

Nov. 8, 1966

N. S. BLODGETT ET AL

3,283,801

STEAM GENERATING UNIT

Filed Feb. 25, 1964

4 Sheets-Sheet 1

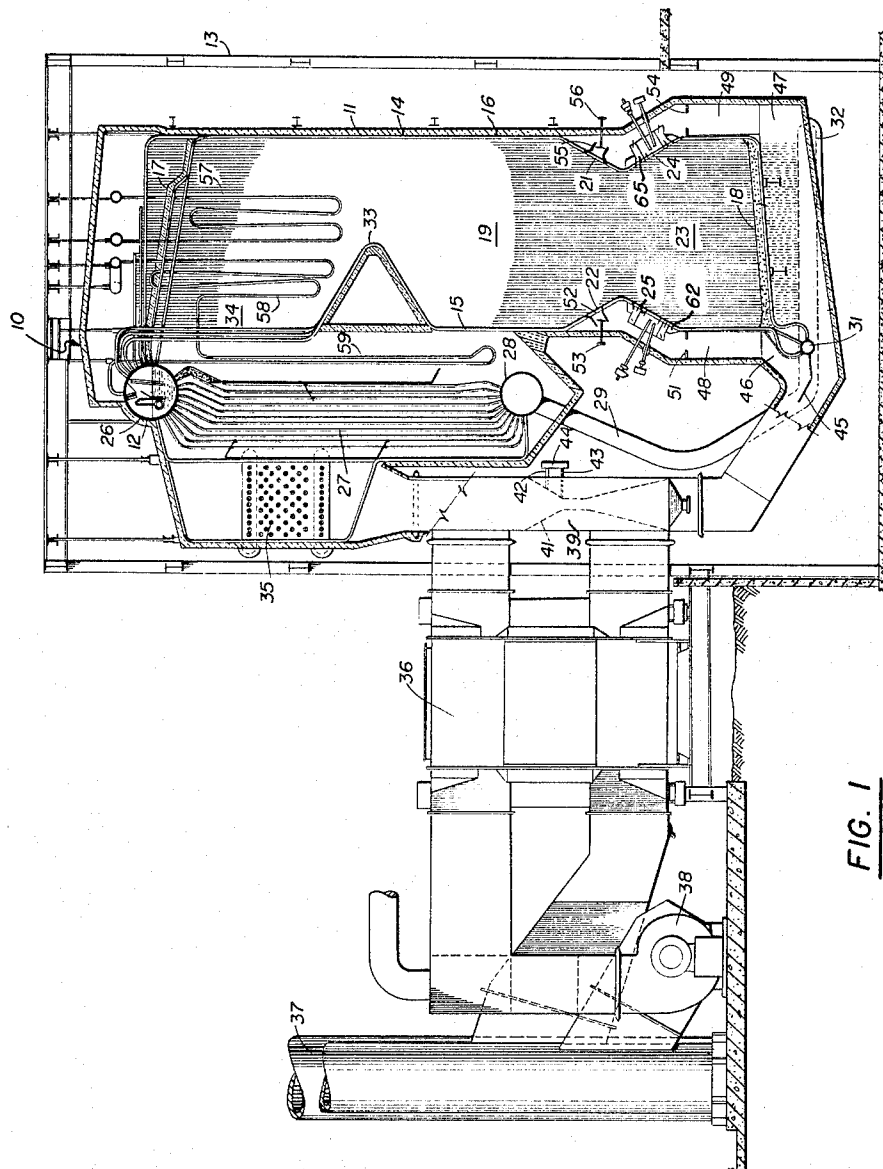


FIG. 1

NORMAN S. BLODGETT
MAX H. KUHNER
EARLE C. MILLER
INVENTOR.

BY

Norman S. Blodgett

Nov. 8, 1966

N. S. BLODGETT ET AL

3,283,801

STEAM GENERATING UNIT

Filed Feb. 25, 1964

4 Sheets-Sheet 2

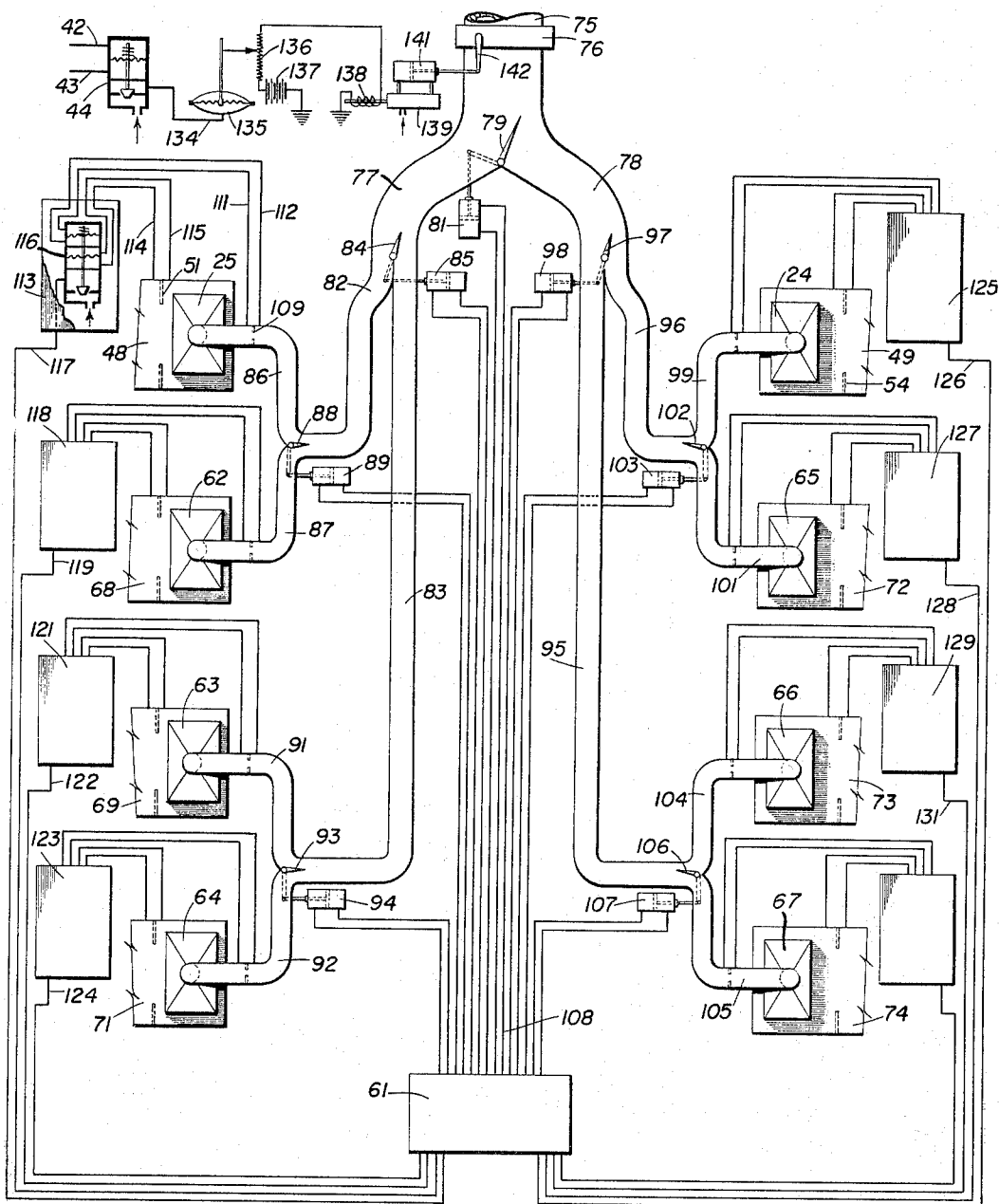


FIG. 2

NORMAN S. BLODGETT
MAX H. KUHNER
EARLE C. MILLER
INVENTOR.

BY

Norman S. Blodgett

Nov. 8, 1966

N. S. BLODGETT ET AL

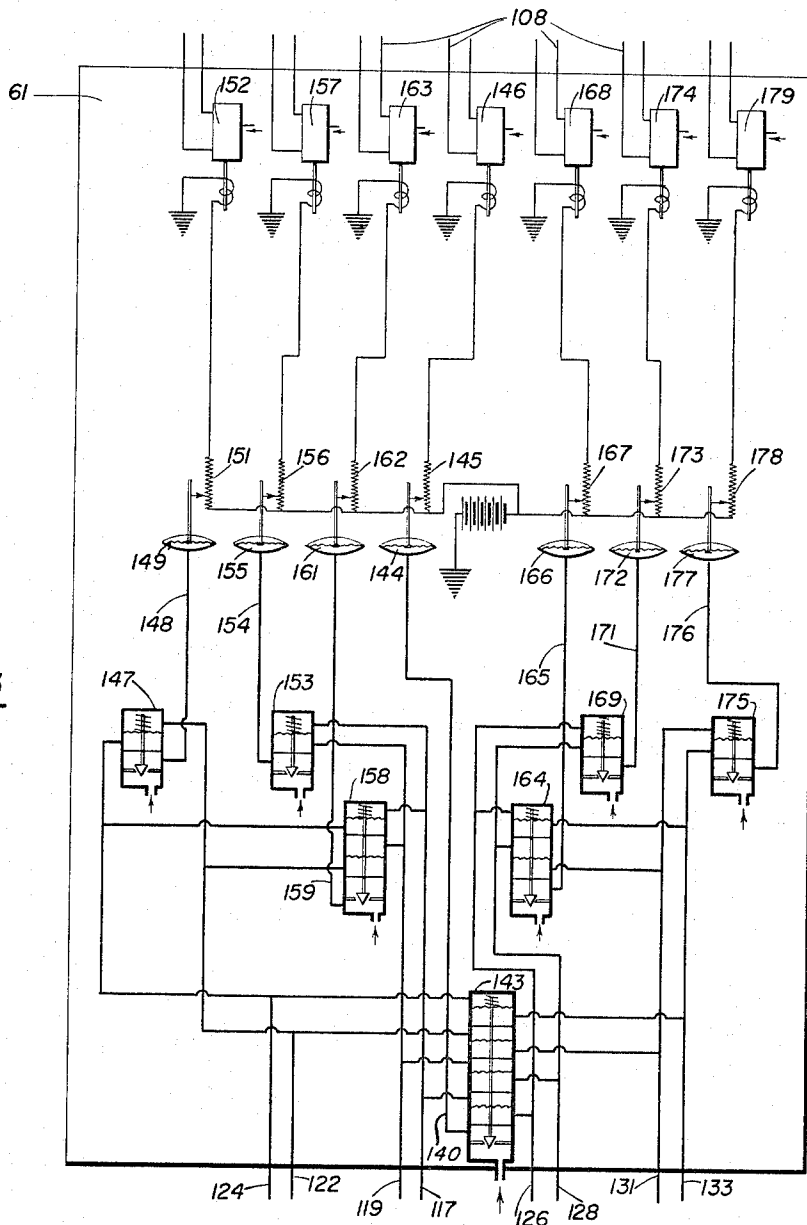
3,283,801

STEAM GENERATING UNIT

Filed Feb. 25, 1964

4 Sheets-Sheet 3

FIG. 3



NORMAN S. BLODGETT
MAX H. KUHNER
EARLE C. MILLER
INVENTOR.

BY
Norman S. Blodgett

Nov. 8, 1966

N. S. BLODGETT ET AL
STEAM GENERATING UNIT

3,283,801

Filed Feb. 25, 1964

4 Sheets-Sheet 4

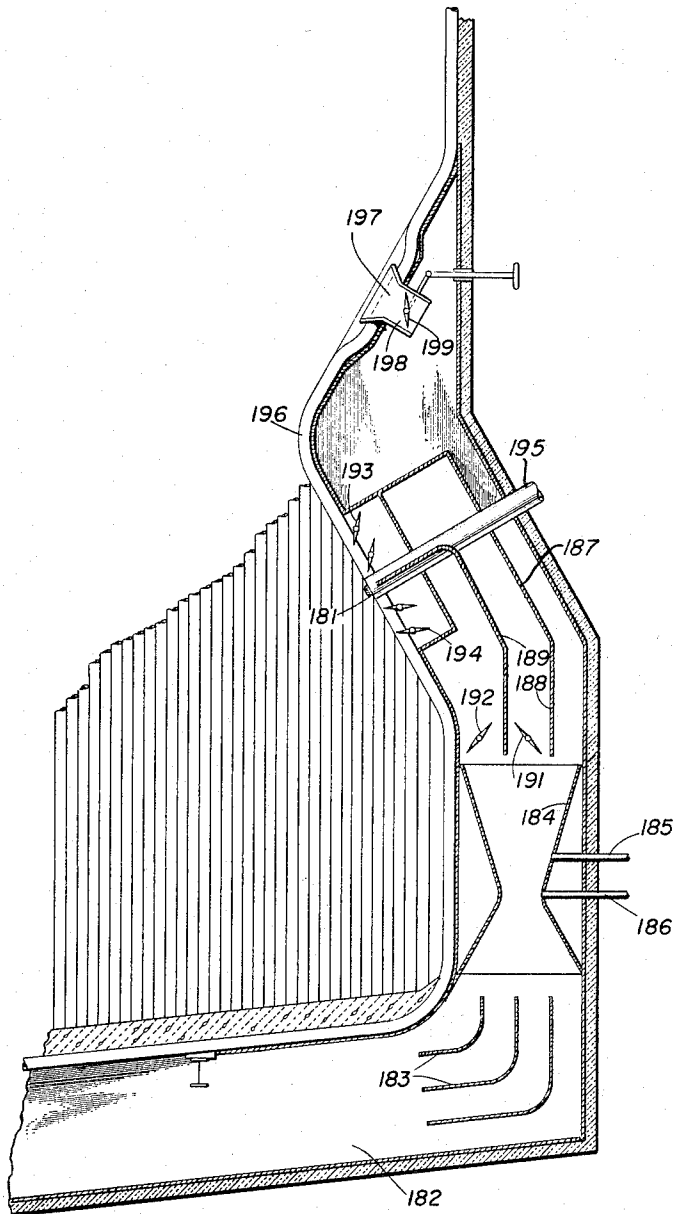


FIG. 4

NORMAN S. BLODGETT
MAX H. KUHNER
EARLE C. MILLER
INVENTOR.

BY
Norman S. Blodgett

1

3,283,801

STEAM GENERATING UNIT

Norman S. Blodgett, Westboro, Max H. Kuhner, Oakham,
and Earle C. Miller, Worcester, Mass., assignors to
Riley Stoker Corporation, Worcester, Mass., a corpora-
tion of Massachusetts

Filed Feb. 25, 1964, Ser. No. 347,189

5 Claims. (Cl. 158—1)

This invention relates to a steam generating unit and, more particularly, to apparatus arranged to produce steam by the burning of fuel in an air suspension.

In the generation of steam, it is common practice to burn a fuel, such as pulverized coal, atomized oil, or combustible gas, in suspension and in mixture with air; the resultant hot products of combustion are then brought into heat exchange relationship with water. In the past, it has always been necessary to use large amounts of air in excess of the stoichiometric amounts necessary to burn the fuel. When attempts have been made to bring the amount of air close to the theoretical amounts, difficulties have been experienced with maintaining ignition of the flame at the burner and in obtaining complete combustion. These and other difficulties experienced with the prior art apparatus have been obviated in a novel manner by the present invention.

It is, therefore, an outstanding object of the invention to provide a steam generating unit in which it is possible to reduce the amount of excess air to an amount only slightly above that theoretically required for combustion.

Another object of this invention is the provision of a steam generating unit in which the efficiency is high, due to reduced stack losses.

A further object of the present invention is the provision of a steam generating unit in which fouling of the heat exchange surfaces is reduced.

It is another object of the instant invention to provide a steam generating unit in which the formation of SO₃ is reduced and cold end corrosion in the air heater is reduced.

It is a further object of the invention to provide a steam generating unit in which it is possible to operate at below 5% excess air without encountering problems due to lack of ignition or complete combustion.

A still further object of this invention is the provision of a steam generating unit in which the gas leaving the air heater may be reduced to temperatures which, in the past, were not permitted because they would result in air heater corrosion.

A further object of the invention is the provision of a steam generating unit in which the amount of nitric oxide in the effluent gas is substantially reduced.

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

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

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

FIG. 2 is a somewhat schematic view of the burners and associated equipment used in the unit,

FIG. 3 is a schematic diagram of a main control used in the unit, and

FIG. 4 is a sectional view of another embodiment of the invention.

Referring first to FIG. 1, wherein are best shown the general features of the invention, the steam generating unit, indicated generally by the reference numeral 10, is

2

shown as consisting of a furnace 11, and a boiler 12, mounted on a structural framework 13. The furnace 11 consists of a front wall 14, a rear wall 15, side walls 16, a roof 17, and a bottom 18 all defining a vertically-elongated combustion chamber 19. Located adjacent the bottom 18 are two horizontal abutments 21 and 22 located, respectively, on the front wall 14 and the rear wall 15 and defining with the bottom 18 a high-temperature cell 23. Located on the abutments 21 and 22 are burners 24 and 25 which are of the directional-flame, inter-tube type shown and described in the patent application of Miller, Serial No. 217,322, filed August 16, 1962, now abandoned. This burner is of the constant velocity type, wherein the velocity of air through the burner proper can be regulated to the optimum constant value irrespective of load, i.e., irrespective of the total air introduced into the furnace.

The boiler 12 consists of a steam-and-water drum 26 connected by downcomers 27 to a lower drum 28. The lower drum is connected by downcomers 29 to a header 31 which is located at the bottom 18 and which is connected to longitudinal headers 32 from which tubes extend upwardly along the side walls 16. The tubes extend upwardly from the header 31 along the rear wall 15 and from the header 31 along the bottom 18 and up the front wall 14. Some of the tubes lining the rear wall 15 are formed into a nose 33 extending from the rear wall 15 toward the front wall 14 and underlying a gas outlet 34 leading into the backpasses of the boiler. Located in the backpass is an economizer 35 and the backpass is then connected through an air heater 36 to a stack 37. A forced draft fan 38 supplies air to the air heater and this air passes through the air heater into a main duct 39. The main duct is provided with a venturi 41 from which extend two pneumatic tubes 42 and 43 located at longitudinally-spaced positions and giving a signal indication of load on the unit to an integrating device 44. The main duct 39 leads to the bottom of the furnace and the air is divided into two parts by a vane 45 so that the air is directed into two ducts 46 and 47. From these main ducts extend branch ducts one for each of the burners; for instance, a branch duct 48 is provided for the burner 25 and a branch duct 49 is provided for the burner 24. Located in the branch duct 48 is an orifice 51 permitting the measurement of air flow. An opening 52 is provided in the upper part of the abutment 22, which opening is provided with a damper 53. Similarly, the duct 49 is provided with an orifice 54 while an overfire air opening 55 is provided in the upper surface of the abutment 21 and has a damper 56 to control the flow of air therethrough into the furnace. Located at the upper part of the combustion chamber 19 is a high-temperature radiant superheater 57. Between the upper surface of the nose 33 and the roof 17 is located an intermediate-temperature convection superheater 58, and in the backpass is located a low-temperature superheater 59. These three superheaters are connected in series for the gradual increase in temperature of steam to be superheated.

FIG. 2 shows the arrangement of the burners, air-admitting ducts, fuel pipes, and their associated controls. Also indicated is the manner in which they are connected to a main control 61. It will be noted that on the under-surface of the abutment 22 are arranged three other burners, 62, 63, and 64 in addition to the burner 25 previously described. In the same manner, along the lower surface of the abutment 21 are arranged the burners 65, 66, and 67 in addition to the burner 24. While the burner 25 has its branch duct 48 leading from the main duct 46, the burner 62 is similarly provided with a separate branch duct 68. The burner 63 is provided with a branch duct 69, and the burner 64 is pro-

3

vided with a branch duct 71. Similarly, the burner 65 is provided with a branch duct 72, the burner 66 is provided with a branch duct 73, and the burner 67 is provided with a branch duct 74 in the same manner that the burner 24 is provided with its branch duct 49. The branch ducts associated with the burners 62, 63, 64, 65, 66, and 67 are provided with individual orifices in the same way that the branch duct 48 of the burner 25 is provided with an orifice 51 and the branch duct 49 of the burner 24 is provided with an orifice 54. The entire supply of fuel for the furnace arrives at the steam generating unit through a pipe 75 in which is located a main fuel supply valve 76. For the purposes of illustration, the pipe 75 is shown as a gas pipe, but it will be understood that the fuel can arrive in an oil pipe in the same manner or in the form of pulverized coal mixed with air. Following the valve 76, the pipe 75 is joined to two branch pipes 77 and 78; the division of fuel between these branch pipes is determined by a damper 79 whose setting is controlled by a hydraulic linear actuator 81. The branch pipe 77 is divided into two branch pipes 82 and 83 and the fuel division at that junction is determined by a damper 84 whose position is controlled by an hydraulic actuator 85. Similarly, the branch pipe 82 is divided into two branch pipes 86 and 87, the division of gas flow into them being determined by a damper 88 whose position is controlled by an hydraulic actuator 89. The branch pipe 86 is connected to the gun of the burner 25, while the branch pipe 87 is connected to the gun of the burner 62.

The branch pipe 83 is joined to two branch pipes 91 and 92, the division of fuel being determined by a damper 93 whose position is controlled by an hydraulic actuator 94. The branch pipe 91 is connected to the gun of the burner 63, while the branch pipe 92 is connected to the gun of the burner 64.

The branch pipe 78 is divided into two branch pipes 95 and 96 and the fuel flow between them is determined by a damper 97 whose position is determined by a hydraulic actuator 98. The branch pipe 96 is, in turn, connected to two branch pipes 99 and 101 and the division of fuel flow between them is determined by a damper 102 whose setting is determined by an hydraulic actuator 103. The branch pipe 101 is connected to the gun of the burner 65, while the branch pipe 99 is connected to the gun of the burner 24. The branch pipe 95 is connected to two branch pipes 104 and 105 and the fuel is divided between these pipes by a damper 106 whose position is determined by an hydraulic actuator 107. The positions of the hydraulic actuators 81, 85, 89, 94, 98, 103, and 107 are determined by a series of hydraulic conduits 108 connected to the main control 61.

The branch pipe 86 is provided with an orifice 109 to opposite sides of which are connected conduits 111 and 112 adapted to take pressure readings on opposite sides of the orifice, which readings are indicative of the flow of fuel through the orifice. It will be understood that the flow measurement apparatus will be different for different types of fuel; an orifice is adequate when the fuel is gas, but a different measuring system would be used for oil or pulverized coal. The other ends of these conduits 111 and 112 are connected to an air-fuel ratio control 113. From opposite sides of the orifice 51 and the branch pipe 49 are connected conduits 114 and 115 which are also connected to the control 113 and give to it a signal indicative of the flow of air to the burner 25. A major portion of the control 113 consists of an integrating device 116 capable of giving an output signal in a conduit 117 in the form of an air pressure indicative of the summation of the gas or air pressures in the conduits 111, 112, 114, and 115. The conduits 111, 112 are connected to the summation device so as to give a result which is the difference between them, while the signals from the conduits 114, and 115 are similarly connected. The net result in the conduit 117 is an air pressure equal

4

to the ratio of the differences of pressures in the two pairs of pipes, i.e., the air-fuel ratio. Each of the other burners 62, 63, 64, 24, 65, 66, and 67 are provided in their branch pipes with orifices and in their branch air ducts with orifices which are connected by conduits to air fuel ratio controls. The burner 62 is provided with such a control 118 which is connected by a conduit 119 to the main control 61 in the same manner that the conduit 117 is connected. Similarly, the burner 63 is provided with a control 121 whose output conduit 122 is connected to the main control. A control 123 and an output conduit 124 connected to the control 61 is supplied for the burner 64, a control 125 is provided for the burner 24, and is provided with an output conduit 126 connected to the main control. The burner 65 is provided with a main control 127 which is connected by a conduit 128 to the main control, the burner 66 is provided with a control 129 which is connected by an output 131 to the main control, and the burner 67 is provided with a control 132 which is connected by a conduit 133 to the main control.

The conduits 42 and 43 leading from the main air venturi 41 carry a signal indicative of load to a summation device 44 which subtracts one signal from the other and gives an output signal in a conduit 134 proportional to the difference between the two signals and, therefore, proportional to the air flowing through the main duct 39, this signal being indicative of the load on the steam generating unit. The conduit 134 is connected to a pneumatic actuator 135 which operates on a rheostat 136 connecting a source 137 of electrical energy to the coil 138 of an electro-hydraulic servo valve 139. The input of this valve is connected to a source of hydraulic oil under pressure and its output is connected to the opposite ends of a hydraulic actuator 141 whose piston rod is connected to an operating handle 142 of the main fuel valve 76 to determine the position thereof.

FIG. 3 shows the details of the main control 61. Entering the control are the conduits 124, 122, 119, 117, 126, 128, 131, and 133 leading from the individual fuel-air ratio controls and indicating the amount of air and fuel which is being introduced into its particular burner. Coming out of the main control 61 are the hydraulic conduits 108 leading to the various damper actuators associated with the introduction of fuel to the burners. Firstly, all of the input conduits are connected to a summation device 143 to give an output signal in a conduit 140 leading away from the device that is indicative of the difference in fuel being delivered to the two sides of the steam generating unit. The conduit 140 is connected to a pneumatic actuator 144 which operates on a rheostat 145 to control a servo valve 146 and thereby control the position of the actuator 81 and the damper 79. The conduits 122 and 124 are connected to a summation device 147 to give a pneumatic output signal in a conduit 148 which is directed to a pneumatic actuator 149. This actuator operates a rheostat 151 which, in turn, controls the valve 152 to operate the hydraulic actuator 94 and the damper 93. The conduits 117 and 119 are connected to a summation device 153 whose output signal is connected by a conduit 154 to a pneumatic actuator 155 which operates on a rheostat 156 to control a valve 157; this valve operates the hydraulic actuator 89 and the damper 83. All four conduits 117, 119, 122, and 124 are connected to a summation device 158 which gives an output signal through a conduit 159 leading to a pneumatic actuator 161 which operates a rheostat 162 to control a valve 163 whose output leads are connected to a hydraulic actuator 85 for control of the damper 84.

The conduits 126, 128, 131, and 133 are connected to a summation device 164 whose output conduit 165 is connected to a pneumatic actuator 166 which operates a rheostat 167 for the control of a valve 168; this valve is connected by its output lead 108 to the hydraulic actuator 98 operating the damper 97. The conduits 126 and 128 are also connected to a summation device 169

whose output conduit 171 is connected to a pneumatic actuator 172 which, in turn, sets a rheostat 173 to determine the setting of a valve 174; the valve 174 is connected by conduits 108 to the hydraulic actuator 103 which controls the setting of the damper 102. Similarly, the conduits 131 and 133 are also connected to a summation device 175 having an output conduit 176 connected to a pneumatic actuator 177; this actuator operates on a rheostat 178 and determines the electrical current on the coil of a servo valve 179, which is connected by its output conduits 108 to the hydraulic actuator 107 which determines the setting of the damper 106.

In FIG. 4 is shown an alternate form of the burner arrangement. In this case, the burner, indicated by the reference numeral 181, is shown as being of the constant-velocity type shown in the patent application of Kuhner, Serial Number 180,503, filed March 19, 1962, now Patent No. 3,160,146. The main duct 182 is bent upwardly to proceed to the burner and is provided in the bend with fixed air-directing vanes 183. Located in the duct is an individual venturi 184 from which extend conduits 185 and 186. The burner box 187 lies within the duct and is provided with a vertically-extending wall 188 dividing a portion of the air passing through the duct and forcing it to go into the burner box 187. Furthermore, an additional wall 189 extends between the wall 188 and the wall of the boiler and is bent around to provide a horizontal section dividing the burner into exactly two parts. A damper 191 is provided between the wall 188 and the wall 189 at the entrance between them, while a similar damper 192 is provided at the entrance between the wall 189 and the wall of the boiler. In the burner itself there are provided upper vanes 193 which lie on the upper side of the wall 189 and lower vanes 194 which lie under this wall, the horizontal portion of the wall being in alignment with the fuel gun 195 of the burner. The walls of the boiler immediately above the upper side of the abutment 196 is provided with an opening 197 formed by bending tubes backward and laterally. In this opening is mounted a sheet metal chute 198; a damper 199 is provided in the chute to control the air which flows from the duct into the boiler to function as overfire air. The burner is capable of regulation to maintain the air velocity past the fuel gun at a constant optimum value irrespective of load.

The operation of the invention will now be readily understood in view of the above description. The fuel-and-air mixture burns in the high-temperature cell 23 and in the combustion chamber 19 and then passes over the elements of the boiler 12 to generate steam, which steam is superheated in the superheaters 59, 58, and 57 before passing to a turbine. Air enters the steam generating unit through the forced draft fan 38 which passes the air to the air heater 36 where it is subjected to heat exchange with the gases leaving the unit. The total flow of air in the unit is measured by means of the venturi 41 and indicated by the conduits 42 and 43 leading to the summation device 44. The output of this summation device is always indicative of the load on the unit, and it is the purpose of the present invention to adjust the fuel introduced into the burners in accordance with this load and with the air. The air coming in the main duct 39 is divided by the damper 45 into two parts, one portion of the air serves the rear burners 25, 62, 63, and 64, while the other part serves the front burners 24, 65, 66, and 67. Each of the burners is served by its own branch duct and each branch duct is provided with an orifice so that it is possible to know exactly how much air goes to each burner. In the same way, the flow of fuel to the gun of each of the burners is measured separately. By arranging the total fuel in the right proportion to the total air and sub-dividing this fuel in proportion to the air going to the individual burners, it is possible to maintain an exact fuel-air ratio to each of the burners and a closely-controlled amount of excess air to each burners. The

signals from the venturi 41 pass to the summation device 44 through the conduits 42 and 43 and the output of the device in the conduit 134 is indicative of the total flow of air to the unit. This signal operates through the pneumatic actuator 135, the rheostat 136, and the servo valve 139 to adjust the actuator 141 which, in turn, sets the feed rate by means of the handle 142 of the valve 76. The total amount of fuel passing to the burners is in a correct desired proportion to the total amount of air passing to the burners at this point. The problem then becomes one of dividing the fuel to the various burners in such a manner that each burner will receive an amount of fuel which is in a pre-determined proportion to the amount of air already flowing to it. This individual control is necessary because of the difficulty of dividing air in exact proportions. No matter how well the duct is designed and how well the air control dampers operate, the air from one burner to another will vary by considerable amounts, particularly from one load to another. In such a situation, without the use of the present invention, if one attempts to reduce the amount of air in such a way as to have a low amount of excess air, the probability is very great that some of the burners will receive more of the excess air than one attempts to provide, while other burners will be provided with even less than the predetermined amount. The possibilities in such a situation are lack of ignition, explosions, instability, and other dangerous situations.

The fuel arriving through the main fuel pipe 75 and the valve 76 is adjusted to an amount exactly equal to the total fuel desired for all of the burners. The fuel is then divided into two parts by the damper 79, one part going into the branch pipe 77 and the other part into the branch pipe 78. The proportions that this is done are determined by the summation device 143 which receives signals of the air and fuel going to all of the back burners and signals of fuel and air going to all the front burners; it balances these signals and determines whether the proportion of fuel between the front and rear burners is correct; if it is not correct, it adjusts the division so that it is correct. In a similar manner, the total fuel going to the rear burners is divided by the damper 84 between the pipe 82 serving the burners 25 and 62 and the pipe 83 serving the burners 63 and 64. Of course, the fuel in the pipe 82 is divided by the damper 88 between the burners 25 and 62, while the fuel flowing in the pipe 83 is divided between the burners 63 and 64. The same sort of arrangement takes place in connection with the front burners; the total fuel passing through the branch pipe 78 to serve the front burners is divided into two parts by the damper 97. One part goes into the branch pipe 96 where it is divided by the damper 102 to serve the burners 24 and 65, while the other part passes through the branch pipe 95 and is divided by the damper 106 to serve the burners 66 and 67. It can be seen, then, that the fuel passing to each of the burners is accurately controlled by the dampers upstream from it. The fuel passing to the burner 25 passes through the orifice 109 and an indication of the amount of fuel passes through the conduits 111 and 112 where the difference operates to regulate the air pressure in the conduit 117 leaving the control 113. At the same time, the air passing to the burner 25 passes through the orifice 51 and an indication of that pressure drop and of the amount of air passing to the burner goes through the conduits 114 and 115 so that the difference between the two also operates to regulate the pressure in the conduit 117. Each of the controls 113, 118, 121, 123, 125, 127, 129, and 132 is connected to the main control 61 by a conduit, and each of the conduits contains an air pressure indicative of the air-fuel ratio at the individual burner. These pressures are added up in various ways in the main control 61; for instance, the signals from the rear burners 25, 62, 63, and 64 pass into the main control 61 through the conduits 124, 122, 119, and 117, respectively, and are presented to the summation device 143, while the signals from the

front wall burners 24, 65, 66, and 67 enter the main control through the conduits 126, 128, 131, 133, respectively and are also presented to the summation device 143. The signals from the front wall burners are presented to one side of the diaphragms in the summation device, while those from the front walls are presented to the other sides of these diaphragms. The net result is that the output signal from the device 143 (which appears in the conduit 144) is indicative of the difference between the fuel and air arriving at the rear wall burners and that arriving at the front wall burners. This difference is carried through the pneumatic actuator 144 and the rheostat 145 to control the valve 146 which operates the hydraulic actuator 81 and sets the dampers 79 to split the fuel between the front and the rear walls. Once the fuel has been divided into front wall fuel and rear wall fuel in this manner, it is sub-divided again between the groups of burners in the front and rear wall and then once more to the individual burners. In every case, this is done by using a summation device to which is presented the pneumatic air-fuel ratio signals from the individual burners. The result is an air-fuel ratio at each burner which is very closely controlled.

It is possible to adjust the excess air passing through the burners to a very low value, the fuel and air passing into the high temperature cell 23 and mixing thoroughly. The use of the close control on the air-fuel ratio, the use of the constant velocity burner, and the use of the high-temperature cell assure that ignition will take place so that the excess air can be reduced to a very low value without danger of the lack of ignition. Even if the air-fuel ratio at a particular burner is accidentally out of adjustment, this will be compensated for by the fact that the actual air velocity passing the fuel gun is at the optimum value and by the thorough mixing which the fuel-and-air mixture receives in the high-temperature cell. In addition, the high temperature in the cell promotes ignition and combustion of mixtures which would be less than ideal in conventional furnaces. In some instances, it may be desirable and necessary to introduce a portion of the air into the gas stream to complete combustion and this can be accomplished through the overfire air ports 52 and 53 controlled by dampers 53 and 56.

In the case of the burner 181 shown in FIG. 4, the air flowing to the individual burner is measured in the venturi 84 and measurements in spaced parts of the venturi are taken through the conduits 185 and 186, thus giving a measure of the amount of air entering the unit. The air is divided by the dampers 191 and 192 so that they flow to the upper and lower parts of the burner and pass over the upper vanes 193 and the lower vanes 194, respectively. In this way, it is possible to have a mixture with a low amount of air passing through the lower part of the burner and a mixture with a high amount of air passing through the upper part of the burner. Then additional overfire air can be added through the opening 197 by means of the damper 199 controlling the flow of air through the chute 198.

There is no question but that burning fuel with near theoretical air results in attractive benefits to a boiler operator but, at the same time, presents problems when previously-known equipment is used. This type of operation results in improved station heat rates from reduced stack losses. Furthermore, in burning oil with a minimum of excess air, apparently, fouling of heating surfaces is eliminated; also, formation of SO_3 is reduced and this almost completely stops condensation and corrosion in air heaters. The virtual absence of excess oxygen in the flue gas permits a lowering of the final flue gas temperatures below that which is presently common practice, and this is possible even with high sulphur fuels. Normal operation with near-theoretical combustion air requires the most careful control over the fuel-air ratio for each individual burner. Another factor has to do with the effect of minimum excess air on the chemistry of stack effluents. Some experimental work indicates that

overfire air is required for the greatest reduction of nitric oxide in the stack discharge. By using a row of air openings above the burner bank through which a controlled amount of tertiary air enters the furnace, the oxygen content of flue gas is increased, and this helps to lower the nitric oxide concentration in flue gas. By regulating the combustion air flow to the individual burner so that the upper half and the lower half of the air openings are separated by controllable dampers, it is possible to increase or decrease air flow through the top and bottom of the burners and direct air into the fuel in the most advantageous pattern. In burning fuel with a bare minimum of excess air it is, of course, important that the combustible portions of the fuel and the oxygen in the air find each other promptly; it is also important that none of the combustion air escape through the furnace without being available for combustion. It should be noted that with the present construction (using the type of furnace shown in FIG. 1) the front wall burners are arranged in a single horizontal row. This makes it possible to run a single conduit to each burner simply and inexpensively so that the air distribution, even before the individual controls for the burners are presented, is quite even. By using the controlled-velocity, directional-flame burner shown in the drawings, it is possible to maintain higher velocities through the burner at low load than with conventional burners, and this will permit the use of less excess air at lower loads than has previously been possible.

In conclusion, it is clear that, by being able to use a low excess air, that is to say, in the range from 0 to 5% excess air, it is possible to obtain a higher station efficiency, since excess air absorbs heat and carries it out of the boiler. There will be less formation of vanadium pentoxide so that the surfaces would be cleaner. There is less generation of SO_3 and, thus, less corrosion in the air heater. There would be less condensation at the cold end, so that there would also be less corrosion in the air heater. In addition, this type of operation permits the lowering of the final flue gas temperatures without any corrosive substances forming in the air heater even with high sulphur fuels. When used with overfire air there is a reduction in the formation of NO_2 and less smog. The present particular arrangement is particularly conducive to smooth operation with low excess air because of the provision of individual air ducts to the burners, this being possible because of the use of the single horizontal rows of burners and the high-temperature cell. The present furnace construction with the high-temperature cell is less critical of the exact maintenance of the theoretical air-fuel ratio because of the mixing and the high temperature in the lower cell promotes rapid ignition and complete combustion. It is also possible to control steam temperature by varying the amount of excess air from a zero amount to a practical maximum.

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

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

1. A steam generating unit, comprising
 - (a) a vertically-elongated combustion chamber,
 - (b) a plurality of burners located at the lower end of the chamber,
 - (c) means supplying fuel to each burner,
 - (d) means supplying air to each burner,
 - (e) means supplying first signals respectively indicative of the flow of fuel to each burner,
 - (f) means supplying second signals respectively indicative of the flow of air to each burner, and
 - (g) control means receiving all of the said first and

9

second signals, the control means correlating the signals to maintain the fuel-air ratio at each burner at a predetermined value.

2. A steam generating unit, comprising
 - (a) a vertically-elongated combustion chamber, 5
 - (b) a plurality of burners located at the lower end of the chamber,
 - (c) means supplying fuel to each burner,
 - (d) means supplying air to each burner,
 - (e) means supplying first signals respectively indicative 10 of the flow of fuel to each burner,
 - (f) means supplying second signals respectively indicative of the flow of air to each burner,
 - (g) means receiving the said first and second signals and supplying third signals respectively indicative 15 of the ratio of the first and second signals of each burner, and
 - (h) control means receiving all of said third signals, each associated with one of the burners, the control means correlating the third signals to maintain the 20 fuel-air ratio at each burner at a predetermined value.
3. A steam generating unit, comprising
 - (a) a vertically-elongated combustion chamber having 25 horizontal abutments adjacent the lower end defining a high-temperature cell,
 - (b) a plurality of burners located in horizontal rows on the abutments and directed into the high-temperature cell,
 - (c) means supplying fuel to each burner,
 - (d) means supplying air to each burner,

10

- (e) means supplying first signals respectively indicative of the flow of fuel to each burner,
- (f) means supplying second signals respectively indicative of the flow of air to each burner,
- (g) means receiving the said first and second signals and supplying third signals respectively indicative of the ratio of the first and second signals, and
- (h) control means receiving all of said third signals, each associated with one of the burners, the control means correlating the third signals to maintain the fuel-air ratio at each burner at a predetermined value at which value the excess of air is only slightly in excess of the theoretical amount required to burn the fuel.

4. A steam generating unit as recited in claim 3, wherein the excess of air to each burner is maintained below 5%.

5. A steam generating unit as recited in claim 3, wherein the total amount of air and fuel passing to the burners is adjusted in accordance with load.

References Cited by the Examiner

UNITED STATES PATENTS

1,620,240	3/1927	Smoot	-----	158—119
2,409,002	10/1946	Smith	-----	110—101
2,823,740	2/1958	Morck	-----	158—119
3,150,644	9/1964	Griffith.		

30 JAMES W. WESTHAVER, *Primary Examiner.*