heat release rate supplies to the fixed superheater surface more heat by gas volume and by gas temperature than it is designed for and a corresponding excessive final steam temperature is experienced. Correspondingly, at operation below the rated load the fixed superheater transfer surface receives less volume and a lower temperature of gases leaving the furnace with corresponding lowering of final steam temperature leaving the superheater. It is therefore a principal object of my invention to provide an improved method and apparatus for extracting excessive heat from the steam at

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high rating and for supplying additional heat to the steam at low ratings, to the end that the final steam temperature will approximate a uniform value over a range of operating ratings at each side of the "rated load" value.

I preferably employ what I term "controlled firing" or selected distribution of load between vertically located burners, proportioning the application of heat as between steam generating surface and steam superheating surface at different loads. I vary the heat release location and consequently the effective furnace absorption area. In other words, as rating falls I utilize proportionately less of the generating surface and thus tend to maintain the temperature of the gases entering the superheating surfaces more nearly constant than would otherwise be the case. This is accomplished by controlled firing wherein two or more vertically spaced sets of burners are sequentially controlled, with or without overlap, to the end of directionally applying the heat of combustion to the generating surface with rating.

My present invention has as a primary object a method and apparatus for operating, and controlling the operation of, such vapor generating units through the utilization of more advantageous indexes of heat availability to the convection superheater and of operation of the unit as a whole.

So far as I am aware no one has previously used the actual gas temperatures between the generating and superheating surfaces as an element in method and apparatus for controlling steam final temperature on units of the type under discussion. Attempts have been made to ascertain continuously the temperature within the superheater tubes near the entrance, near the exit, and at intermediate locations. Attempts have also been made to obtain the temperature of the steam before it enters the convection superheater and to use this temperature measurement, in conjunction with the final steam temperature, in controlling spray attenuators, gas by-passes, and the like. These methods and arrangements have not been entirely satisfactory. A considerable time and heat lag occurs in the heat transfer through the films and metal of the tube surfaces, and with rapidly fluctuating heat release loads and temperature effects as caused by slagging or deslagging of the furnace walls with corresponding fluctuating variations in heat absorption of the generating surfaces as well as flame drift around the furnace, has introduced lags in final steam temperature control systems with corresponding hunting and overshooting. Through the use of my invention I avoid these inaccuracies and adverse effects by utilizing the actual furnace exit temperatures as an element in my control system to maintain final steam total temperature.

In the drawings:

Fig. 1 is a somewhat diagrammatic sectional elevation of a vapor generating unit having radiant generating surfaces and convection superheating surfaces.

Fig. 2 is a somewhat diagrammatic front view of the burner box of Fig. 1.

Fig. 3 is a section taken along the line 3—3 of Fig. 1, in the direction of the arrows.

Fig. 4 is a graph of characteristic values in connection with the other figures of the drawing.

Fig. 5 is a diagrammatic showing of my invention in connection with controlled firing and a gas by-pass damper.

Fig. 6 is a diagrammatic showing of my invention in connection with controlled firing and a spray type attenuator.

Fig. 7 is a schematic showing of a complete control system in connection with Fig. 5.

Fig. 7A is a modification of a portion of Fig. 7.

Fig. 8 is a diagrammatic view of another control system embodying my invention in connection with controlled firing.

Fig. 9 is a diagrammatic view of a control system for controlled firing from a sequence controller.

Fig. 10 is a further embodiment of my invention.

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Fig. 11 diagrammatically shows the burner box of a generating unit with a different arrangement of controlled firing and excess heat by-passing or absorption.

It will be appreciated that I am illustrating and describing my invention in a preferred mode of operation and combination of apparatus. For example, while I speak of steam generation and superheating, the invention is useful in the generation and superheating of other vapors. Furthermore, while I particularly refer to the burning of pulverized coal in suspension, it will be understood that the invention is applicable to the burning of other fuels in suspension, such for example, as oil or gas.

In general it may be said that for a fixed design of furnace volume, steam generating surface, and steam superheating surface, with fuel and air supplied to satisfy the rating demand, I preferably control the unit to raise the characteristic superheat curve below the rated load value and to lower the curve above the rated load value, so that a more uniform final steam temperature will be attained, throughout a wider range of operating values, than would otherwise be the case. I preferably raise the curve at the lower rating by controlled firing or vertical distribution of the application of heat within the furnace, and lower the curve in the upper ratings by either by-passing some of heating gases around the superheater or through a spray attenuator absorbing some of the excess heat from the steam.

Fig. 1 shows in somewhat diagrammatic sectional elevation a typical vapor generator of the size and type herein contemplated and in connection with which I will explain my invention. Fig. 2 is a front elevation of the burner box of Fig. 1 while Fig. 3 is a section, in the direction of the arrows, along the line 3—3 of Fig. 1. Reference may also be made at this time to Fig. 4 to observe the normal characteristic curve of a convection superheating surface so designed as to produce final steam temperature 1000 FTT at 100% rated load. From this curve it will be observed that the expected final steam temperature would be in the neighborhood of 1050 FTT at peak load and would fall off throughout the lower ratings.

The generator is of the radiant type, having a furnace or combustion chamber 1 which is fully water cooled with the walls 2 of vertically, closely spaced, plain tubes constituting the vapor generating portion of the unit. Products of combustion pass upwardly through the furnace 1 in the direction of the arrow, through the tube screen 3, over a secondary superheater surface 4 and a primary superheating surface 5. A tubular economizer section 6 follows the superheater 5 and in turn may be followed by an air heater 7. Heated gases leaving the secondary superheater 4 may be divided through a path 8 containing the primary superheater 5 and a portion of the economizer 6, or over a path 9 containing a portion of the economizer 6. Distribution of the gases between the paths 8 and 9 is by means of dampers 10, 10'. The unit is fired by three vertically spaced sets of burners which I have designated as X, Y and Z in connection with Figs. 1 and 2. I have shown each set as comprising two horizontally spaced burners but there may be one or more burners in each set. Pulverized fuel and primary air for carrying the fuel in suspension is supplied to each of the six burners and it is understood that the control of pulverized fuel 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.

Preferably the burners X, Y and Z have a mill for each set and all of the burners of a set are controlled in unison by a control of the primary air to the respective mill. It is however possible to shut off one of the burners of a set if such is desired, by manual means.

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Reference to Figs. 1 and 2 will show that each of the horizontal sets of burners is surrounded by a burner box as at 11X, 11Y and 11Z and that secondary air is supplied through a duct 12 to the three burner boxes under the control of dampers 13X, 13Y and 13Z. Thus it will be apparent that a control of the primary air to mill X regulates the amount of primary air and pulverized fuel carried in suspension therein to the burners X and a simultaneous control of the dampers 13X will control the supply of secondary air to the burners X. In similar fashion the firing of burners Y and of burners Z is accomplished.

In the past it has been known to simultaneously control the burners X, Y and Z to supply air and fuel for combustion variable with rating. It will be apparent that substantially the same percentage of the vapor generating heat absorbing walls of the furnace 1 will be contacted by the heat of combustion at all rates of operation with the result that as rating decreases a greater proportion of the heat of combustion will be absorbed in the furnace for generating steam than is available to the superheating surfaces 4 and 5 because the gases passing through the superheating surfaces 4 and 5 will be at a lower temperature than they otherwise would be.

It has also been proposed to proportionately or sequentially vary the firing of the vertically spaced sets of burners X, Y and Z so that at the lower rating the principal firing is done by the burners Z. With such operation, principally in the upper part of the furnace 1, the lower portion of the furnace will be substantially unused and thus the gases of combustion will reach the superheating surface 4 at a higher temperature than would otherwise be the case. As rating increases the burners Y may be next brought on and lastly the burners X. On the other hand, the three sets of burners may be simultaneously controlled but in a direction to increase the firing through burners Z, while correspondingly decreasing the firing through burners X or vice versa.

The operation just described illustrates how the flame body can be raised or lowered over a considerable distance to make use of more or less furnace heat absorption surface and thereby proportion the amount of heat subjected upon the generating surface compared to that subjected upon the superheating surface and thus effect a wide range control over the gas temperatures leaving the furnace at the screen tubes 3. By thus providing control of furnace heat absorption the effect is similar to that which would be accomplished by the ability to increase or decrease the size of the furnace at will, relative to a fixed convection superheating surface.

I have found that a most desirable index of heat available to superheat the steam is a continuous measure of the temperature of the gases contacting the superheating surface. In a unit of the size and type being described the temperature of the gases first contacting the convection superheating surface 4 should be in the neighborhood of 2000 F. for steam final temperature of 1000 FTT and under different conditions of operation will be in the range of 1700-2300 F. When there is a change in furnace exit gas temperature, for any reason, there is of necessity a time lag of heat transfer and metal temperature stabilization before the gas temperature change is reflected in final steam temperature change. Thus the use of actual gas temperatures as an operating guide or control index anticipates the effect of the gas temperature change upon the superheating of the steam.

I have found it possible to provide a continuous determination of furnace exit gas temperatures by means of a bolometer or other radiation sensitive device as well as by bare metal thermocouples or high velocity thermocouples. In Fig. 1 I designate certain temperature determining locations to which reference will later be made. Representative of furnace exit gas temperature is location A at the entrance to tube screen 3; location B is the gas entrance to secondary superheater 4; C represents gas en-

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trance to the primary superheater 5. I expect that the gas temperature at location A or B will be in the range of 1700-2300 F. while at locations C and D the gas temperatures will be in successively lower ranges as the heat of the gases is transferred to the steam.

I preferably employ thermal radiation sensitive devices at locations A and B of which I will refer to a bolometer as satisfactorily representative. The bolometer of the Rutherford et al. Patent 2,524,478 has been successfully used as a device sensitive to total thermal radiation for producing an effect representative of the energy level of radiation received. Patent 2,624,012 to English et al. discloses and claims a circuit including the bolometer for actuating a recorder-controller in terms of temperature.

In Fig. 3 I show somewhat diagrammatically a section taken through the unit of Fig. 1, along the line 3-3, in the direction of the arrows. The locations A, B, and C are not necessarily spot locations but are substantially all of the areas between the various transfer surfaces. At 15 I designate a bolometer or other radiation receptive head sighted across A and at 16 a similar head sighted across B. These devices may preferably operate in the range 1700-2300 F. I have also found that bare metal thermocouples or high velocity thermocouples may be used to obtain gas temperatures in locations A and B if proper precautions are taken against the corrosive and erosive effect of the gases and entrained solid matter.

By way of example I illustrated in Fig. 3 four bare metal thermocouples TC-1, TC-2, TC-3 and TC-4 spaced across the area A in front of the tube screens. These are preferably spaced across the screen tubes 3 and are connected in series with each other in a measuring bridge network to obtain an average of the temperatures to which they are subjected. Preferably the thermocouples are suspended downwardly through the roof of the unit until the thermocouple ends are in a line across the entrance to the screen 3 at about location A of Fig. 1. The thermocouple itself is encased in a thin wall protecting tube to protect it against abrasive and corrosive action of the gases but may under certain conditions be directly exposed to the gases. When encased in a thin tube protector the latter is fastened to and suspended from an alloy tube which encases the lead wires upwardly to and through the roof. Such a construction has been found to have a reasonably long life and to satisfactorily obtain an accurate average of the temperatures across the location A.

A similar use of thermocouples may be had through the area B or the area C. In Fig. 3 I show an alternate possible construction where the thermocouples TC-10, TC-20, TC-30 and TC-40 are projected through horizontally from the unit assembly on supporting pipes which additionally act as protectors of the lead wires.

Regardless of the type of temperature sensitive device, or its mode of installation, the result is to obtain the actual temperature of the gases rather than any metal temperature or steam temperature in the different locations.

Referring now to Fig. 4 I show therein graphs of characteristics and expected operation of the unit under consideration both with and without the features of my invention. It will be appreciated that the values used in Fig. 4 are exemplary only and are not to be considered as absolute values or of those necessarily found under actual operating conditions. They are adequate, however, for explaining the characteristics and operation of the entire system and apparatus.

Referring to the curves at the upper part of Fig. 4 I show therein the general shape of the characteristic curve of a convection superheater arranged to intercept the "rated load" operation at a desired final steam temperature of 1000 FTT. As rating is increased to "peak load" the characteristic curve rises to some value approximately 1050 FTT. Conversely, as rating is decreased

below "rated load," the characteristic droops off to a temperature of some 775 FTT at 20% "rated load."

Adjacent the characteristic curve is a broken line curve representing expected final steam temperature with the controlled firing arrangement depicted in the lower portion of the sheet. It will be observed that the entire broken line curve is at a higher temperature level from 20% rated load to peak load condition. The desired final steam temperature is obviously a straight line through 1000 FTT for all expected operating loads.

A study of these two curves shows that the final steam temperature is attained (or exceeded) by controlled firing from a rating of approximately 55% rated load to the peak load. The excess temperature between these rating values has been shown in shaded area and, through the agency of my invention, it is contemplated that the majority or all of this shaded area may be removed either by spray attemperation or through the use of a gas by-pass such as the control of dampers 10, 10'.

For any given design of furnace and generating unit, if the convection superheater characteristic curve is lowered, there will be a saving in the initial cost of the superheater per se and thus of the entire unit. Referring to Fig. 4, the characteristic curve may be lowered to some parallel curve crossing the "rated load" line as at P representing a design final steam temperature of 975 FTT with a final steam temperature of 1025 FTT at peak load. Such a design would materially reduce the shaded area between the desired final steam temperature (1000 FTT) and the upper dotted curve, thereby materially reducing the work of the spray attemperator or gas by-pass and still retain the vernier control of temperature by a selected one of those means throughout an operating range of 55% rated load to peak load. I cite this example merely to show the possibilities of selective operation and its effect upon the initial design and proportioning of the generating surface to the more expensive superheating surface.

The lower portion of Fig. 4 shows a suggested operation of the burner groups X, Y and Z to produce the dotted temperature curve above. It is to be understood that the controlled firing arrangement of the sets of burners X, Y and Z in Fig. 4 is a suggested example only and that different arrangements may be chosen to fit the equipment and desired operation.

As shown in the lower portion of Fig. 4, peak load on the steam generating unit is carried by the operation of all three rows of burners X, Y and Z, with each row supplying approximately $\frac{1}{3}$ of the total fuel requirement of this load. Also at peak load each row of burners is operating at substantially its full design capacity. As the rate of operation of the unit is reduced, the upper row of burners Z continues to supply substantially its rated capacity of fuel while the reduction in furnace fuel requirement is obtained by a reduction in the amount of fuel delivered by the lower and middle rows of burners X and Y respectively. For example, at rated load the burner row Z continues to supply substantially its full rated capacity of fuel while the remaining fuel requirements are supplied by the burner rows Y and X. At this operation approximately half of the total fuel is supplied by the burners Z while the burners X and Y each supply approximately $\frac{1}{4}$ of the total fuel requirement. A further reduction in steam output operation requires a corresponding reduction of the fuel delivered to the furnace by the burners X and Y until the fuel input to those burners reaches a minimum preferred capacity. This condition is shown in Fig. 4 at approximately 70% rated load where one row of burners, namely the lower row X, is removed from service and the input from the burners Y is correspondingly increased. Between a boiler load of approximately 70% and of 55%, fuel is supplied to the furnace 1 at the same base rate by burners Z while burners Y are operated at a rate sufficient to make up the dif-

ference in fuel requirements. It will be noted that at an operating rate of approximately 65% rated the burners Z are cut back so that a smoother transition in operation will be had from the capacity operation of burners Z. Below 60% rated load burners Y and Z are operated in parallel with each providing approximately an equal share of the fuel requirement. The transition to parallel regulation of burners Y and Z thus occurs at approximately 65% rated load and carries down to some 25% load where burners Y are removed from service and all of the fuel requirements are supplied by burners Z to its minimum operating capacity. The removal of any pulverizer from service, or its restarting, is accomplished manually in accordance with usual operating practice or may be accomplished automatically if desired. It will be understood that the operation described in connection with Fig. 4 is illustrative only and that the sequential or parallel control of the three sets of burners may be adjusted to pick up or drop off at different ratings and in different proportionality between the rows of burners.

In the operation 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 fired 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 consideration, flame stability or pulverizer operation. Other minimum capacity values may be used where the source of fuel is pulverized fuel from the storage or unit system, liquid or gaseous.

It will now be evident, from what has been previously said, that at all rates of operation the upper portion of the furnace 1, receiving heat from the row of burners Z, receives one-half or more of the heat input so that a more uniform gas temperature is always available at area A than would otherwise be the case. As rating increases the burner row Z is left at maximum base load operation and the additional fuel, required to supply the increasing demand for steam, is added in progressively increasing quantity downwardly in the furnace 1. At peak load relatively the same amount of fuel is admitted through the burner rows X, Y and Z so that the lower portion of the furnace, opposite the burner rows Y and X, is used to its full possibility and to equal extent with the area opposite the burner row Z used primarily at the lower ratings. The over-all effect is to proportion the heat receiving generating surface to the fixed heat receiving superheating surface in accordance with operating rating to the end that a more nearly uniform temperature of the gases at locations A and B will be experienced than otherwise would be the case. With this entering gas temperature more nearly constant then the volume of the gases, varying with fuel input with load, predicates a substantially uniform final steam temperature at a steam quantity rate varying as demand. To facilitate such a method and control system, my invention utilizes a determination of the actual temperature of the gases entering the convection superheating surface as being a control index continually indicative of the heat available for superheating and without the time lag and other deleterious effects which past systems have experienced where the control index has been the temperature of the steam per se or of a metal surface in connection therewith. Regardless of the cause affecting the temperature of the gases entering the superheating surface an actual measurement of such temperature continuously provides the proper index without the necessity of awaiting stabilization of metal parts and the time lag experienced therewith.

Referring now to Fig. 5 I show therein in very diagrammatic form the gas flow path in relation to the different heat exchange surfaces. Around a portion of the superheating surfaces I diagrammatically show a gas by-pass

duct 17 having therein a control damper 10 positionable by a control drive 19. Positioning of the damper 10 allows a controllable portion of the heated gases leaving the furnace to by-pass some of the superheating surfaces to the entrance of the economizer section 6 and thus to be ineffective in superheating the generated steam.

In this figure of the drawing I have not shown any representation of the burners or of that portion of the control system regulating the controlled firing of the burners. This will be explained in connection with a later figure.

In the present arrangement the bolometer 16 is sensitive to gas temperatures at location B and is arranged to activate a recorder-controller 20 continuously positioning the stem 21 of a pneumatic pilot valve 22 to establish in a pipe 23 an air loading pressure representative of the average temperature of the gases at location B. The pilot valve 21, 22 is of a known type as disclosed in the Johnson Patent 2,054,464 and is so arranged in the present disclosure that an increase in temperature at location B results in an increase in the air loading pressure within pipe 23.

The temperature of the gases entering the steam superheating surfaces is an index of the heat available for superheating the steam. Many factors may contribute to variation of temperature of the gases entering the convection heating surfaces. Change in demand, with consequent increase or decrease in fuel-air admission rate will change the gas mass flow as well as the velocity and temperature. For steady state demand, the furnace exit gas temperature may vary from such causes as flame waver resulting in varying generating surface absorption, slagging or deslagging of generating surface, burnability of the fuel, etc. Regardless of the cause of the variation, the fact remains that a variation in such temperature may cause an undesired deviation in final steam temperature from the desired value.

The temperature of the gases at the entrance to the superheating surface is therefore a "cause" index materially in time advance of any "effect" index such as metal or steam temperature of the superheating surfaces. By utilizing such "cause" index I may anticipate its effect upon the final steam temperature and provide an initial coarse adjustment to be verniered from final steam temperature which is the desideratum.

Referring again to Fig. 5 I show therein at 25 a recorder-controller of final steam temperature arranged to position the movable element 26 of a pilot valve 27 continuously establishing in a pipe 28 a fluid loading pressure representative of final steam temperature. In the example being described it is desired to maintain a final steam temperature of 1000 FTT as nearly constant as possible regardless of demand. It will be understood that the generating and superheating heat exchange surfaces are so designed and proportioned as to give a final steam temperature of 1000 FTT at rated load operation. The characteristics of such a radiant furnace generator with convection heated superheating surfaces predicates a tendency toward excessive final steam temperature for peak load and a deficiency in final steam temperature for loads below the design rated value. However, as explained in connection with Fig. 4, the controlled firing of the three vertically spaced rows of burners provides a tendency to over-superheat the steam throughout a major portion of the operating load and the vernier adjustment is provided by the gas by-pass damper 10 of Fig. 5.

In Fig. 5 it will be seen that the air pressure loading line 28 joins the A chamber of a standardizing relay 30 which may be of the type described and claimed in the Gorrie Patent Re. 21,804 and whose output communicates with a pipe 31. Such a relay provides a proportional control with reset characteristics. It provides for the final control index (final steam temperature) a floating control of high sensitivity superimposed upon a positioning control of relatively low sensitivity. A function

of the adjustable bleed connection in the relay 30 is to supplement the primary control of the pressure of pipe 28, effective in pipe 31, with a secondary control of the same or of different magnitude as a follow-up or supplemental action to prevent over-travel and hunting.

The output of the relay 30, available through the pipe 31, is admitted through an adjustable bleed valve to the C chamber of an averaging relay 32, to the A chamber of which is connected the pipe 23. The relay 32 may be of the type described and claimed in the Dickey Patent 2,098,913.

The output of relay 32 is available in a pipe 33 to the control drive 19. Positioned in the pipe 33 is a manual-automatic selector valve 34 which is preferably of the type disclosed in the patent to Fitch 2,202,485 providing a possibility of hand or automatic control of the damper 10.

The necessary, and known, adjustments are provided in the recorder-controllers 20, 25 as well as in the relays 30, 32 and in the control drive 19, to the end that the by-pass damper 10 may be biased relative to the control of the burners X, Y and Z and may be sequentially responsive to the control indexes. The relative effect of the index "gas temperature" and the index "final steam temperature" may be adjusted by the air loading pressures established through the pilot valves and utilized through the relays.

The operation of Fig. 5 is as follows. It will be understood that the response rate of bolometer 16 and its recorder-controller 20 may be adjusted to rapidly fluctuating gas temperatures to produce an averaging effect, if desired. Assuming a steady state of operation, an increase in temperature at location B indicates an increase of heat available for superheating the steam and under steady state operation it may be assumed that such an increase could cause an undesirable increase in steam final temperature. Thus I provide that an increase in temperature at location B will increase the loading pressure value within pipe 23 and within the A chamber of relay 32. This produces an increase in pressure within the D chamber of relay 32 and thus in the pipe 33 leading to the control drive 19. Preferably an increase in pressure within pipe 33 will cause the control drive 19 to operate the damper 10 in an opening direction to tend to by-pass some of the available heating gases around a portion of the superheating surfaces.

Assuming for the moment that the temperature of the entering-gases at location B is unvarying, then an increase in final steam temperature results in an increase in air loading pressure in pipe 28 and in the A chamber of relay 30 and correspondingly in pipe 31 which joins the C chamber of relay 32 through an adjustable restriction. An increase in loading pressure in the C chamber of relay 32 acts in the same direction as an increase in air pressure within chamber A and as previously explained results in an opening of damper 10. The relative effect, upon the loading pressure in line 33, of variations in gas temperature at location B and in final steam temperature, may be adjusted and furthermore the control drive 19 may be so arranged that it will not begin to move until a predetermined change in loading pressure in line 33 has occurred. Thus the sensitivity and tendency to over-travel of the damper 10 may be adjusted in known manner.

Referring now to Fig. 6, I show therein an arrangement somewhat similar to that of Fig. 5 except utilizing a spray attemperator between the primary superheater and the secondary superheater to remove excess heat from the steam being superheated, as an alternate to the gas by-pass of Fig. 5. The general operation of the system is the same and the function (Fig. 4) of the attemperator in the one case and of the by-pass damper in the other case is to prevent final steam temperature from rising above the desired value. With the by-pass damper control of Fig. 5 some of the heating gases, heated at an

excessive temperature, are by-passed around a portion of the superheating surface. With the arrangement of Fig. 6 all of the gases are allowed to pass across the superheating surfaces but some of the excessive heat is extracted by spray attemperation between the superheaters.

The arrangement of Fig. 6 is substantially the same as that of Fig. 5 except that in the former the pipe 33 leads to a diaphragm actuated control valve 35 for controlling the flow of attempering water through a pipe 36 to an attemperator 37 serially located between the primary superheater 5 and the secondary superheater 4 in the fluid flow path. The attemperator 37 is preferably of the type described in Patent 2,550,683 to Fletcher et al. wherein the superheated steam conduit has therein a Venturi acting as a part of a thermal sleeve to protect the conduit against thermal stresses. Forwardly of the entrance of the Venturi is a spray nozzle through which water is atomized in a conical spray which is enveloped by the high velocity superheated steam. The nozzle is thus disposed in a relatively low velocity zone so there is a low pressure loss due to turbulence created by the nozzle body. The water leaves the nozzle in the form of a spray cone with a hollow vortex, the outer limits of this cone being within the entrance surfaces of the Venturi.

In Fig. 7 I show a complete control system for the unit of Fig. 1 and incorporating the by-pass damper control of Fig. 5. I might as readily incorporate in Fig. 7 the attemperator control of Fig. 6. See Fig. 7A.

In the control diagram shown in Fig. 7 the forced draft fan 40 (Fig. 1) is controlled to provide an optimum amount of combustion air to the burners X, Y and Z for the combustion of the fuel supplied. The fan 40 is provided with both speed control and damper regulation, both of which are actuated in response to a steam flow-air flow type of control system. The forced draft fan speed is regulated by a valve 41. 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 control drive 42. This type of control system is well known and consists of a steam flow-air flow relation controller 43, where a change in the steam flow-air flow relation of the unit causes a proportional change in the position of the pneumatic pilot valve 44 establishing an air loading pressure in the pipe 45 leading to the A chamber of a standardizing relay 46. The output of relay 46 enters an averaging relay 47 whose output is available through a pipe 48 to position the valve 41 and the control drive 42. A calibrating relay 49 regulates the transmittal of the control impulse to the control drive 42 while the valve 41 regulates fan speed through a range of fan speeds in accordance with the adjustment of a differential relay 50 correlated with a hydraulic tachometer 51 and acting through an accelerating relay 52 so that the drive 42 will become operative below the selected fan speed operating range. The regulation of the fan 40 in accordance with the steam flow-air flow controller 43 controls the total amount of combustion air delivered, with the fuel, to the furnace 1, with the exception of a minor amount of tempering air introduced into the primary air steam entering the pulverizers.

An induced draft fan has speed control by way of a valve 55 and inlet vane control by way of a control drive 56 correlated in a manner similar to that explained in connection with the forced draft fan control. A furnace draft sensitive controller 57 establishes a loading pressure in a pipe 58 leading through a standardizing relay 59 to the pipe 60. Thus the induced draft fan and dampers are controlled to maintain furnace draft or absolute pressure at desired value.

The firing rate of the furnace 1 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 61 positioning the movable element of a pilot 62 and thus continuously establishing in the A chamber of a standardizing relay 63 a loading pressure representative of steam pressure value. The output of the relay 63 is available through a ratio relay 64 to a header 65, and through a pipe 66 to the A chamber of the averaging relay 47 previously mentioned. It will thus be seen that the forced draft fan, or air supply to the unit, is under the conjoint control of steam pressure and of steam flow-air flow interrelation.

Power devices 67, 67', 67'' are arranged to position the burner dampers 13X, 13Y and 13Z respectively. Power devices 68, 68', 68'' are arranged to position the primary air dampers of the mills feeding burners X, Y and Z respectively. As previously pointed out a control of primary air to the mill controls the supply of fuel to the burners mentioned. It is thus apparent that the power controllers in connection with burners X, Y and Z, namely, 67, 68, 67', 68', 67'', and 68'' all receive the effect of the impulse or loading pressure in pipe 65.

A separate control system is interposed to regulate the operation of the burners Z over a selected range of steam generating and superheating capacities. This system includes a controller 70 actuated by a measurement of steam flow leaving the unit and includes a characterizing cam in the positioning of the movable element of a pilot valve 71. The control impulse from pilot 71 is passed through a ratio controller 72 to an averaging relay 73 where it is joined by the control impulse in pipe 65 after passing through a calibrating relay 74. The control impulse output of relay 73 is then passed to the power drives 67'' and 68''.

In the operation of the system of Fig. 7, the steam flow-air flow controller 43 regulates the operation of the forced draft fan 40 and the forced draft dampers so as to supply the proper amount of total air to the furnace 1 as required for the combustion of sufficient fuel to generate the steam demand of the boiler. This control system is modified by a superimposed control impulse produced by Bourdon tube 61 and standardizing relay 63 so as to insure immediate control response to a change in boiler operating conditions. The change in boiler operating conditions created by a change in steam pressure actuates the ratio controller 64 while a change in boiler operating conditions created by a change in steam flow actuates the ratio controller 72. The steam pressure actuated ratio controller 64 creates changes in the position of the primary air control dampers of the pulverizers for burners X and Y as well as the corresponding secondary air dampers therefor. However, in accordance with the present system, the control impulse from the controller 64 will be ineffective over a selected operating capacity range of the unit in altering the damper positions of the burners Z and the secondary air flow therefor, through the drives 67'' and 68''. This is accomplished by adjustment of the calibrating relay 74 and the averaging relay 73. When the steam flow rate from the boiler unit is below a predetermined value, the pulverizer Z, power controllers 67'' and 68'' are regulated in parallel with controllers 67, 68, 67' and 68' in accordance with the control impulses from the ratio controller 64. Thus, the burners Z are supplied with a substantially uniform supply of fuel and air for combustion throughout an upper range of steam generating and superheating capacity (base load) as clearly shown in Fig. 4, while the burners X and Y 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 X, Y, and Z are operated in parallel in response to steam pressure through the controller 64. To avoid an abrupt changeover in the operation of the burners Z at the lower end of their oper-

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ation, the relays 73 and 74 are adjusted to permit a gradual or smooth changeover from a predominately steam flow regulation to a predominately steam pressure regulation of the fuel and air supplied through the burners Z. If desired, the cam actuated pilot 71 can be used to accentuate or diminish the controlling impulse obtained from steam flow. In accordance with the usual control practice, selector valves similar to 34 are provided in the control circuits to permit selective manual or automatic operation of the controlling elements.

The effect on the burners X, Y and Z proposed is a smooth transition from base loading to steam pressure control. At the predetermined higher rating steam flow effect overbalances steam pressure effect and holds the burner Z base loaded. As rating decreases steam flow effect decreases until equal to steam pressure effect. Continued decrease in rating decreases the steam flow effect relative to the steam pressure effect and the result, from the averaging relay, is the rating band through which the burners Z are conjointly under the control of steam flow and steam pressure. On continued decrease in rating steam flow effect fades out and steam pressure effect takes over.

In Fig. 8 I show a slight modification in the arrangement of the fuel control or controlled firing of the burner rows X, Y and Z. Herein the measure of load or demand, namely steam pressure, provides a loading pressure in the pipe 65 going in parallel to three calibrating relays 80, 81 and 82 respectively for the burner rows X, Y and Z. In this modification the complete control of fuel supply to the furnace 1 is from the measure of load or demand, namely steam pressure and is sequential, with or without overlap, and graduated control of the three vertically spaced sets of burners is through the adjustment of the various loading pressures of the calibrating relays 80, 81 and 82. Through the agency of these relays the loading pressure available in the pipe 65 may be first effective through one range of pressures in regulating the burners Z and then sequentially effective in regulating the burner groups Y and X. Such regulation may pick the burner groups up in sequence with or without overlap.

Fig. 9 shows a further modification in controlled firing wherein the measure of load or demand may be either a continuous measurement of steam flow rate or of air flow rate through the unit as a whole. With the use of either index I provide a controller 85 having a set of cams 86, 87 and 88 positioning the movable element of pilot valves 89, 90 and 91 respectively to establish separate loading pressures for the calibrating relays 80, 81 and 82. In this arrangement the cams 86, 87 and 88 may be so shaped and interrelated as to pick up and overlap, in connection with the calibrating relays 80, 81 and 82, to give the desired interrelation of firing between the burners X, Y and Z as depicted in Fig. 4 or with other desirable overlap, parallel or sequential operating relation between the sets of burners X, Y and Z.

It is understood in this art that either vapor outflow rate or air flow rate may be used as an index of output or rating. By "air flow" I intend to include the rate of flow of the gaseous products of combustion and excess air passing through the unit, i. e., leaving the furnace and contacting the following heat exchange surfaces. Under certain conditions I preferably employ the "air flow" index as an index of heat quantity together with a "temperature" index, to give an availability measure.

In Fig. 10 I illustrate the possibility of more closely coordinating the controlled firing of fuel with attemperaturaion or gas by-pass damper control. Herein the index of demand, steam pressure, establishes an air loading pressure in the A chamber of standardizing relay 63, to the B chamber of which is joined an air loading pressure developed by the gas temperature responsive pilot valve 22. The pipe 95 leads from the lower portion of pilot 22 and is provided with a variable restriction 96 at its entrance to the B chamber of relay 63. Thus a modify-

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ing effect of gas temperature, upon the control of fuel, may be regulated by the valve 96.

The operation of the system is as follows. The primary impulse for controlled firing of the fuel is established by the steam pressure controller 61. If steam pressure tends to fall then the pressure within the A chamber of relay 63 decreases, as does the loading pressure in pipe 97 leading to the fuel control drives, and the arrangement is such that a decreasing loading pressure in pipe 97 results in an increase in rate of fuel firing. On the other hand, should the gas temperature decrease, this results in an increase in loading pressure within pipe 95 and effective in the B chamber of relay 63 again increasing the loading pressure in pipe 97 and causing an increase in the controlled fuel firing.

The over-all arrangement of Fig. 10 provides a controlled fuel firing primarily in accordance with steam pressure demand modified, if necessary, in accordance with gas temperature at the entrance to the superheater surface. At the same time the gas temperature and final steam temperature are effective to regulate the spray valve 35 or the gas by-pass damper 10. The relative effect of gas temperature upon relays 63 and 32 may be adjusted as desired.

In Fig. 11 I show a different arrangement for the basic controlled firing of vertically spaced rows of fuel burners to a furnace. While I have illustrated in Fig. 11 an arrangement of two vertically spaced sets of two each burners it is not limited thereto but this might be three vertically spaced sets of two each or other combinations as desired.

The burner box 100 is divided into four compartments 101, 102, 103 and 104 supplying secondary air to burners Z', Z'', X' and X'' respectively. Burners X' and Z' are supplied with primary air and pulverized coal from a mill 105 while burners Z'' and X'' are supplied with primary air and pulverized coal from a mill 106. The mills 105 and 106 are under the control of loading pressures in pipes 107 and 108 respectively in manner previously described. The conjoint control of the two mills is from a total fuel controller 109 responsive to steam pressure or other index of demand.

The burner X' receives fuel and primary air through the pipe 110 under the control of the damper 111 and receives secondary air through a pipe 112 under the control of a damper 113. In similar fashion the burner Z' receives fuel and primary air from the mill 105 through a pipe 114 under the control of damper 115 and secondary air through a pipe 116 under the control of damper 117. In similar manner the mill 106 supplies burner X'' with fuel and primary air through a pipe 118 under the control of a damper 119 and secondary air through a pipe 120 under control of a damper 121. The mill 106 also supplies the burner Z'' with fuel and primary air through a pipe 122 under the control of a damper 123 and with a secondary air through a pipe 124 under control of a damper 125. The dampers 111, 113 are jointly positioned by a control drive 126, dampers 115, 117 by a control drive 127, dampers 119, 121 by a control drive 128, and dampers 123, 125 by a control drive 129. The features of these four control drives are such that proper motion and relationship characteristics of the dampers under the control of each control drive may be adjusted to provide the proper amount of secondary air for the fuel being supplied. It is only necessary to remember that control drive 126 basically controls the firing of burner X', drive 128 the firing of burner X'', drive 127 the firing of burner Z' and drive 129 the firing of burner Z''. To effect the desired controlled firing of the four burners I preferably increase the firing rate of burner Z', Z'' while decreasing the firing rate of burners X', X'' upon a decreasing rating and increase the relative firing of burners X', X'' while decreasing the firing of burners Z', Z'' upon an increasing rating.

It will be appreciated that the control of all four

burners, under the dictates of regulator 109, will vary the total rate of supply of fuel and air in desired proportionality to total rating. The response rate of the controllers 127, 129 relative to controllers 126, 128 may be varied, or so adjusted that the burners at one elevation may be increased or decreased at a different rate than those at the other elevation.

The loading pressure from the gas temperature controller 20, through pipe 95, enters the A chamber of a relay 130 whose output loading pressure in a pipe 131 is supplied to the A chambers of relays 132, 133 and to the B chambers of relays 134, 135. It will be observed that relays 134, 135 are reversing relays relative to relays 132, 133 to the end that the loading pressures in output pipes 136, 137 are in reverse direction to those in output pipes 138, 139. The result is that a change in loading effect, in pipe 131, tends to move regulators 127, 129 in one direction while moving regulators 126, 128 in the opposite direction. Obviously the adjustability of the various relays may be such that desired relation of movement and effect is gained between the different burners under control.

It will be appreciated that I have chosen to illustrate and describe certain preferred embodiments of my invention, but that the invention may be embodied in other forms, and thus I do not desire to be limited to the specific showings disclosed.

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

1. In a vapor generating and superheating unit of the type having a fluid-cooled combustion chamber having opposite end portions and an intermediate portion with a heating gas outlet in one end portion thereof and having convection vapor superheating surface positioned beyond the combustion chamber outlet in the path of heating gas flow, the method of operation which includes introducing fuel and air for combustion separately into the intermediate portion and other end portion of the combustion chamber, maintaining a substantially uniform fuel and air input rate into the intermediate portion of said chamber throughout a selected upper range of vapor generating rating while varying the fuel and air input rate into said other end portion inversely in accordance with vapor pressure value determination, so proportionately varying the fuel and air input rate to both the said intermediate portion and other end portion of said combustion chamber in accordance with vapor pressure during unit operation at capacity rates below said selected upper range that the rate of supply to the intermediate portion closest to the gas outlet is always equal to or greater than the rate to the other end portion further from the outlet while the total supplied rate varies directly with capacity demand, maintaining a substantially uniform optimum final total vapor temperature leaving the superheater over at least a portion of the said selected upper range of rating through controllably by-passing heating gases around a portion of the superheating surface in a direction to increase the amount by-passed as final total vapor temperature tends to rise and vice versa, and controlling the by-passing conjointly responsive to a determination of temperature of the heating gases entering the superheating surfaces and a determination of the final vapor temperature.

2. In a vapor generating and superheating unit of the type having a fluid-cooled combustion chamber having opposite end portions and an intermediate portion with a heating gas outlet in one end portion thereof and having convection vapor superheating surface positioned beyond the combustion chamber outlet in the path of heating gas flow, the method of operation which includes introducing fuel and air for combustion separately into the intermediate and other end portions of the combustion chamber, regulating the fuel and air input rate into an intermediate portion of said chamber in accordance with capacity demands upon the unit throughout a se-

lected upper range of vapor generating rating while variably supplying the remainder of the fuel and air input requirements for each capacity rate to the said other end portion of the combustion chamber in accordance with vapor pressure determination; over an intermediate range of vapor generating capacity regulating the fuel and air input rate to the said intermediate portion of the combustion chamber conjointly responsive to capacity demand upon the unit and to vapor pressure while variably supplying the remainder of the fuel and air input requirements to the said other end portion of the combustion chamber in accordance with vapor pressure determination; over a lower range of vapor generating capacity so proportionately varying the fuel and air input to the said intermediate and other end portions of the combustion chamber in accordance with vapor pressure determination that the rate of supply to the intermediate portion is proportionately greater than the rate of supply to the said other end portion as unit rating decreases; the regulation of fuel and air supply rates over all ranges of operation being in the direction to increase the supply rate as demand increases and/or as vapor pressure decreases, maintaining a substantially uniform optimum final total vapor temperature leaving the superheating surface over at least a portion of the said selected upper rating range through controllably by-passing heating gases around a portion of the superheating surface in a direction to increase the amount by-passed as the final total vapor temperature tends to rise and vice versa, and controlling the by-passing conjointly responsive to a determination of temperature of the heating gases entering the superheating surfaces and a determination of the final vapor temperature.

3. The method of claim 2 wherein the index of capacity demand is vapor outflow rate.

4. The method of claim 2 wherein the index of capacity demand is rate of supply of heating gases through the unit.

5. In a vapor generating and superheating unit of the type having a fluid-cooled combustion chamber having opposite end portions and an intermediate portion with a heating gas outlet in one end portion thereof and having convection vapor superheating surface positioned beyond the combustion chamber outlet in the path of heating gas flow, the method of operation which includes introducing fuel and air for combustion separately into the intermediate and other end portions of the combustion chamber, continuously ascertaining rate of unit operation and value of generated vapor pressure for guidance in fuel and air supply rate to the unit, regulating the fuel and air input rate into said intermediate portion of the combustion chamber throughout an upper range of vapor generating capacity at a substantially base rate, as rate of operation decreases progressively decreasing the effect of rating while progressively increasing the effect of vapor pressure upon the supplying of fuel and air to the said intermediate portion, until as rate of operation further decreases the rating effect fades out and the vapor pressure effect predominates; simultaneously proportionately supplying the remaining fuel and air requirements to the opposite end portion of the combustion chamber in accordance with vapor pressure throughout the entire range of capacity operation; the regulation of fuel and air supply rates over all ranges of operation being in the direction to increase the supply rates as demand increases and/or as vapor pressure decreases, maintaining a substantially uniform optimum final total vapor temperature leaving the superheater over at least a portion of the capacity range of rating through controllably by-passing heating gases around a portion of the superheating surfaces in a direction to increase the amount by-passed as final total temperature tends to rise and vice versa, and controlling the by-passing conjointly responsive to a determination of the heat availability of

the heating gases entering the superheating surfaces and a determination of the final vapor temperature.

6. The method of claim 5 wherein the "heat availability of the heating gases" is continuously manifest from determination of temperature of the heating gases entering the superheating surfaces.

7. The method of claim 5 including the step of controlling the total supply of air to support combustion conjointly responsive to vapor outflow pressure and an effect continuously representative of the relation between vapor outflow rate and rate of flow of the heating gases through the unit.

8. In a vapor generating and superheating unit of the type having a fluid-cooled combustion chamber with a heating gas outlet in one end portion thereof and having convection vapor superheating surface positioned beyond the combustion chamber outlet in the path of the heating gas flow, the uncontrolled characteristic of final steam temperature leaving such a convection superheating surface rising with rating, the method of operation which includes introducing fuel and air for combustion separately into a plurality of portions including an intermediate portion of the combustion chamber spaced progressively from the said one end portion, regulating the total fuel and air input to the combustion chamber primarily from a measure of load or demand on the unit by increasing the supply rate with increased load and vice versa, proportionately varying the fuel and air supply as between the different combustion chamber portions as unit load changes in direction such that the rate of fuel and air supply to the intermediate portion of the chamber predominates over the rate of supply to the end portion furthest from the outlet at low loads with the proportioning approaching equality between the various chamber portions as demand increases to thus regulate total heat availability leaving the heating gas outlet to the convection vapor superheating surfaces as demand varies, and further regulating the unit toward maintaining a substantially uniform final vapor temperature through at least a portion of the load range in a direction to return final vapor temperature toward optimum value upon departure therefrom through controllably by-passing heating gases around a portion of the superheating surfaces in a direction to increase the amount by-passed as final vapor temperature tends to rise and vice versa, and controlling the by-passing conjointly responsive to a determination of the available heat of the heating gases entering the superheating surfaces and a determination of the final vapor temperature.

9. The method of claim 8 wherein the load index is vapor pressure.

10. The method of claim 8 wherein the determination of available heat of the heating gases is indexed by temperature of the heating gases entering the superheating surfaces.

11. The method of claim 8 wherein the proportioning of the fuel and air input between the different combustion chamber portions in accordance with load demand is, predominately to the portion nearest the chamber outlet as compared to the remainder of the chamber at low loads and, as load increases the predominance decreases until at peak load the proportionality is equal among the chamber portions.

12. The method of claim 11 wherein the proportioning of fuel among the several chamber portions varies progressively with load.

13. The method of claim 8 wherein the proportioning of the fuel and air input between the different combustion chamber portions in accordance with load demand is, as load increases the fuel supply rate to one chamber portion increases while that to another portion decreases and, as load decreases the reverse.

14. Apparatus for generating and superheating vapor including in combination, an upright elongated furnace having fluid-cooled walls and a heating gas outlet in one

end portion thereof, a convection superheater positioned adjacent said furnace gas outlet in the path of gas flow leaving said furnace, a plurality of fuel burners opening to said furnace and spaced at different distances from said furnace outlet and including an intermediate portion of said furnace, operating rate responsive means regulating the delivery of a substantially uniform heat input to an intermediate portion of the furnace in an upper range of operating rate of vapor generation while increasing and decreasing the heat input rate to the other end portion of said furnace in accordance with increase and decrease respectively in the actual operating rate, means regulating the delivery of substantially equal rates of heat input through all operating burners at vapor generating rates less than the lower limit of said upper range of operating rates, a passage for heating gases to provide the possibility of diverting a controllable portion of the heating gases around at least a portion of the superheating surface, damper means arranged to control the by-passing, first temperature determining means of the heating gases leaving the furnace, second temperature determining means of the final superheated vapor, and control means for the damper means conjointly responsive to said first and second temperature determining means acting to increase the by-passing of heating gases around the superheating surfaces when final vapor temperature tends to rise above optimum value and vice versa.

15. Apparatus for generating and superheating vapor including in combination, an upright elongated furnace having fluid-cooled walls and a heating gas outlet in one end portion thereof, a convection superheater positioned adjacent said furnace gas outlet in the path of gas flow leaving said furnace, a plurality of fuel burners opening to said furnace and spaced at different distances from said furnace outlet, operating rate responsive means regulating the delivery of a substantially uniform heat input to that portion of the furnace closest to said gas outlet in an upper range of operating rate of vapor generation while increasing and decreasing the heat input rate to another portion of said furnace in accordance with increase and decrease respectively in the actual operating rate, means regulating the delivery of substantially equal rates of heat input through all operating burners at vapor generating rates less than the lower limit of said upper range of operating rates, means for regulating final superheat temperature, means continuously obtaining a representation of heat availability of the heating gases leaving the furnace, means continuously responsive to the final temperature of the vapor leaving the unit, and control means regulating the superheating of the generated vapor responsive to both said last named means to actuate said final superheat temperature regulating means to return final vapor temperature toward optimum value upon departure therefrom.

16. Apparatus for generating and superheating vapor including in combination, an upright elongated furnace having fluid-cooled walls and 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 row of burners spaced at a different distance from the furnace outlet, a controllable source of fuel and air for each row of burners, control means responsive to generated vapor pressure for inversely regulating the supply of fuel and air to all burners as vapor pressure varies, a separate control means responsive to vapor outflow rate overriding said vapor pressure control means to the burners closest to said furnace outlet throughout an upper range of vapor generating rate and regulating the supply of fuel and air directly as vapor outflow rate varies and becoming ineffective below said selected upper rate range, the vapor pressure responsive control means tending to decrease fuel and air supply rate as vapor pressure increases above optimum value and the vapor outflow responsive control

means tending to increase fuel and air supply rate as vapor outflow rate increases, a measuring device sensitive to temperature of the heating gases approaching the superheating surfaces, a second measuring device sensitive to final total temperature of the vapor, and control means responsive to both devices adapted to return final vapor temperature toward optimum value upon departure therefrom.

17. Apparatus for generating and superheating vapor including in combination, an upright elongated furnace having fluid-cooled walls and 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 row of burners spaced at a different distance from the furnace outlet, a controllable source of fuel and air for each row of burners, a device sensitive to generated vapor pressure, a second device sensitive to vapor outflow rate, separate control means regulating fuel and air to each row of burners, the vapor pressure responsive control means tending to decrease fuel and air supply rate as vapor pressure increases above optimum value and the vapor outflow responsive control means tending to increase fuel and air supply rate as vapor outflow rate increases, all of said control means responsive to the first device, the control means for the burners closest to the furnace outlet also under domination of the second device, a temperature measuring instrument of the heating gases leaving the furnace, a second temperature measuring instrument for final total vapor temperature, and a by-pass damper for the heating gases around at least a portion of the superheating surface positioned responsive to both instruments acting to increase the by-passing of heating gases around the superheating surfaces when final vapor temperature tends to rise above optimum value and vice versa.

18. Apparatus for generating and superheating vapor including in combination, an upright elongated furnace having fluid-cooled walls and a heating gas outlet in one end 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 row of burners spaced at a different distance from the furnace outlet, a controllable source of fuel and air for each row of burners, a measuring device sensitive to an index of demand upon the unit, separate control means regulating fuel and air

to each row of burners responsive to the measuring device in direction to increase fuel and air supply rate as demand increases and vice versa, means so proportioning the fuel and air among the rows of burners in accordance with demand that the rate of supply to the burners closest to the gas outlet is always equal to or greater than the rate to any row of burners further from the heating gas outlet, a temperature determining instrument for the gases leaving the furnace, a temperature determining instrument for the final total vapor temperature, and control means sensitive to both instruments tending to return final vapor temperature to optimum value upon departure therefrom.

19. The combination of claim 18 wherein the measuring device sensitive to an index of demand is sensitive to vapor pressure.

20. The combination of claim 18 wherein the measuring device sensitive to an index of demand is sensitive to vapor outflow rate.

21. The combination of claim 18 wherein the measuring device sensitive to an index of demand is sensitive to rate of supply of heating gases to the superheating surfaces.

22. The method of claim 8 wherein regulation of final vapor temperature at a substantially uniform optimum value is obtained by controlled attemperation of the vapor.

23. The combination of claim 15 wherein said means for regulating final superheat temperature includes an attemperator.

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