PULVERIZED COAL BOILER

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The present invention provides a highly reliable pulverized coal boiler that ensures suppression of a rise in flame temperature caused during the combustion of an unburnt gas in a furnace when combustion air is supplied from after-air ports so as to reduce the concentration of thermal NOx generated during the combustion.

A pulverized coal boiler (100) according to the present invention comprising a furnace (1), burners (2) provided on the wall of the furnace for supplying pulverized coal to the inside of the furnace and burning the pulverized coal, and an after-air port (3 or 61) provided on the wall of the furnace at a position downstream of the burner for supplying combustion air to the inside of the furnace, the pulverized coal boiler further comprising: a spray nozzle (6) disposed near a jet port (3 or 60) of the after-air port for supplying water, steam, or two fluids including water and steam to the inside of the furnace; whereby the water, the steam, or the two fluids including water and steam are sprayed from the spray nozzle and are supplied to the inside of the furnace together with the combustion air supplied from the after-air port.
FIG. 1

BOILER LOAD SIGNAL (FROM CONTROL ROOM)
FIG. 7

FIG. 8

VIEWED ALONG LINE C-C
FIG. 12

NOx CONCENTRATION SIGNAL

CONTROL ROOM LOAD SIGNAL

BOILER LOAD SIGNAL (FROM CONTROL ROOM)
**FIG. 15**

CONTROLLER 50

BOILER LOAD SETTING UNIT 51

BOILER LOAD DETECTOR 56

NOx DETECTOR 55

SPRAY AMOUNT CALCULATOR 53

NOx CONCENTRATION SETTING UNIT 52

**FIG. 16**

(A) NOx CONCENTRATION OF EXHAUST GAS

(B) BOILER LOAD

SETTING

OPENING OF VALVE (%)
FIG. 17

NOx CONCENTRATION SIGNAL

CONTROL SIGNAL

BOILER LOAD SIGNAL (FROM CONTROL ROOM)
PULVERIZED COAL BOILER

TECHNICAL FIELD

[0001] The present invention relates to a pulverized coal boiler that uses pulverized coal as a fuel, more particularly to a pulverized coal boiler that suppresses the generation of thermal nitrogen oxides.

BACKGROUND ART

[0002] Pulverized coal boilers use the two-stage combustion method because the concentrations of NOx generated during the combustion of pulverized coal used as a fuel need to be reduced.

[0003] The two-stage combustion method is applied to pulverized coal boilers in which pulverized coal burners are provided in the furnace of the pulverized coal boiler and after-air ports are also provided downstream of the burners, as disclosed in Japanese Patent Laid-open No. Hei 6(1994)-201105; pulverized coal used as a fuel and combustion air is supplied from the burners, and combustion air is supplied from the after-air ports.

[0004] Specifically, for the combustion in the burner section, combustion air is supplied from the burners by an amount by which the theoretical stoichiometric ratio necessary for complete combustion of the pulverized coal used as a fuel is not exceeded, the combustion air being supplied together with the pulverized coal as a fuel gas; the pulverized coal included in the fuel gas is burnt in a state in which air is insufficient in the furnace so that a reducing atmosphere is created, and NOx generated during the combustion is reduced to nitrogen to suppress the generation of NOx.

[0005] In the reducing atmosphere, unburnt pulverized coal is left in the fuel gas supplied from the burners into the furnace due to the oxygen insufficiency, generating CO (carbon monoxide). To completely burn the unburnt pulverized coal and CO generated in the reducing atmosphere, combustion air is supplied from the after-air ports located downstream of the burners to the furnace by an amount a little more than the amount of air equivalent to an insufficiency relative to the theoretical stoichiometric ratio, so that the unburnt pulverized coal and CO are burnt to reduce the generation of NOx and CO.

[0006] The combustion gas resulting from the combustion of the pulverized coal included in the fuel is directed down in the furnace so that the combustion gas exchanges heat with a heat exchanger (not shown) installed in the furnace to extract heat from the combustion gas; the combustion gas is then cooled and expelled from the furnace to the outside of the pulverized coal boiler as an exhaust gas.

[0007] NOx gases generated in boilers are broadly classified into fuel NOx and thermal NOx. Fuel NOx is generated when nitrogen compounds included in coal used as a fuel are oxidized. This type of fuel NOx is substantially reduced by improved technologies applied to combustion in burners. Thermal NOx is generated when nitrogen included in the air is oxidized at high temperature.

[0008] As fuel NOx has been reduced, the amount of thermal NOx generated can be no longer neglected in recent years. To further reduce NOx, thermal NOx must be reduced. [0009] Japanese Patent Laid-open No. 2003-322310 discloses a technology for reducing thermal NOx, in which retractable and insertable spray nozzles, each of which has a driving unit, are inserted from the wall of the furnace at the central part of the furnace, at which combustion temperature is high and a high thermal load is applied, the center part being located above the topmost burner and below a secondary super heater; water or steam is sprayed from the spray nozzles toward the central part of the furnace to lower the flame temperature of the combustion gas.


DISCLOSURE OF THE INVENTION

Problems to be Solved by the Invention

[0012] In the technology disclosed in Japanese Patent Laid-open No. 2003-322310, however, water or steam is sprayed from the retractable and insertable spray nozzles provided on the wall of the furnace toward the central part of the furnace, at which the combustion temperature is high and the thermal load is high, to lower the flame temperature, as described above. In a method in which spray nozzles with a structure of this type are provided on the wall of the furnace, however, the area at high temperature where thermal NOx is generated is variable due to the load condition of the boiler, so it is difficult to lower the flame temperature by reliably spraying water or steam at the area where the flame temperature is high unless many spray nozzles are provided on the furnace wall. Accordingly, it is difficult to sufficiently lower thermal NOx.

[0013] Since it is also necessary to have the spray nozzle include the driving unit for retracting and inserting the spray nozzle through which water or steam is supplied, the structure of the spray nozzle becomes complex, increasing costs for the maintenance and other services for the unit. It is also conceivable in terms of reliability that if the spray nozzle is kept inserted into the inside of the furnace for a long period of time, the spray nozzle may not withstand prolonged use due to ash adhesion to the spray nozzle and structural member deformation caused by a contact with the combustion gas at high temperature.

[0014] An object of the present invention is to provide a highly reliable pulverized coal boiler that ensures suppression of a rise in flame temperature caused during the combustion of an unburnt gas in a furnace when combustion air is supplied from after-air ports so as to reduce the concentration of thermal NOx generated during the combustion.

Means for Solving the Problems

[0015] A pulverized coal boiler according to the present invention comprising a furnace, a burner provided on the wall of the furnace for supplying pulverized coal to the inside of the furnace and burning the pulverized coal, and an after-air port provided on the wall of the furnace at a position downstream of the burner for supplying combustion air to the inside of the furnace, the pulverized coal boiler further comprising: a spray nozzle disposed near a jet port of the after-air port for supplying water, steam, or two fluids including water and steam to the inside of the furnace; whereby the water, the steam, or the two fluids including water and steam sprayed from the spray nozzle are supplied to the inside of the furnace together with the combustion air supplied from the after-air port.

[0016] A pulverized coal boiler according to the present invention comprising a furnace, a burner provided on a wall of the furnace for supplying pulverized coal to the inside of the
furnace and burning the pulverized coal, and an after-air port provided on the wall of the furnace at a position downstream of the burner for supplying combustion air to the inside of the furnace, wherein a plurality of after-air ports are disposed in the furnace in a combustion gas flow direction; and at least one of the plurality of after-air ports disposed upstream in the combustion gas flow direction in the furnace supplies combustion air less than that of combustion air supplied from the after-air ports disposed downstream in the combustion gas flow direction.

In the pulverized coal boiler according to the present invention, wherein at least one of the plurality of after-air ports disposed upstream in the combustion gas flow direction in the furnace supplies combustion air less than that of combustion air supplied from the after-air ports disposed downstream in the combustion gas flow direction.

In the pulverized coal boiler according to the present invention, wherein each of the after-air ports for supplying the water, the steam, or the two fluids including water and steam is provided with a straight flow path for jetting the combustion air as a straight flow, and a swirl flow path formed around an outer circumference of the straight flow path for jetting the combustion air as a swirl flow, internally; and the water, the steam, or the two fluids including water and steam are jetted from the swirl flow path.

A pulverized coal boiler according to the present invention comprising a furnace, burners provided on a wall of the furnace for supplying pulverized coal to the inside of the furnace and burning the pulverized coal, an after-air port provided on the wall of the furnace at a position downstream of the burner for supplying combustion air to the inside of the furnace, a wind box having the after-air port, and a duct pipe for externally supplying the combustion air to the wind box, the pulverized coal boiler further comprising:

- a spray nozzle disposed in the wind box or in the duct pipe for supplying water, steam, or the two fluids including water and steam; whereby the water, the steam, or the two fluids including water and steam sprayed from the spray nozzle into the inside of the wind box or the duct pipe are supplied to the inside of the furnace together with the combustion air supplied from a jet port of the after-air port.

Effects of the Invention

The present invention can achieve a highly reliable pulverized coal boiler that ensures suppression of a rise in flame temperature caused during the combustion of an unburnt gas in a furnace when combustion air is supplied from after-air ports so as to reduce the concentration of thermal NOx generated during the combustion.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram indicating the structure of a pulverized coal boiler in an embodiment of the present invention.

FIG. 2 is a cross sectional view showing the structure of an after-air port having a spray nozzle, the after-air port being applied to the pulverized coal boiler in the embodiment shown in FIG. 1.

FIG. 3 shows the cross section of the after-air port having a spray nozzle, as viewed along line A-A in FIG. 2.

FIG. 4 shows an exemplary spray pattern of the spray nozzle disposed in the after-air port shown in FIG. 2.

FIG. 5 is a cross sectional view showing the structure of another after-air port having spray nozzles, the after-air port being applied to the pulverized coal boiler in the embodiment shown in FIG. 1.

FIG. 6 shows the cross section of the after-air port having spray nozzles, as viewed along line B-B in FIG. 5.

FIG. 7 is also a cross sectional view showing the structure of other after-air port having spray nozzles, the after-air port being applied to the pulverized coal boiler in the embodiment shown in FIG. 1.

FIG. 8 shows the cross section of the after-air port having spray nozzles, as viewed along line C-C in FIG. 7.

FIG. 9 is also a cross sectional view showing the structure of other after-air port having spray nozzles, the after-air port being applied to the pulverized coal boiler in the embodiment shown in FIG. 1.

FIG. 10 is also a cross sectional view showing the structure of other after-air port having spray nozzles, the after-air port being applied to the pulverized coal boiler in the embodiment shown in FIG. 1.

FIG. 11 is a schematic diagram indicating the structure of a pulverized coal boiler in another embodiment of the present invention.

FIG. 12 is also a schematic diagram indicating the structure of a pulverized coal boiler in another embodiment of the present invention.

FIG. 13 is a cross sectional view of a wind box, which has spray nozzles, applied to the pulverized coal boiler in another embodiment shown in FIG. 12.

FIG. 14 is the cross section of the wind box having spray nozzles, as viewed along line D-D in FIG. 13.

FIG. 15 is a block diagram showing the structure of a controller disposed in the pulverized coal boiler in the embodiment shown in FIG. 1 of the present invention to control the amount of cooling fluid sprayed.

FIGS. 16A and 16B are graphs indicating characteristics for controlling a valve that adjusts the flow rate of the cooling fluid in the controller shown in FIG. 15. FIG. 16A shows a relation ship between the NOx concentration of an exhaust gas and the opening of the valve. FIG. 16B shows a relationship between a boiler load and the opening of the valve.

FIG. 17 is a schematic diagram indicating the structure of a pulverized coal boiler in another embodiment of the present invention.

FIG. 18 is also a schematic diagram indicating the structure of a pulverized coal boiler in another embodiment of the present invention.

LEGENDS

concentration setting unit, 53: Spray amount calculator, 55: NOx detector, 60: Sub after-air port, 61: main after-air port, 100: Pulverized coal boiler.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

[0042] Next, a pulverized coal boiler in an embodiment of the present invention will be described with reference to the drawings.

**First Embodiment**

[0043] FIG. 1 is a schematic diagram indicating the structure of a pulverized coal boiler, in a first embodiment of the present invention, that burns pulverized coal used as a fuel. The pulverized coal boiler 100 comprises, on the wall of a furnace 1, burners 2, and after-air ports 3, each of which has a spray nozzle 6 for spraying water, to supply combustion air.

[0044] In the pulverized coal boiler 100 in the embodiment in FIG. 1, the spray nozzle 6, which is a single-fluid nozzle, is disposed on the after-air port 3.

[0045] The pulverized coal boiler 100 in FIG. 1 has a furnace 1, on the wall of which a plurality of burners 2 are disposed; a fuel gas, in which pulverized coal used as a fuel and combustion air are mixed, is supplied from the plurality of burners 2.

[0046] The burners 2 supply the combustion air by an amount by which the theoretical stoichiometric ratio necessary for complete combustion of the pulverized coal used as a fuel is not exceeded, the combustion air being supplied together with the pulverized coal as a fuel gas to the inside of the furnace 1. The fuel gas is burnt in a state in which there is an insufficient amount of air in the furnace so that a reducing atmosphere is created, and NOx generated during the combustion is reduced to nitrogen to suppress the generation of NOx.

[0047] A plurality of after-air ports 3 are provided at positions downstream of the burners 2 on the wall of the furnace 1.

[0048] Part of the fuel gas supplied from the burners 2 to the inside of the furnace 1 is left as an unburnt gas 10a, which has not been burnt due to the insufficient oxygen in the reducing atmosphere. To completely burn the unburnt gas 10a and CO generated in the reducing atmosphere, combustion air is supplied from the after-air ports 3 to the inside of the furnace 1 by an amount little more than the amount of air equivalent to an insufficiency relative to the theoretical stoichiometric ratio, so that the pulverized coal included in the unburnt gas 10a and CO are burnt to reduce the generation of NOx and CO.

[0049] Coal used as a fuel in the pulverized coal boiler 100 is crushed into powder by a plurality of mills 7, resulting in pulverized coal. The pulverized coal is then supplied through pipes 7b to the burners 2, and further supplied from the burners 2 to the inside of the furnace 1 together with combustion air supplied by a blower 12 through a duct pipe 14, as a fuel gas, and the fuel gas is burnt therein.

[0050] The combustion air for burning the unburnt gas 10a, which is part of the fuel gas supplied from the burners 2 to the inside of the furnace 1 and left unburnt, is externally supplied by the blower 12 to a heat exchanger 13, where a heat exchange occurs between the combustion air and hot exhaust gas 11 extracted from the furnace 1, heating the combustion air to about 500°C. The heated combustion air is then supplied to the after-air ports 3 through the duct pipe 14.

[0051] Part of the hot air resulting from the heat exchange is adjusted for the amount to be apportioned by dampers 8 disposed at intermediate points on the duct pipe 14. The apportioned air is supplied to each wind box 4, which is provided on the wall of the furnace 1 and internally includes burners 2, and further supplied from the wind box 4 to the inside of the furnace 1 as outer circumferential air of the burners 2.

[0052] Another part of the hot air is also adjusted for the amount to be apportioned by dampers 9. The apportioned air is supplied to a wind box 5, which is provided on the wall of the furnace 1 and internally includes the after-air port 3, and further supplied from the wind box 5 through the after-air port 3 to the inside of the furnace 1 as the combustion air, as described above.

[0053] A combustion gas 10 resulting from the combustion of the pulverized coal included in the furnace 1 flows in the furnace 1 toward the downstream side and is exhausted through a pipe 14b to the outside of the furnace 1, as an exhaust gas 11. Since the heat exchanger 13 is disposed in the pipe 14b, a heat exchange occurs in the heat exchanger 13 between the exhaust gas 11 and the combustion air. Denitrification and desulfurization (not shown) are then performed for the combustion air, after which the exhaust gas 11 is released from a chimney 15 with which the pipe 14b connects.

[0054] The spray nozzle 6 is disposed in the after-air port 3 provided on the wall of the furnace 1. Water 18, which is a cooling fluid for suppressing the generation of thermal NOx during the combustion of the combustion gas, is supplied from a pump 16 through a pipe 42 to the spray nozzle 6.

[0055] The flow rate of the water 18 (cooling fluid) to be sprayed from the spray nozzle 6 toward the inside of the furnace 1 is adjusted based on the NOx concentration of the exhaust gas 11, the NOx concentration being detected by a NOx detector 55 provided in the pipe 14b through which the exhaust gas 11 from the furnace 1 is exhausted to the outside.

[0056] Specifically, a NOx concentration signal about the exhaust gas 11 detected by the NOx detector 55 is input to a controller 50. The controller 50 then compares the NOx concentration with a desired NOx setting, calculates a flow rate command signal about the cooling fluid to be sprayed from the spray nozzles 6 toward the inside of the furnace 1 so that the NOx concentration of the exhaust gas 11 is maintained at the desired setting, and outputs the command signal to a valve 17 used for flow rate adjustment, which is provided in a pipe 42, through which the water 18 (cooling fluid) is supplied to the spray nozzles 6.

[0057] If the NOx detector 55 detects, from the exhaust gas 11, a higher NOx value than the desired setting, the opening of the valve 17 is adjusted in response to the flow rate command signal calculated by the controller 50 to raise the flow rate of the water 18 (cooling fluid) to be supplied from the spray nozzles 6, so that a rise in the flame temperature is suppressed and NOx is reduced.

[0058] If the NOx detector 55 detects, from the exhaust gas 11, a lower NOx value than the desired setting, the opening of the valve 17 is adjusted in response to the flow rate command signal calculated by the controller 50 to lower the flow rate of the water 18 (cooling fluid) or the supply of the water 18 is stopped, so that an appropriate amount of water is sprayed from the spray nozzle 6 and an efficient operation is performed.
In addition to responding to the NOx concentration of the exhaust gas 11, the flow rate of the water 18 (cooling fluid) to be sprayed from the spray nozzles 6 toward the inside of the furnace 1 may be controlled based on the load of the pulverized coal boiler 100.

In this case, the load of the pulverized coal boiler 100 is structured so that the flow rate of the water 18 (cooling fluid) to be sprayed from the spray nozzles 6 toward the inside of the furnace 1 is adjusted based on a boiler load signal commanded from a control room.

Specifically, the boiler load signal commanded from the control room is entered to the controller 50, and then the controller 50 calculates a flow rate command signal about the cooling fluid to be sprayed from the spray nozzles 6 toward the inside of the furnace 1. The command signal is output from the controller 50 to the valve 17, used for flow rate adjustment, which is disposed on the pipe 42 for supplying the cooling fluid to the spray nozzles 6 so that the flow rate of the cooling fluid is adjusted.

The flow rate of the water 18 (cooling fluid) to be sprayed from the spray nozzles 6 is adjusted so that if the load of the pulverized coal boiler 100 is low, the opening of the valve 17 is adjusted to lower the flow rate of the water 18, or if the load is high, the opening is adjusted to raise the flow rate of the water 18. Then, it becomes possible to spray an appropriate amount of cooling fluid and perform an efficient operation.

The structure of the controller 50, which calculates the flow rate command signal about the cooling fluid to be sprayed from the spray nozzles 6 and outputs a command signal about a valve opening to the valve 17 to control the flow rate of the cooling fluid, will be described below. FIG. 15 is a block diagram showing the structure of the controller 50. As shown in the drawing, the controller 50 includes a spray amount calculator 53 to which the boiler load signal and the NOx detection value of the exhaust gas 11, which is detected by the NOx detector 55, are input.

The controller 50 also includes a boiler load setting unit 51 for setting an operation load for the boiler and a NOx concentration setting unit 52 for setting a NOx concentration.

The spray amount calculator 53 in the controller 50 compares the boiler load signal with the load setting (threshold) in the boiler load setting unit 51. If the detected value exceeds the setting, the spray amount calculator 53 calculates the flow rate of the water 18 (cooling fluid) that corresponds to the difference between the setting and detected value, and outputs an opening of the valve 17, which corresponds to the calculated spray amount, to the valve 17 as a command signal so that the flow rate of the water 18 to be sprayed from the spray nozzles 6 toward the inside of the furnace 1 is adjusted.

Similarly, the spray amount calculator 53 in the controller 50 compares the NOx detection signal, detected by the NOx detector 55, about the exhaust gas 11 with a NOx setting (threshold) in the NOx concentration setting unit 52. If the detected value exceeds the setting, the spray amount calculator 53 calculates the flow rate of the water 18 (cooling fluid) that corresponds to the difference between the setting and detected value, and outputs an opening of the valve 17, which corresponds to the calculated spray amount, to the valve 17 as a command signal so that the flow rate of the water 18 to be sprayed from the spray nozzles 6 toward the inside of the furnace 1 is adjusted.

The opening of the valve 17 operated by the controller 50 to adjust the flow rate of the water 18 to be sprayed will be described below. FIGS. 16A and 16B are graphs indicating characteristics for controlling the valve that adjusts the flow rate of the cooling fluid. In FIG. 16A, the vertical axis indicates the detected NOx concentration of the exhaust gas 11, and the horizontal axis indicates the opening of the valve 17, while the dashed line indicates a setting and the solid line indicates opening characteristics of the valve 17 with respect to the detected NOx concentration.

In FIG. 16B, the vertical axis indicates the boiler load and the horizontal axis indicates the opening of the valve 17, while the dashed line indicates a setting and the solid line indicates the opening characteristics of the valve 17 with respect to the boiler load.

As seen from the characteristic chart in FIG. 16A, if the value of the detected NOx concentration of the exhaust gas 11 is lowered to or below the setting (an NOx emission standard, for example) as a result of control by the controller 50, the opening of the valve 17 is set to 0 (closed) to stop the water from being sprayed from the spray nozzles 6. If the value of the detected NOx concentration exceeds the setting, the valve 17 is opened based on the opening of the valve 17, which corresponds to a calculated spray amount based on a difference from the setting, so that the spray of the water from the spray nozzles 6 is controlled. Although, in the drawing, there is a proportional relationship between the NOx concentration and the opening of the valve 17, this is not a limitation.

Similarly, as seen from the characteristic chart in FIG. 16B, when the boiler load is lowered due to control by the controller 50, the opening of the valve 17 is set to 0 (closed) to stop the water from being sprayed from the spray nozzles 6 because the amount of NOx emissions is originally small. As the boiler load is increased and brought close to a rated load, the amount of NOx emissions also increases. Accordingly, as the boiler load increases, the water spray from the spray nozzles 6 is controlled by opening the valve 17 based on the opening of the valve 17, which corresponds to a calculated spray amount based on a difference from the setting. Although, in the drawing, there is a proportional relationship between the NOx concentration and the opening of the valve 17, this is not a limitation.

Even when the boiler load is high, if the NOx concentration of the exhaust gas is lower than or equal to the setting (emission standard) shown in FIG. 16A, there is no need to reduce the NOx concentration to a lower value than necessary by further spraying water from the spray nozzles 6.

Accordingly, when the boiler load is raised (near the rating) due to control by the controller 50 and the NOx concentration of the exhaust gas is high, if water is sprayed from the spray nozzles 6, the boiler can be operated in an efficient manner.

Next, the after-air port 3 used in the pulverized coal boiler in this embodiment of the present invention will be described in detail.

FIG. 2 is an enlarged view showing part of the structure of the after-air port 3, which has a spray nozzle, the after-air port 3 being used in the pulverized coal boiler, shown in FIG. 1, in this embodiment of the present invention. In FIG. 2, the after-air port 3 in this embodiment is provided on the wind box 5 at one end; at the other end, the after-air port 3 has a straight flow path 30, which is cylindrical and communicates with an opening 3a of the after-air port 3, which is formed in the wall of the furnace 1.

The after-air port 3 also has a swirl flow path 31, which has a truncated cone shape, on the outer circumference
of the straight flow path 30; an end of the swirl flow path 31 is connected to the wall of the furnace 1, forming an external edge of the opening 3a of the after-air port 3.

[0076] A straight flow 35, which is part of the combustion air, is led from a hole formed in the barrel of the straight flow path 30 to the inside of the straight flow path 30, and supplied from an opening at the end of the straight flow path 30 to the inside of the furnace 1.

[0077] A swirl flow 36, which is also part of the combustion air, is adjusted for its swirl intensity by means of a register 32 provided in the swirl flow path 31, which has a truncated cone shape and is formed around the outer circumference of the straight flow path 30, and supplied from the opening at the end of the swirl flow path 31 to the inside of the furnace 1.

[0078] A movable damper 33 is provided outside the hole formed in the barrel of the straight flow path 30, and another movable damper 34 is also provided upstream of the swirl flow path 31. The apportionment of the flow rate of the combustion air flowing down in the straight flow path 30 is adjusted by operating the damper 33. Similarly, the apportionment of the flow rate of the combustion air flowing down in the swirl flow path 31 is adjusted by operating the damper 34.

[0079] The spray nozzle 6 is disposed in the jet port at the end of the cylindrical straight flow path 30 formed in the after-air port 3. The spray nozzle 6 is placed along the center of the axis of the straight flow path 30 so that the end of the spray nozzle 6 is positioned near the opening 3a of the after-air port 3. The water 18 (cooling fluid) is sprayed from the end of the spray nozzle 6 toward the inside of the furnace 1 to suppress NOx generation.

[0080] When the water 18 (cooling fluid) is sprayed from the spray nozzle 6 toward the inside of the furnace 1, the effect of suppressing NOx generation is obtained as described below.

[0081] A jet flow 40 of combustion air is formed in the inside of the furnace 1, the inside communicating with the opening 3a of the after-air port 3; the jet flow 40 spreads from the opening 3a toward the center of the furnace 1, as shown in FIG. 2, by the combustion air supplied from the straight flow path 30 and swirl flow path 31 formed in the after-air port 3.

[0082] When the jet flow 40 of combustion air is supplied from the straight flow path 30 and swirl flow path 31 through the opening 3a of the after-air port 3 to the inside of the furnace 1, the jet flow 40 is mixed with the unburnt gas 10a, including unburnt pulverized coal, which flows down from the burners 2 to the after-air port 3 on the downstream side in the inside of the furnace 1, together with the combustion gas 10, forming a mixed area 41 along the outer edge of the jet flow 40 of combustion air.

[0083] In the mixed area 41, the unburnt gas 10a is burnt as a result of mixing the combustion air supplied as the jet flow 40 and the unburnt gas 10a; when the temperature of a generated flame rises, thermal NOx is generated.

[0084] The amount of thermal NOx generated is unequivocally determined by the flame temperature. When the flame temperature reaches about 1700K, the generation of thermal NOx starts. The amount of thermal NOx generated is approximately proportional to the square of the flame temperature rise; the higher the temperature is, the more the amount of generation increases significantly.

[0085] Accordingly, in this embodiment, the water 18 (a cooling fluid), which has been led through the pipe 42 from the spray nozzle 6 disposed near the opening 3a of the after-air port 3, is sprayed in a spray range 18a that overlaps the mixed area 41. The latent heat and sensible heat of the water 18 sprayed in the spray range 18a overlapping the mixed area 41 deprive the heat of the flame resulting from the combustion of the unburnt gas 10a in the mixed area 41, suppressing the flame temperature from rising. The generation of thermal NOx can then be reduced in the mixed area 41 in which thermal NOx is most easily generated.

[0086] According to this embodiment, the water 18 can be sprayed with precision in the spray area 18a overlapping the mixed area 41 from the spray nozzle 6, so it is possible to suppress the flame temperature of the unburnt gas 10a burnt in the mixed area 41 to about 1600K or below, preferably about 1600K to about 1400K. The concentration of NOx generated in the boiler can thereby be reduced by about 10% to 30%.

[0087] Since the spray nozzle 6 in this embodiment is disposed near the opening 3a of the after-air port 3, it becomes possible to prevent ash from adhering to the spray nozzle and the structural members from being deformed due to contact with the combustion gas at high temperature and thereby obtain a highly reliable spray nozzle that can withstand prolonged use.

[0088] The water 18 (cooling fluid) is sprayed in the spray area 18a from the spray nozzle 6 toward the mixed area 41 formed in the furnace 1, as described above. To have the water 18 sprayed in the spray area 18a overlapping the mixed area 41, where the water 18 is mixed with the unburnt gas 10a, according to the spread and shape of the jet flow 40 of combustion air supplied from the after-air port 3, the spray nozzle 6 may be structured so that it can be turned and moved fore and aft in the axial direction.

[0089] FIG. 3 shows the opening 3a of the after-air port 3 having the spray nozzle 6, as viewed along line A-A in FIG. 2. In FIG. 3, the water 18 (cooling fluid) is sprayed so that it spreads concentrically from the spray nozzle 6, as one form of the spray range 18a overlapping the mixed area 41, where the jet flow 40 of combustion air supplied from the opening 3a of the after-air port 3 shown in FIG. 2 is mixed with the unburnt gas 10a.

[0090] Even if, as another form of the spray range 18a, as shown in FIG. 4, a spray pattern different from in FIG. 3 is used by changing the shape of the end of the spray nozzle 6 so that the water 18 is sprayed in a cone-like shape, the same effect is obtained because the moisture of the water 18 (cooling fluid) is supplied to the spray range 18a overlapping the mixed area 41, where the jet flow 40 of combustion air and the unburnt gas 10a are mixed, which is the area where NOx is generated.

[0091] The above embodiment in the present invention can achieve a highly reliable pulverized coal boiler that ensures suppression of a flame temperature rise that is caused during the combustion of an unburnt gas in a furnace when combustion air is supplied from after-air ports, so as to reduce the concentration of thermal NOx generated during the combustion.

**Second Embodiment**

[0092] Next, FIGS. 5 and 6 show part of the structure of an after-air port in another embodiment that is used in the pulverized coal boiler shown in FIG. 1, which embodies the present invention.

[0093] FIG. 5 shows the structure of the after-air port, having spray nozzles, in the other embodiment. FIG. 6 shows a
section as viewed along line B-B in FIG. 5. A pulverized coal boiler in which the after-air port 3 in this embodiment is used has the same structure as the pulverized coal boiler 100 in the embodiment shown in FIG. 1, so the explanation of the pulverized coal boiler including the after-air port 3 in this embodiment will be omitted.

[0094] The basic structure of the after-air port 3 in this embodiment shown in FIGS. 5 and 6 is the same as the basic structure of the after-air port 3 in the embodiment shown in FIGS. 2 to 4, so the explanation of the same basic structure will be omitted and only different parts will be described.

[0095] In the after-air port 3 in this embodiment shown in FIGS. 5 and 6, in which spray nozzles used in the pulverized coal boiler are included, a plurality of spray nozzles 6 are provided in the opening in the swirl flow path 31, which is formed around the outer circumference of the straight flow path 30. The end of each spray nozzle 6 for spraying water (cooling fluid) is positioned near the opening 3a of the after-air port 3, as in the structure of the after-air port 3 shown in the embodiment shown in FIG. 2.

[0096] In the after-air port 3 in this embodiment as well, the water 18 (cooling fluid) can be precisely sprayed from the spray nozzles 6 in the spray range 18a overlapping the mixed area 41, where the jet flow 40 of combustion air and the unburnt gas 10a are mixed, the jet flow 40 being jetted from the after-air port 3 to the inside of the furnace 1, the inside communicating with the opening 3a of the after-air port 3.

[0097] Accordingly, in this embodiment, the latent heat and sensible heat of the sprayed water 18 deprive the heat of the flame resulting from the combustion of the unburnt gas 10a in the mixed area 41, so it is possible to suppress the flame temperature to about 1600K or below, preferably about 1600K to about 1400K. The concentration of NOx generated in the boiler can thereby be reduced by about 10% to 30%.

[0098] Since the spray nozzles 6 in this embodiment are also disposed near the opening 3a of the after-air port 3, it becomes possible to prevent ash from adhering to the spray nozzles and the structural members from being deformed due to contact with the combustion gas at high temperature and thereby obtain a highly reliable spray nozzle that can withstand prolonged use. Furthermore, since a plurality of spray nozzles are provided, even if some of the plurality of spray nozzles are clogged, a necessary amount of cooling fluid can still be sprayed by the remaining spray nozzles, so it becomes possible to obtain highly reliable spray nozzles that can withstand prolonged use.

Third Embodiment

[0099] Next, FIGS. 7 and 8 show part of the structure of an after-air port in another embodiment that is used in the pulverized coal boiler shown in FIG. 1, which embodies the present invention.

[0100] FIG. 7 shows the structure of the after-air port, having spray nozzles, in the other embodiment. FIG. 8 shows a section as viewed along line C-C in FIG. 7. A pulverized coal boiler in which the after-air port 3 in this embodiment is used has the same structure as the pulverized coal boiler 100 in the embodiment shown in FIG. 1, so the explanation of the pulverized coal boiler including the after-air port 3 in this embodiment will be omitted.

[0101] The basic structure of the after-air port 3 in this embodiment shown in FIGS. 7 and 8 is the same as the basic structure of the after-air port 3 in the embodiment shown in FIGS. 2 to 4, so the explanation of the same basic structure will be omitted and only different parts will be described.

[0102] In the after-air port 3 in this embodiment shown in FIGS. 7 and 8, in which spray nozzles used in the pulverized coal boiler are included, a plurality of spray nozzles 6 for spraying water (cooling fluid) are provided in the opening inside the straight flow path 30 and the opening in the swirl flow path 31, which is formed around the outer circumference of the straight flow path 30. The end of each spray nozzle 6 is positioned near the opening 3a of the after-air port 3, as in the structure of the after-air port 3 shown in the embodiment shown in FIG. 2.

[0103] In the after-air port 3 in this embodiment as well, the water 18 (cooling fluid) can be precisely and evenly sprayed from the plurality of spray nozzles 6 in the spray range 18a overlapping the mixed area 41, where the jet flow 40 of combustion air and the unburnt gas 10a are mixed, the jet flow 40 being jetted from the after-air port 3 to the inside of the furnace 1, the inside communicating with the opening 3a of the after-air port 3.

[0104] Accordingly, in this embodiment, the latent heat and sensible heat of the sprayed water 18 deprive the heat of the flame resulting from the combustion of the unburnt gas 10a in the mixed area 41, so it is possible to precisely suppress the flame temperature to about 1600K or below, preferably about 1600K to about 1400K. The concentration of NOx generated in the boiler can thereby be reduced by about 10% to 30%.

[0105] Since the spray nozzles 6 in this embodiment are also disposed near the opening 3a of the after-air port 3, it becomes possible to prevent ash from adhering to the spray nozzles and the structural members from being deformed due to contact with the combustion gas at high temperature. Furthermore, since a plurality of spray nozzles are provided, even if some of the plurality of spray nozzles are clogged, a necessary amount of cooling fluid can still be sprayed by the remaining spray nozzles, so it becomes possible to obtain highly reliable spray nozzles that can withstand prolonged use.

Fourth Embodiment

[0106] Next, FIGS. 9 and 10 show part of the structures of after-air ports in other embodiments that are used in the pulverized coal boiler shown in FIG. 1, which embodies the present invention.

[0107] FIGS. 9 and 10 show the structures of the after-air ports, having spray nozzles, in the other embodiment. Pulverized coal boilers in which the after-air ports 3 in this embodiment are used have the same structure as the pulverized coal boiler 100 in the embodiment shown in FIG. 1, so the explanation of the pulverized coal boilers including the after-air ports 3 in this embodiment will be omitted.

[0108] The basic structure of the after-air ports 3 in this embodiment shown in FIGS. 9 and 10 are the same as the basic structure of the after-air ports 3 in the embodiments shown in FIGS. 5 and 7, so the explanation of the same basic structure will be omitted and only different parts will be described.

[0109] In FIGS. 9 and 10, each spray nozzle 6, included in the after-air port 3 in each embodiment, from which the water 18 (cooling fluid) is sprayed, is disposed so that the end of the spray nozzle 6 is positioned near the wall of the wind box 5 rather than the opening 3a of the after-air port 3 to leave a distance from the furnace 1; the end of the spray nozzle 6 is
located, in the after-air port 3, at an upstream position of the jet flow 40 of combustion air, relative to the opening 3a of the after-air port 3.

[0110] According to this embodiment, the water 18 (cooling fluid) is sprayed from each spray nozzle 6 at an upstream position of the jet flow 40 of combustion air supplied from the opening 3a of the after-air port 3 into the inside of the furnace 1, and vaporized so that moisture is further evenly mixed with the jet flow 40 of combustion air supplied from the after-air port 3, adding the moisture to the jet flow 40 itself of the combustion air supplied from the after-air port 3. Accordingly, the moisture can be more precisely supplied to the spray range 18a overlapping the mixed area 41, where the jet flow 40 and the unburnt gas 10a are mixed, and thereby a rise in flame temperature can be more surely suppressed.

[0111] Although the spray nozzles 6 disposed in the after-air ports 3 in this embodiment have been indicated as one-fluid spray nozzles that spray the water 18 as the cooling fluid, the embodiment can also be applied to a two-fluid spray nozzle that sprays a cooling liquid including water 18 and steam 20.

[0112] Although not described, control of the cooling fluid by the spray nozzles 6 in the after-air ports 3 in this embodiment, shown in FIGS. 9 and 10, can be carried out by having the controller 50 adjust the flow rate of the cooling fluid as in the embodiments described above.

[0113] The above embodiments in the present invention can also achieve a highly reliable pulverized coal boiler that ensures suppression of a flame temperature rise that is caused during the combustion of an unburnt gas in a furnace when combustion air is supplied from after-air ports so as to reduce the concentration of thermal NOx generated during the combustion.

Fifth Embodiment

[0114] Next, a pulverized coal boiler in another embodiment of the present invention will be described with reference to the drawings.

[0115] FIG. 11 is a schematic diagram indicating the structure of a pulverized coal boiler 100 in another embodiment of the present invention. The pulverized coal boiler 100 comprises, on the wall 21 of the furnace 1, burners 2 for burning pulverized coal used as a fuel and after-air parts 3, each of which has a spray nozzle 6 for spraying both water and steam.

[0116] The basic structure of the pulverized coal boiler in this embodiment is the same as the basic structure of the pulverized coal boiler 100 in the embodiment shown in FIG. 1, so the explanation of the same basic structure will be omitted and only different parts will be described.

[0117] In the pulverized coal boiler 100 in this embodiment shown in FIG. 11, a two-fluid nozzle, which can spray two fluids including water 18 and steam 20 is used as the spray nozzle 6 disposed in the after-air port 3.

[0118] A system for supplying the water 18 to the spray nozzles 6, each of which sprays the two fluids including water 18 and steam 20 as the cooling fluid uses the same the pipe 42 and the valve 17 as shown in FIG. 1.

[0119] A system for supplying the steam 20 to the spray nozzles 6, each of which sprays the two fluids, has a steam tank 21 to which part of steam used in a power generation plant is supplied for storage purposes, the pressure in the steam tank 21 being set to a prescribed value. The system also has a pipe 43 through which the steam 20 stored in the steam tank 21 is supplied to the spray nozzles 6, a valve 22 for adjusting the flow rate of the steam 20 supplied is provided on the pipe 43.

[0120] The opening of the valve 22, which adjusts the flow rate of the steam 20 sprayed from the two-fluid spray nozzles 6 into the inside of the furnace 1, is controlled by the controller 50. Specifically, as with control of the opening of the valve 17 for adjusting the amount of spray of the water 18, the spray amount controller 53 in the controller 50 compares a boiler load and the NOx emission concentration of the exhaust gas 11, which is detected by the NOx detector 55, with the setting in the boiler load setting unit 51 and the setting in the NOx concentration setting unit 52, respectively. Then, the spray amount controller 53 calculates the amount of the steam 20 that needs to be supplied. The opening of the valve 22 that corresponds to the amount of steam is commanded as an opening signal by the spray amount controller 53 in the controller 50 for the valve 22 so that the necessary amount of steam 20 is sprayed from the spray nozzles 6.

[0121] The steam 20 is sprayed from the two-fluid spray nozzle 6 toward the inside of the furnace 1 in a form similar to the spray range 18a, which overlaps mixed area 41, extending from the spray nozzle 6 shown in FIGS. 2 to 4.

[0122] The opening of the valve 22 is controlled by the controller 50 in the same way as the opening of the valve 17 is controlled by the controller 50 as shown in FIGS. 16A and 16B.

[0123] Due to the above arrangement in this embodiment, the flow rate of the steam 20 sprayed from the spray nozzles 6, which spray two fluids including water 18 and steam 20 can follow a change in the flow rate of the water 18 sprayed.

[0124] Accordingly, when the two-fluid spray nozzle 6 in this embodiment is used, droplets of the cooling fluid sprayed toward the inside of the furnace 1 become finer and evaporation of the water is facilitated, quickly suppressing the rise in the flame temperature.

[0125] The above embodiment in the present invention can also achieve a highly reliable pulverized coal boiler that ensures suppression of a flame temperature rise that is caused during the combustion of an unburnt gas in a furnace when combustion air is supplied from after-air ports so as to reduce the concentration of thermal NOx generated during the combustion.

Sixth Embodiment

[0126] Next, a pulverized coal boiler in another embodiment of the present invention will be described with reference to the drawings.

[0127] FIG. 12 is a schematic diagram indicating the structure of a pulverized coal boiler 100 in other embodiment of the present invention. The pulverized coal boiler 100 comprises burners 2 for burning pulverized coal used as a fuel, after-air parts 3 for supplying combustion air, and spray nozzles 6 for spraying water (cooling fluid) into the after-air parts 3.

[0128] The basic structure of the pulverized coal boiler in this embodiment is the same as the basic structure of the pulverized coal boiler 100 in the embodiment shown in FIG. 1, so the explanation of the same basic structure will be omitted and only different parts will be described.

[0129] FIG. 13 shows the structure of the wind box 5, which includes the after-air parts 3 used in the pulverized coal boiler
In the embodiment of the present invention shown in FIG. 12, FIG. 14 shows a section as viewed along line D-D in FIG. 13. In this embodiment, the spray nozzles 6 are provided on the wall of the wind box 5 as shown in FIGS. 13 and 14. The water 18 (cooling fluid) is sprayed from the spray nozzles 6 toward the spray range 18b in the wind box 5.

When combustion air is supplied from the opening 3a of each after-air port 3 disposed in the wind box 5 into the inside of the furnace 1 as the jet flow 40, the temperature of the combustion air is about 300°C. In the wind box 5, which is sufficiently high for combustion air to vaporize the water 18 sprayed from the spray nozzle 6 into the spray area 18a in the wind box 5.

After being vaporized in the wind box 5, the water 18 is adequately and evenly mixed with the flow of combustion air in the wind box 5, and the mixture of the water 18 and the flow of combustion air is supplied, as part of the jet flow 40 of combustion air, from the opening 3a of the after-air port 3 toward the inside of the furnace 1. Then, the mixture is supplied to the mixed area 41, where the jet flow 40 of combustion air and the unburnt gas 10a are mixed, reducing the temperature of the flame in the combustion of the unburnt gas 10a.

In this embodiment as well, the jet flow 40 of combustion air, with which the water 18 (cooling fluid) sprayed from the spray nozzle 6 into the wind box 5 and vaporized is mixed, can be precisely and evenly sprayed in the mixed area 41, where the jet flow 40 of combustion air and the unburnt gas 10a are mixed, the jet flow 40 being jetted toward the inside of the furnace 1, the inside communicating with the opening 3a of the after-air port 3.

Accordingly, in this embodiment, the latent heat and sensible heat of the water 18 sprayed from the spray nozzle 6 deprive the heat of the flame resulting from the combustion of the unburnt gas 10a in the mixed area 41, so it is possible to suppress the flame temperature to about 1600K or below, preferably about 1600K to about 1400K. The concentration of NOx generated in the boiler can thereby be reduced by about 10% to 50%.

In this embodiment, any spray pattern is allowed if the water 18 (cooling fluid) sprayed from the spray nozzle 6 in the wind box 5 is vaporized. It is not necessary that the sprayed water 18 be completely vaporized. The water 18 remaining in the wind box 5 without being vaporized may be collected as drain water and reused.

According to this embodiment, since the water 18 sprayed from the spray nozzle 6 is vaporized in the wind box 5 and moisture is evenly mixed with the jet flow 40 itself supplied from the after-air port 3 into the inside of the furnace 1, the moisture can be precisely supplied to the mixed area 41, suppressing a flame temperature rise that is caused during combustion in the mixed area 41.

Due to the evaporation of the sprayed moisture, the temperature of the combustion air in the wind box 5 is lowered and thereby the jet flow 40 itself supplied from the after-air port 3 into the inside of the furnace 1 becomes cold, more precisely suppressing the flame temperature rise that is caused during combustion in the mixed area 41.

Although a case in which the water 18 is used as the cooling fluid sprayed from the spray nozzle 6 has been described in this embodiment, the steam 20 or two fluids including the water and steam may be sprayed instead of the water.

Although not described, control of the cooling fluid by the spray nozzles 6 disposed in the wind boxes 5 in this embodiment can be carried out by having the controller 50 adjust the flow rate of the cooling fluid as in the embodiments described above.

The above embodiment in the present invention can also achieve a highly reliable pulverized coal boiler that ensures suppression of a flame temperature rise that is caused during the combustion of an unburnt gas in a furnace when combustion air is supplied from after-air ports so as to reduce the concentration of thermal NOx generated during the combustion.

Seventh Embodiment

Next, a pulverized coal boiler in other embodiment of the present invention will be described with reference to the drawings.

FIG. 17 is a schematic diagram indicating the structure of a pulverized coal boiler 100 in other embodiment of the present invention. The pulverized coal boiler 100 comprises burners 2 for burning pulverized coal used as a fuel, after-air ports 3 for supplying combustion air, and spray nozzles 6 for spraying water (cooling fluid) into a duct pipe 14 through which the combustion air is supplied to the after-air ports 3.

The basic structure of the pulverized coal boiler in this embodiment is the same as the basic structure of the pulverized coal boiler 100 in the embodiment shown in FIG. 1, so the explanation of the same basic structure will be omitted and only different parts will be described.

In this embodiment, the spray nozzles 6 are disposed in the pipe 14 positioned further upstream than the wind boxes 5 through which combustion air is supplied to the after-air ports 3, and the water 18 (cooling fluid) is sprayed from these spray nozzles 6 to the combustion air flowing in the pipe 14, so the sprayed water 18 is mixed with the combustion air. Accordingly, the water 18 stays in the combustion air at high temperature, which is supplied to the after-air ports 3, for an increased period of time.

As a result, the ratio of the vaporization of the water 18 sprayed from the spray nozzle 6 is increased and lessens drainage water, and thereby the water 18 (cooling fluid) sprayed from the spray nozzle 6 is more efficiently vaporized.

According to this embodiment, since the water 18 sprayed from the spray nozzle 6 is vaporized in the pipe 14 disposed upstream of the wind box 5 and moisture is evenly mixed with the jet flow 40 itself supplied from the after-air port 3 into the inside of the furnace 1, the moisture can be precisely supplied to the mixed area 41, suppressing a flame temperature rise that is caused during combustion in the mixed area 41.

Due to the evaporation of the sprayed moisture, the temperature of the combustion air supplied to the inside of the wind box 5 is lowered and thereby the jet flow 40 itself supplied from the after-air port 3 into the inside of the furnace 1 becomes cold, more precisely suppressing the flame temperature rise that is caused during combustion in the mixed area 41.

Although a case in which the water 18 is used as the cooling fluid sprayed from the spray nozzle 6 has been described in this embodiment, the steam 20 or two fluids including the water and steam may be sprayed instead of the water.
Although not described, control of the cooling fluid by the spray nozzles 6 disposed in the wind boxes 5 in this embodiment can be carried out by having the controller 50 adjust the flow rate of the cooling fluid as in the embodiments described above.

Accordingly, in this embodiment, the latent heat and sensible heat of the water 18 sprayed from the spray nozzle 6 deprive the heat of the flame resulting from the combustion of the unburnt gas 10a in the mixed area 41, so it is possible to suppress the flame temperature to about 1600K or below, preferably about 1400K to about 1400K. The concentration of NOx generated in the boiler can thereby be reduced by about 10% to 30%.

The above embodiment in the present invention can also achieve a highly reliable pulverized coal boiler that ensures suppression of a flame temperature rise that is caused during the combustion of an unburnt gas in a furnace when combustion air is supplied from after-air ports so as to reduce the concentration of thermal NOx generated during the combustion.

Eighth Embodiment

Next, a pulverized coal boiler in other embodiment of the present invention will be described with reference to the drawings.

FIG. 18 is a schematic diagram indicating the structure of a pulverized coal boiler 100 in another embodiment of the present invention. The pulverized coal boiler 100 comprises, on the wall of the furnace 1, burners 2 for spraying and burning pulverized coal used as a fuel, main after-air ports 61 for supplying combustion air, and sub after-air ports 60, each of which has the spray nozzle 6 for spraying both water and steam to supply combustion air.

The basic structure of the pulverized coal boiler in this embodiment is the same as the basic structure of the pulverized coal boiler 100 in the embodiment shown in FIG. 17, so the explanation of the same basic structure will be omitted and only different parts will be described.

On the wall of the furnace 1 in the pulverized coal boiler 100 in this embodiment shown in FIG. 18, the sub after-air ports 60 are disposed in the direction in which the combustion gas 10 flows in the furnace 1 on the upstream side, and the main after-air ports 61 are disposed in the downstream side.

The sub after-air port 60 has the spray nozzle 6, from which water or both water and steam is sprayed.

In the pulverized coal boiler 100 in this embodiment, the amount of air supplied from the sub after-air port 60 is smaller than the amount of air supplied from the main after-air port 61.

In the pulverized coal boiler 100 structured as described above, air sprayed from the sub-after ports 60 into the inside of the furnace 1 flows as air flows 62 and air sprayed from the main after-air ports 61 into the inside of the furnace 1 flows as air flows 63, as schematically shown in FIG. 18.

The air flows 62 supplied from the sub-after ports 60 into the inside of the furnace 1 by being sprayed are directed toward the downstream side along the inner wall of the furnace 1 because the amount of air sprayed is small.

The air flows 63 supplied from the main after ports 61 into the inside of the furnace 1 by being sprayed reaches the central part of the furnace 1 because the amount of air sprayed is large.

While flowing from downstream to upstream in the furnace 1, the combustion gas 10a is mixed with the air flows 62 and 63. Near the wall of the furnace 1, the temperature of the combustion gas 10a mixed with the air flow 62 on the upstream side is higher than the temperature of the combustion gas 10a mixed with the air flow 63 on the downstream side.

The temperature of the combustion gas 10a is highest at the central part of the furnace 1 because it is distant from the wall.

When the hot combustion gas 10a including the unburnt gas is mixed with the supplied air, a combustion reaction proceeds and the temperature of the mixture of the combustion gas 10a and the supplied air is raised. At that time, nitrogen gas in the air or the combustion gas 10a is oxidized in a hot oxidation atmosphere, generating nitrogen oxides (NOx), which is so-called thermal NOx. The higher the temperature is, the more thermal NOx is generated.

Since the pulverized coal boiler 100 in this embodiment is structured so that water is sprayed from the spray nozzles 6 disposed in the sub after-air ports 60 on the upstream side, the air flow 62 includes much moisture supplied from the sub after-air port 60 toward the inside of the furnace 1.

The water sprayed from the spray nozzle 6 deprives evaporation heat from the surrounding air during the evaporation, lowering the temperature of the air.

Since the air flow 62 includes much moisture, its specific heat is raised. Accordingly, when the combustion gas 10a is mixed with the air flow 62 jetted from the sub after-air ports 60, it is possible to suppress the combustion reaction by the amount of moisture included in the air flow 62 and thereby the combustion temperature can be reduced.

Therefore, the amount of thermal NOx generated during the combustion reaction can be reduced.

In the pulverized coal boiler 100 in this embodiment, after the air flow 62 including moisture has been mixed with the combustion gas 10a, part of the air flow 62 is further mixed with the air flow 63 jetted from the main after-air port 61 located downstream of the air flow 62.

When the part of the air flow 62 including moisture is mixed with the air flow 63, part of a gas already burned in an inner wall vicinity 64 in the furnace 1 is involved in the air flow 63 jetted from the main after-air port 61, so a burnt gas including moisture flows along the outermost circumference of the air flow 63.

Accordingly, when the unburnt gas including moisture, the air flow 63, and the combustion gas 10a are mixed, the combustion temperature can be reduced due to the specific heats of the moisture included in the burnt gas. As a result, the amount of thermal NOx generated at the central part of the furnace 1 can be reduced.

When the air flow jetted from the after-air port and the combustion gas 10a are mixed, as described above, the air flow including much moisture and the burnt gas including moisture are supplied to the inner wall vicinity 64 in the furnace 1 in a relatively upstream region, the central part 65 of the furnace 1, and other parts where high temperature is easily reached, enabling the amount of thermal NOx generated to be suppressed to a small value.

Since the burnt gas including much moisture is involved in the outermost circumferential part of the air flow 63, both reduction in the amount of water supply and suppression of thermal NOx can be achieved.
Although the thermal efficiency is lowered by the supplied water, since thermal NOx is suppressed, it is possible to suppress, at a downstream site of the furnace 1, power for operating units to reduce NOx and the amount of chemicals supplied.

In this embodiment, a situation in which the amount of air in the air flow 62 supplied from the sub after-air port 60 disposed upstream of the furnace 1 is smaller than the amount of air in the air flow 63 supplied from the main after-air port 61 disposed downstream has been described. However, even if the amount of air in the air flow 62 supplied from the sub after-air port 60 disposed upstream of the furnace 1 is larger than the amount of air in the air flow 63 supplied from the main after-air port 61, almost the same effect can be obtained.

To reduce thermal NOx generated in this case, it is clear as described above that much more water must be sprayed from the spray nozzle 6 disposed in the sub after-air port 60 than described above.

However, since much air of the air flow 62 supplied from the sub after-air port 60 is mixed with the combustion gas 10a upstream of the furnace 1, the amount of unburnt gas can be reduced at the exit of the furnace 1.

Although a case in which the water 18 is used as the cooling fluid sprayed from the spray nozzle 6 has been described in this embodiment, the steam 20 or two fluids including water 18 and steam 20 may be sprayed instead of water 18.

In this embodiment, a case in which the end of the spray nozzle 6 is positioned in the opening of the sub after-air port 60 has been described. Even if, however, the spray nozzle 6 is disposed in a wind box 5a which accommodates the sub after-air port 60, or the pipe 14, through which air is supplied to the wind box 5a, as in the sixth embodiment shown in FIG. 12 and the seventh embodiment shown in FIG. 17, the same effect as described above can be obtained.

The effect obtained when the spray nozzle 6 is disposed at any of the above positions is the same as in the sixth embodiment shown in FIG. 7 and the seventh embodiment shown in FIG. 17.

It is also possible to dispose the spray nozzle 6 in the opening in the swirl flow path 31, which is formed around the outer circumference of the straight flow path 30, as in the second embodiment of the present invention shown in FIGS. 5 and 6.

In this case, the swirl flow causes much of the water 18 jetted from the spray nozzle 6 to flow around the outer circumference of the air flow 62, so much moisture is included in the mixture of the combustion gas 10a and the air flow 62. Accordingly, the concentration of the thermal NOx can be reduced with a small amount of water.

In the pulverized coal boiler 100 in this embodiment, the cooling fluid sprayed from the spray nozzle 6 disposed in the sub after-air port 60 is controlled by the controller 50, as in the embodiments described above.

Specifically, a NOx concentration signal about the exhaust gas 11 detected by the NOx detector 55 is entered to the controller 50. The controller 50 then compares the NOx concentration with a desired NOx setting, calculates a flow rate command signal about the cooling fluid to be sprayed from the spray nozzles 6 toward the inside of the furnace 1 so that the NOx concentration of the exhaust gas 11 is maintained at the desired setting, and outputs the command signal to the valve 17 used for flow rate adjustment, which is disposed in the pipe 42, through which the water 18 (cooling fluid) is supplied to the spray nozzles 6. This arrangement enables the flow rate of the cooling fluid to be appropriately controlled and thereby the thermal NOx concentration to be reduced.

The pulverized coal boiler 100 described above can be a highly reliable pulverized coal boiler that ensures suppression of a flame temperature rise that is caused during the combustion of an unburnt gas in a furnace when combustion air is supplied from after-air ports so as to reduce the concentration of thermal NOx generated during the combustion.

INDUSTRIAL APPLICABILITY

The present invention can be applied to a pulverized coal boiler that uses pulverized coal as a fuel, more particularly to a pulverized coal boiler that suppresses the generation of thermal nitrogen oxides. The present invention can also be applied to conventional pulverized boilers with ease.

1. A pulverized coal boiler comprising a furnace, a burner provided on a wall of the furnace for supplying pulverized coal to the inside of the furnace and burning the pulverized coal, and an after-air port provided on the wall of the furnace at a position downstream of the burner for supplying combustion air to the inside of the furnace, the pulverized coal boiler further comprising:
   a spray nozzle disposed near a jet port of the after-air port for supplying water, steam, or two fluids including water and steam to the inside of the furnace; whereby the water, the steam, or the two fluids including water and steam sprayed from the spray nozzle are supplied to the inside of the furnace together with the combustion air supplied from the after-air port.

2. The pulverized coal boiler according to claim 1, wherein the plurality of after-air ports are disposed in the furnace in a combustion gas flow direction; and at least one of the plurality of after-air ports disposed upstream in the combustion gas flow direction in the furnace supplies the water, the steam, or the two fluids including water and steam to the inside of the furnace.

3. The pulverized coal boiler according to claim 2, wherein at least one of the plurality of after-air ports disposed upstream in the combustion gas flow direction in the furnace supplies combustion air less than that of combustion air supplied from the after-air ports disposed downstream in the combustion gas flow direction.

4. The pulverized coal boiler according to claim 2, wherein each of the after-air ports for supplying the water, the steam, or the two fluids including water and steam is provided with a straight flow path for jetting the combustion air as a straight flow, and a swirl flow path formed around an outer circumference of the straight flow path for jetting the combustion air as a swirl flow, internally; and the water, the steam, or the two fluids including water and steam are jetted from the swirl flow path.

5. The pulverized coal boiler according to claim 1, further comprising:
   a NOx detector for detecting a NOx concentration of an exhaust gas exhausted from the pulverized coal boiler; and
   a controller for controlling a flow rate of the water, the steam, or the two fluids including water and steam, which are supplied from the spray nozzle to the inside of the furnace, based on the NOx concentration detected by the NOx detector.
6. The pulverized coal boiler according to claim 1, further comprising a controller for controlling a flow rate of the water, the steam, or the two fluids including water and steam, which are supplied from the spray nozzle to the inside of the furnace, based on a load of the pulverized coal boiler.

7. The pulverized coal boiler according to claim 1, wherein a jet port of the spray nozzle for supplying the water, the steam, or the two fluids including water and steam into the inside of the furnace is disposed upstream in a jet flow of combustion air jetted from the jet port of the after-air port.

8. A pulverized coal boiler comprising a furnace, a burner provided on a wall of the furnace for supplying pulverized coal to the inside of the furnace and burning the pulverized coal, an after-air port provided on the wall of the furnace at a position downstream of the burner for supplying combustion air to the inside of the furnace, a wind box for supplying the combustion air into the after-air port, and a duct pipe for externally supplying the combustion air into the wind box, the pulverized coal boiler further comprising: a spray nozzle disposed in the wind box or in the duct pipe for supplying water, steam, or two fluids including water and steam; whereby the water, the steam, or the two fluids including water and steam sprayed from the spray nozzle into the inside of the wind box or the duct pipe are supplied to the inside of the furnace together with the combustion air supplied from a jet port of the after-air port.

9. The pulverized coal boiler according to claim 8, further comprising: a NOx detector for detecting a NOx concentration of an exhaust gas exhausted from the pulverized coal boiler; and a controller for controlling a flow rate of the water, the steam, or the two fluids including water and steam, which are supplied from the spray nozzle to the inside of the furnace, based on the NOx concentration detected by the NOx detector.

10. The pulverized coal boiler according to claim 8, further comprising a controller for controlling a flow rate of the water, the steam, or the two fluids including water and steam, which are supplied from the spray nozzle to the inside of the furnace, based on a load of the pulverized coal boiler.

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