US 20100107940A1

(19) United States
(12) Patent Application Publication
SHIBATA et al.
(10) Pub. No.: US 2010/0107940 A1
(43) Pub. Date: May 6, 2010

(54) OXYFUEL BOILER SYSTEM AND METHOD OF CONTROLLING THE SAME

(75) Inventors: Tsuyoshi SHIBATA, Hitachiota (JP); Masayuki Taniguchi, Hitachinaka (JP); Akihiro Yamada, Tokai (JP); Yoshiharu Hayashi, Hitachinaka (JP)

Correspondence Address:
CROWELL & MORING LLP
INTELLECTUAL PROPERTY GROUP
P.O. BOX 14300
WASHINGTON, DC 20044-4300 (US)

(73) Assignee: Hitachi, Ltd., Tokyo (JP)

(21) Appl. No.: 12/608,491

(22) Filed: Oct. 29, 2009

(30) Foreign Application Priority Data

Oct. 31, 2008 (JP) 2008-280675

Publication Classification

(51) Int. Cl.
F23C 9/00 (2006.01)
F23C 7/00 (2006.01)
F23J 3/00 (2006.01)
F23L 7/00 (2006.01)
F23L 9/00 (2006.01)

(52) U.S. Cl. 110/347; 110/205; 110/234; 110/216; 110/261; 110/297

(57) ABSTRACT

The oxyfuel boiler system comprises: an oxygen generator; a coal mill; a burner to burn pulverized coal; an after-gas port to which oxygen generated at the oxygen generator is supplied; a boiler provided with the burner and the after-gas port on its wall; a flue introducing combustion exhaust gas from the boiler to the outside; a recirculation gas supply pipe having an exhaust gas tapping port in the midway of the flue and supplying recirculation exhaust gas to the coal mill, the burner, and the after gas port; and an oxygen supply pipe supplying oxygen from the oxygen generator to the burner and the after-gas port, wherein the exhaust gas tapping port is disposed downstream of a dry dust-removing apparatus arranged in the flue, and there is provided an oxygen controlling apparatus for making a concentration of oxygen to be supplied to the after-gas port lower than that of oxygen to be supplied to the burner.

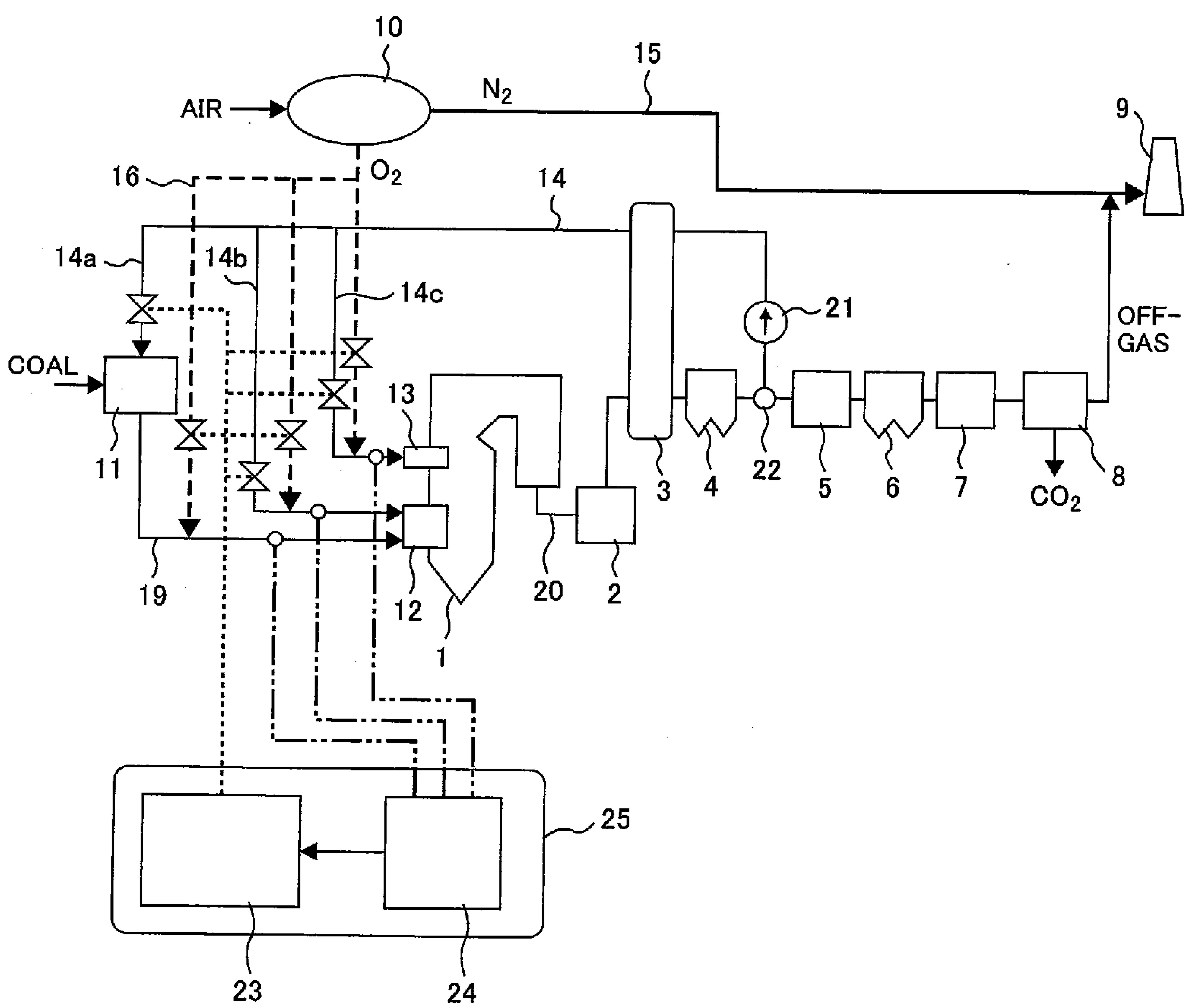

FIG. 1

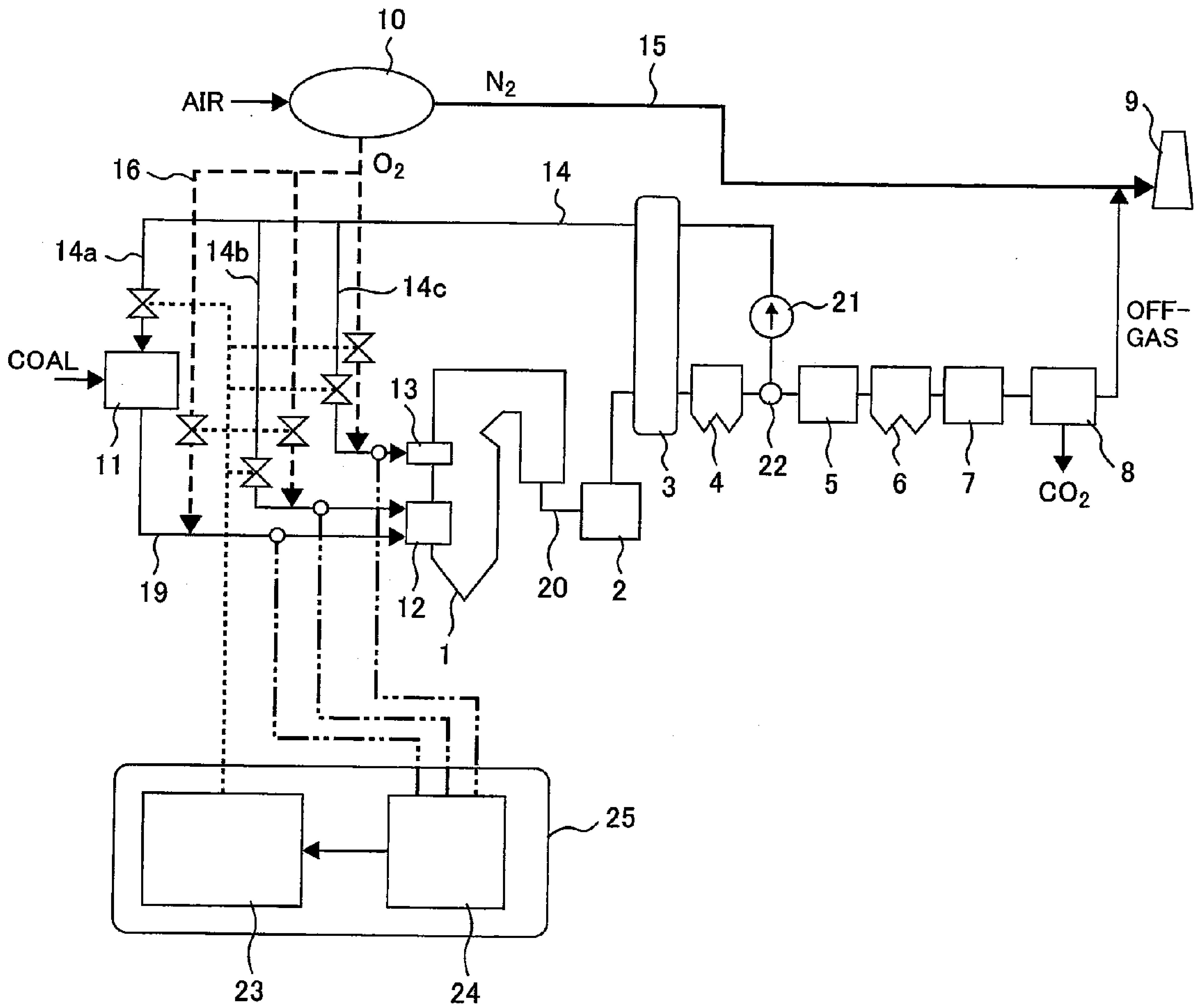
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FIG. 2

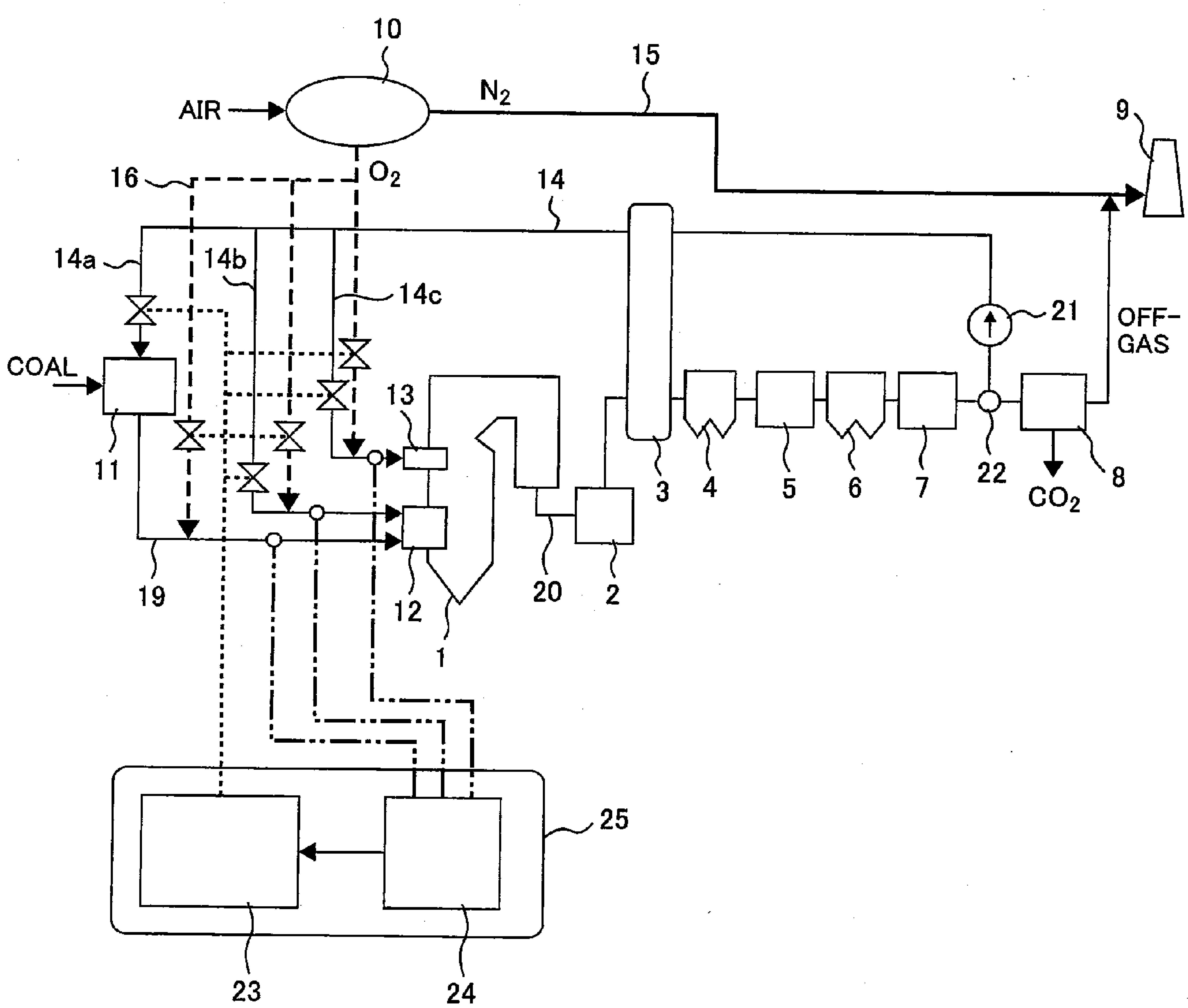
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FIG. 3

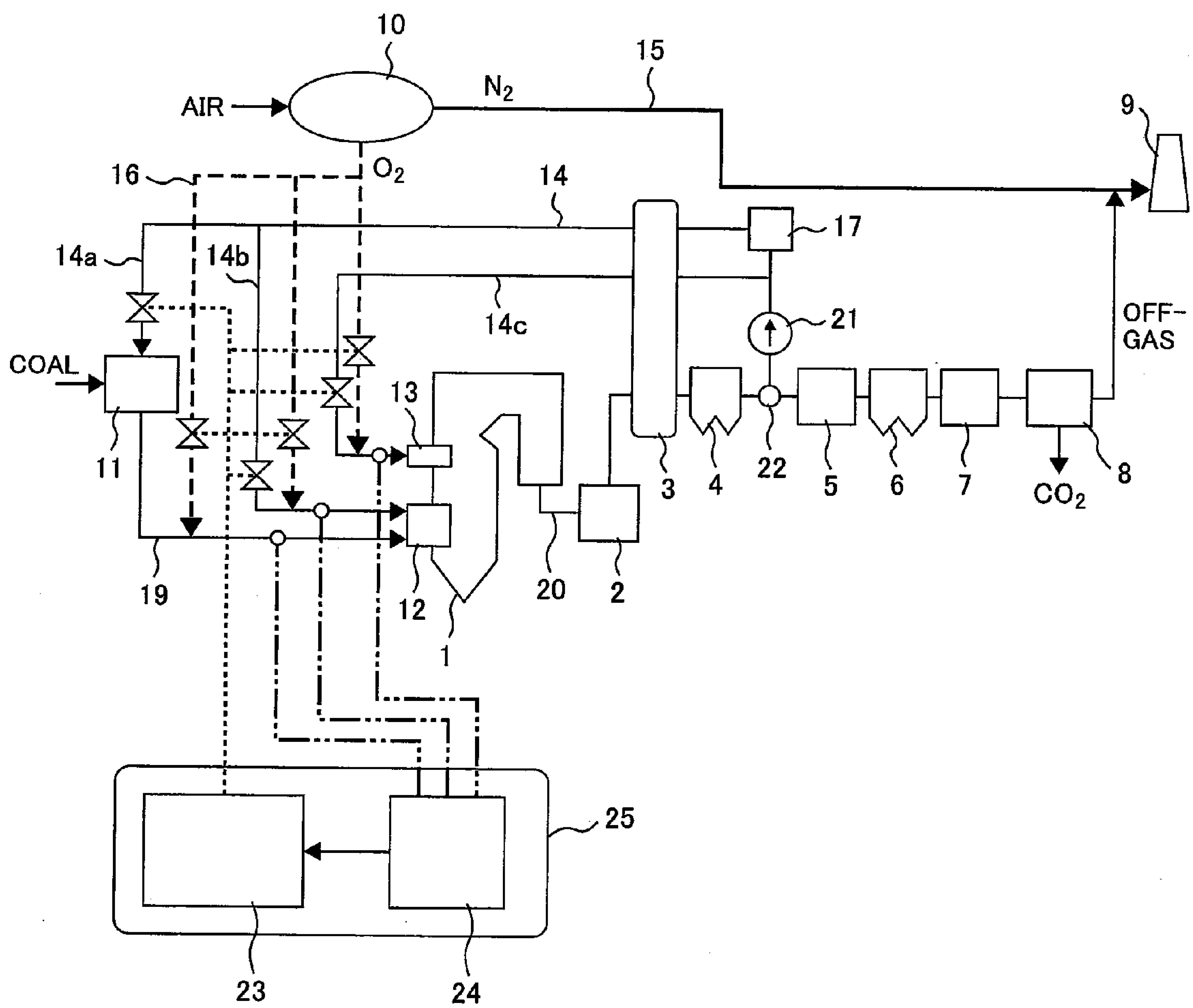

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FIG. 4

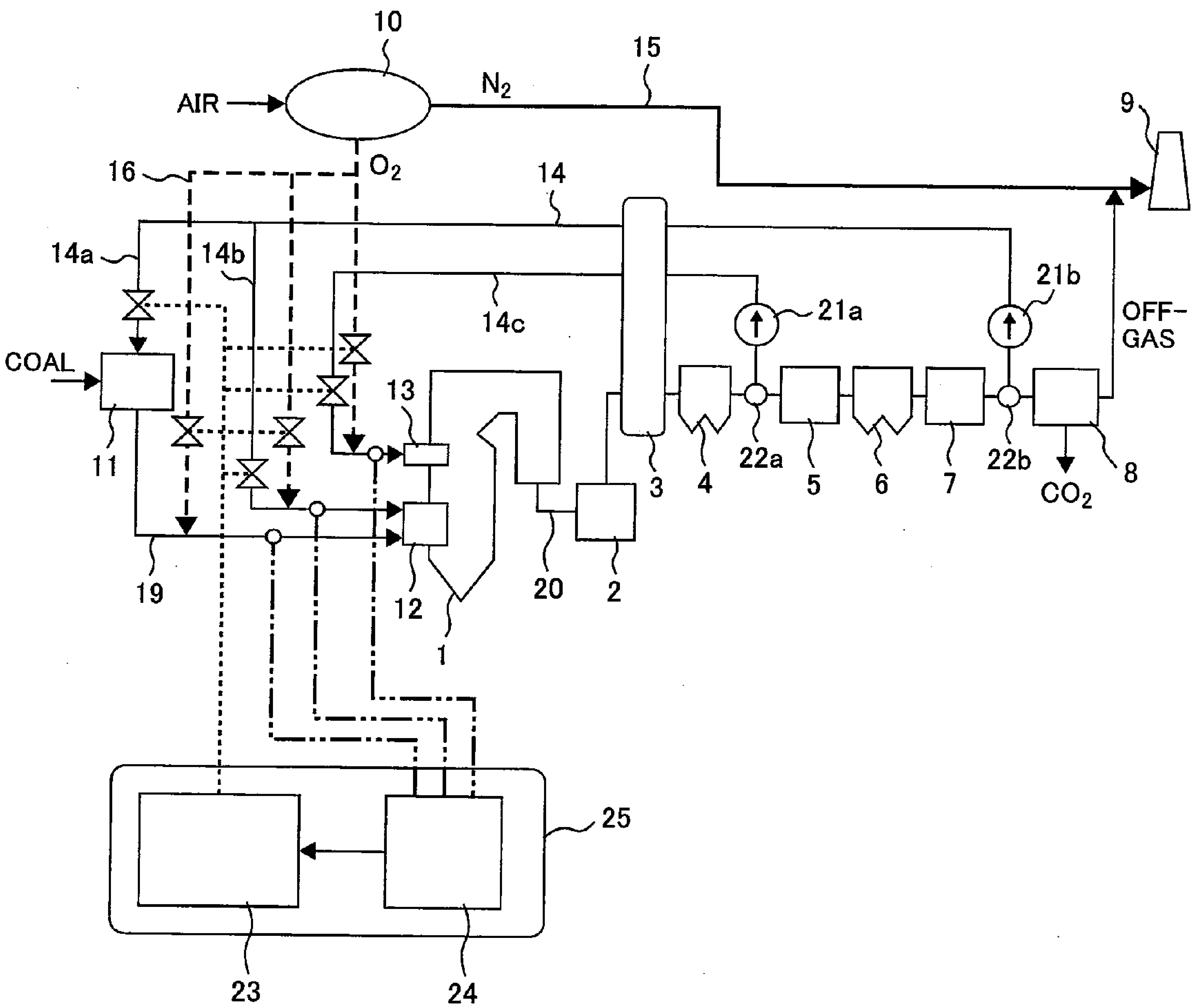

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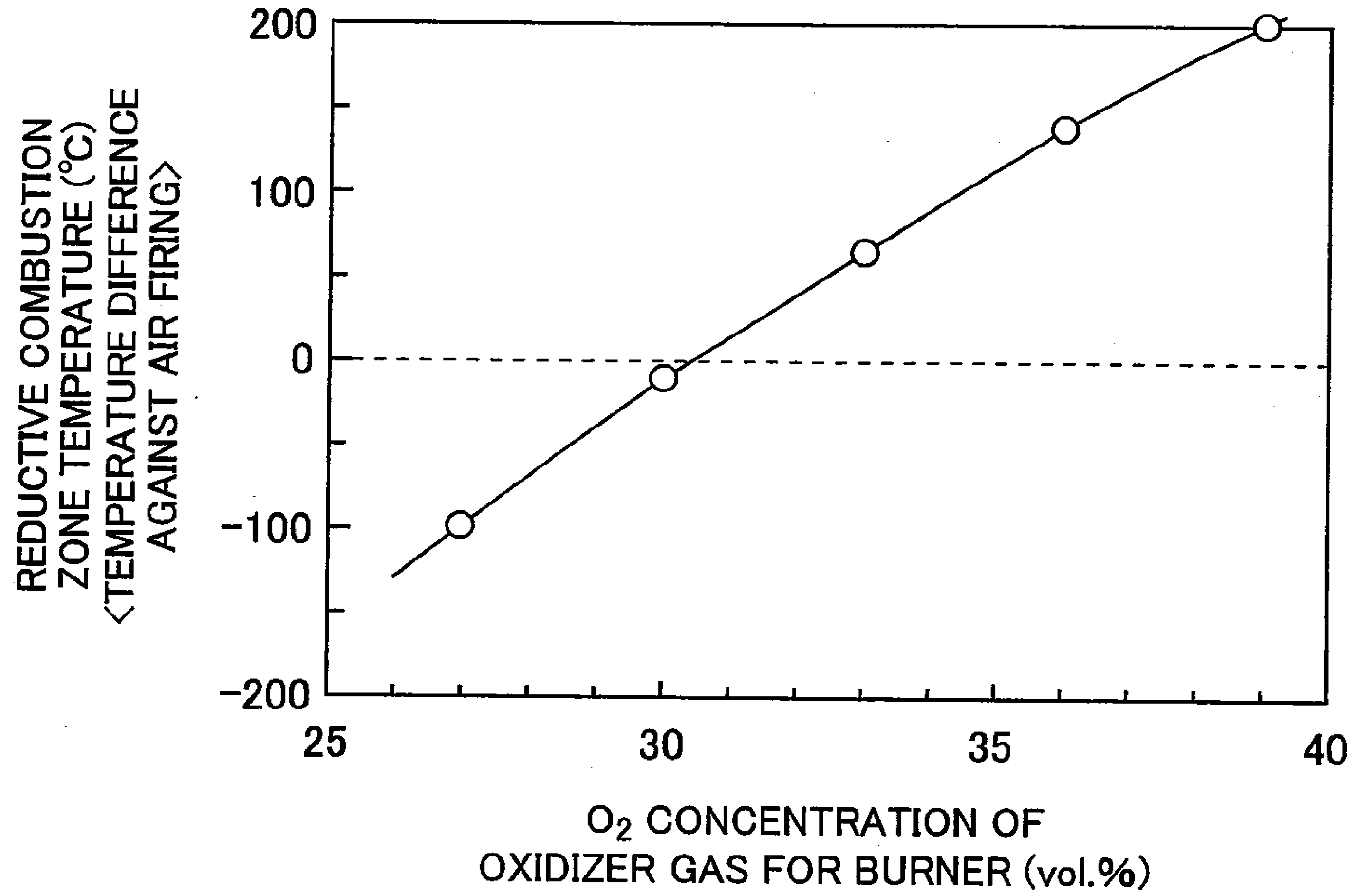
FIG. 5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35
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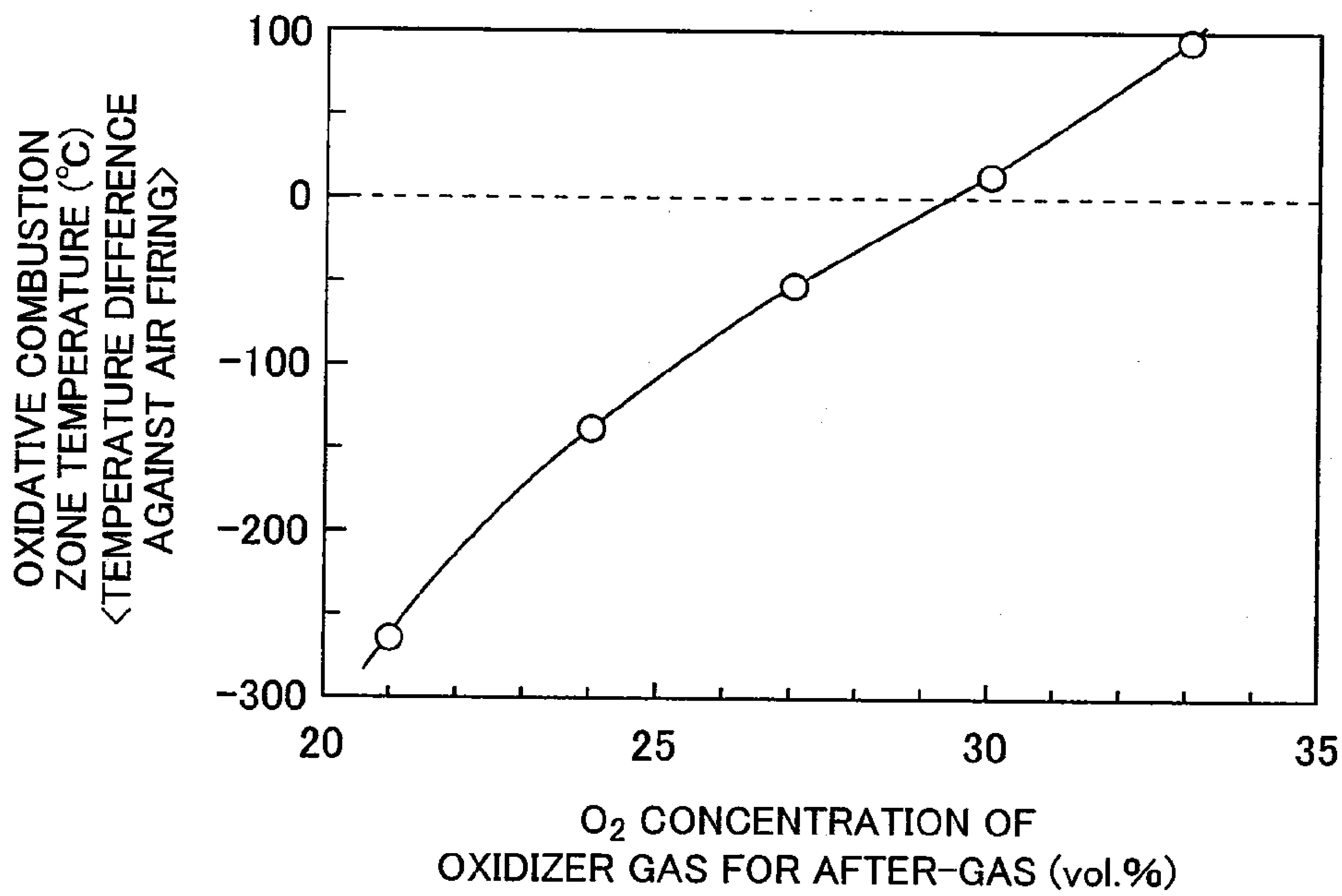
O_2 CONCENTRATION OF
OXIDIZER GAS FOR BURNER (vol.%)

FIG. 6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35
O_2 CONCENTRATION OF
OXIDIZER GAS FOR AFTER-GAS (vol.%)

OXYFUEL BOILER SYSTEM AND METHOD OF CONTROLLING THE SAME

CLAIM OF PRIORITY

[0001] The present application claims priority from Japanese patent application serial No. 2008-280675, filed on Oct. 31, 2008, the content of which is hereby incorporated by reference into this application.

FIELD OF THE INVENTION

[0002] The present invention relates to an oxyfuel boiler system and a method of controlling the same.

BACKGROUND OF THE INVENTION

[0003] A coal firing power generation system configured with a pulverized coal firing boiler and a steam turbine electric generator plays a significant role, given the recent years' price increase of natural gas and the like resulting from oil supply shortage and increase of natural gas demand.

[0004] As a means to greatly reduce CO_2 emissions from the coal firing power generation system, oxyfuel boiler systems have been proposed.

[0005] Japanese Unexamined Patent Application Publication No. 2007-147162 discloses a technology for adjusting oxygen concentration in the total gas introduced to a boiler main body by controlling recirculation flow rate of combustion exhaust gas so that the heat absorbing amount of the boiler main body becomes the target heat absorbing amount.

[0006] However, in Japanese Unexamined Patent Application Publication No. 2007-147162, no consideration is given on reduction of fuel NO_x.

[0007] In view of above, an object of the present invention is to provide an oxyfuel boiler system and a method of controlling the same capable of further reducing the forming amount of the fuel NO_x.

SUMMARY OF THE INVENTION

[0008] The present invention provides an oxyfuel boiler system in which an exhaust gas tapping port is arranged downstream of a dry dust-removing apparatus arranged in a flue, and there is provided an oxygen controlling apparatus for making a concentration of oxygen to be supplied to an after-gas port lower than that of oxygen to be supplied to a burner. More specifically, the present invention provides an oxyfuel boiler system comprising: an oxygen generator; a coal mill; a burner burning pulverized coal; an after-gas port to which oxygen generated at the oxygen generator is supplied; a boiler provided with the burner and the after-gas port on its wall; a flue introducing combustion exhaust gas from the boiler to the outside; a recirculation gas supply pipe having an exhaust gas tapping port disposed in the midway of the flue and supplying recirculation exhaust gas to the coal mill, the burner, and the after gas port; and an oxygen supply pipe supplying oxygen from the oxygen generator to the burner and the after-gas port; wherein the exhaust gas tapping port is disposed downstream of a dry dust-removing apparatus arranged in the flue, and an oxygen controlling apparatus for making a concentration of oxygen to be supplied to the after-gas port lower than that of oxygen to be supplied to the burner is provided.

BRIEF DESCRIPTION OF THE DRAWING

[0009] FIG. **1** illustrates configuration of an oxyfuel boiler system according to a first embodiment;
[0010] FIG. **2** illustrates configuration of an oxyfuel boiler system according to a second embodiment;
[0011] FIG. **3** illustrates configuration of an oxyfuel boiler system according to a third embodiment;
[0012] FIG. **4** illustrates configuration of an oxyfuel boiler system according to a fourth embodiment;
[0013] FIG. **5** illustrates an example of a calculation result of reductive combustion zone temperature of a boiler in the first embodiment; and
[0014] FIG. **6** illustrates an example of a calculation result of oxidative combustion zone temperature of a boiler in the first embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] Oxyfuel boiler systems according to respective embodiments will be described below referring to the accompanying drawings. However, the present invention is not limited to those embodiments.

[0016] Meaning of each reference numeral in the description below is as follows.

[0017] **1**: Boiler,
[0018] **2**: NO_x removing apparatus,
[0019] **3**: Heat exchanger,
[0020] **4**: Dry dust-removing apparatus,
[0021] **5**: Wet desulfurization apparatus,
[0022] **6**: Wet dust-removing apparatus,
[0023] **7**: Moisture removing cooler,
[0024] **8**: CO_2 separation and liquefaction apparatus,
[0025] **9**: Discharge stack,
[0026] **10**: Oxygen generator,
[0027] **11**: Coal mill,
[0028] **12**: Burner,
[0029] **13**: After-gas port,
[0030] **14**: Recirculation gas supply pipe,
[0031] **14***a:* Primary gas pipe,
[0032] **14***b:* Secondary gas pipe,
[0033] **14***c:* After-gas pipe,
[0034] **15**: Nitrogen gas transfer pipe,
[0035] **16**: Oxygen supply pipe,
[0036] **17**: Recirculation exhaust gas moisture removing cooler,
[0037] **19**: Coal supply pipe,
[0038] **20**: Flue,
[0039] **21**, **21***a*, **21***b:* Recirculation fan,
[0040] **22**, **22***a*, **22***b:* Exhaust gas tapping port,
[0041] **23**: Oxygen and recirculation gas flow controller,
[0042] **24**: Oxygen analyzer, and
[0043] **25**: Oxygen controlling apparatus for oxidizer.

First Embodiment

[0044] FIG. **1** illustrates a configuration of an oxyfuel boiler system. Fuel coal is supplied to a coal mill **11** via a coal transfer device and is pulverized to a particle size suitable for pulverized coal firing. The pulverized coal (powdered coal) is supplied to a burner **12** through a coal supply pipe **19**. The coal mill **11** is connected with a primary gas pipe **14***a* which supplies recirculation exhaust gas to the coal mill **11**. An oxygen supply pipe **16** is connected to a location along the coal supply pipe **19**, where oxygen is mixed as needed. Mixing of a proper amount of oxygen with the recirculation exhaust gas in the coal supply pipe **19** has the effect of enhancing the ignition performance of the coal in the burner **12**.

[0045] An oxygen generator **10** separates oxygen from air and supplies oxygen to the coal supply pipe **19** and the like through the oxygen supply pipe **16**. A great deal of nitrogen gas generated in separation of oxygen is diffused from a discharge stack **9** by a nitrogen gas transfer pipe **15**.

[0046] The burner **12** is provided with a secondary gas pipe **14***b*, which is a recirculation gas supply pipe, and the oxygen supply pipe **16** is connected to the secondary gas pipe **14***b*. Also, the burner **12** ejects gas mixture of the oxygen supplied from the oxygen supply pipe **16** and the recirculation exhaust gas to a furnace. Further, the burner **12** also ejects the pulverized coal supplied from the coal supply pipe **19** to the furnace and forms a flame by the pulverized coal and the gas mixture.

[0047] An after-gas port **13** is arranged downstream of the burner **12**, and the recirculation gas supply pipe **14** is connected to the after-gas port **13** as well through an after-gas pipe **14***c*. Also, the oxygen supply pipe **16** is connected to the after-gas supply pipe **14***c* as well. Further, independently of the burner **12**, the after-gas port **13** also feeds the gas mixture of the oxygen and the recirculation gas to a boiler **1**.

[0048] The after-gas port **13** has a function similar to that of the after-air port of an air fired boiler. That is, by properly regulating the flow amounts of the gas mixture and the oxygen concentration supplied to the burner **12** and the after-gas port **13**, a burning zone of reductive atmosphere is formed in the boiler **1**, thus reducing the rate of conversion of the nitrogen in the coal to NO_x. Also, by the oxygen contained in the gas supplied from the after-gas port **13**, a burning zone of oxidative atmosphere is formed in the upper part of the boiler. Further, the jet exiting from the after-gas port **13** promotes gas mixing in the boiler and reduces unburned portion remaining in the exhaust gas of the boiler.

[0049] The flow rates of the recirculated exhaust gases supplied to the coal mill **11**, burner **12**, and after-gas port **13** can each be regulated independently by a flow rate regulator attached to the primary gas pipe **14***a*, secondary gas pipe **14***b*, and after-gas pipe **14***c* respectively. Further, the oxygen supply pipe **16** also has separate flow regulators in its branches for regulating the supply amount to the branches. These three recirculation gas supply pipes **14** are connected with gas sampling pipes for measuring each oxygen concentration.

[0050] An oxygen controlling apparatus for oxidizer **25** comprises an oxygen and recirculation gas flow controller **23** and an oxygen analyzer **24**. The oxygen analyzer **24** can always measure the oxygen concentration in the gas mixture in each pipe taken by a gas sampling pipe. The oxygen and recirculation gas flow controller **23** can regulate the recirculation gas flow rate and the oxygen flow rate of the three recirculation gas supply pipes **14** independently. Also, the oxygen and recirculation gas flow controller **23** can automatically control the oxygen concentration using the oxygen concentration measured value from the oxygen analyzer **24** as an input signal. That is, with this controller, for the gas mixture supplied to the boiler **1** from the coal supply pipe **19**, secondary gas pipe **14***b*, after-gas pipe **14***c*, the distribution ratio of the oxygen feeding amount and oxygen concentration can be set/regulated independently.

[0051] High temperature and high pressure steam generated in the boiler **1** is supplied to a steam turbine generating system and is converted to electric power.

[0052] Exhaust gas generated in the boiler **1** is introduced to a flue **20** and supplied to an NO_x removing apparatus **2**, and the NO_x component in the exhaust gas is reduced. In the flue **20**, an exhaust gas treatment system comprising a plurality of apparatuses treating the exhaust gas is provided in addition to the NO_x removing apparatus **2**. However, when the forming amount of NO_x can be sufficiently reduced by improvement of the combustion method and the like, the NO_x removing apparatus **2** may be omitted. The exhaust gas exited from the NO_x removing apparatus **2** is supplied to a heat exchanger **3** and the temperature is reduced. Heat recovered from the exhaust gas by the heat exchanger **3** is given to the recirculation exhaust gas supplied similarly to the heat exchanger **3** for recirculating to the boiler **1** and inhibits deterioration of thermal efficiency of the plant. The exhaust gas exited from the heat exchanger **3** is introduced to a dry dust-removing apparatus **4**, and 95% or more of the dust component is removed.

[0053] An exhaust gas tapping port **22** is disposed downstream of the dry dust-removing apparatus **4**. A part of the exhaust gas taken in from the exhaust gas tapping port **22** is induced to a recirculation gas supply pipe **14** by a recirculation fan **21** and is heated by the heat exchanger **3**. The exhaust gas is thereafter supplied to the coal mill **11**, burner **12** and after-gas port **13** as described above.

[0054] 95% or more of SO_2 of the exhaust gas not recirculated is removed by a wet desulfurization apparatus **5**. Then, the exhaust gas is removed of 98% or more of SO_3 component by a wet dust-removing apparatus **6**, and the moisture content in the exhaust gas is substantially reduced by a moisture removing cooler **7**. Further, in the present embodiment, with respect to the removing apparatus for dust and sulfur compound in the exhaust gas such as the dry dust-removing apparatus, wet desulfurization apparatus, and wet dust-removing apparatus, decision on necessity or non-necessity of installation and alteration of specification of the removal rate may be made at a designer's discretion. Also, an apparatus with a similar function such as a dry desulfurization apparatus maybe installed as an alternative.

[0055] The CO_2 concentration of the exhaust gas exiting from the moisture removing cooler **7** becomes approximately 90% or more. Therefore, a CO_2 separation and liquefaction apparatus **8** can separate and liquefy CO_2 in the exhaust gas easily. Also, the separated CO_2 may be supplied to a user through a pipe line and the like as high-pressure gas. The balance not liquefied by the CO_2 separation and liquefaction apparatus **8** is discharged as off-gas. Main components of the off-gas are nitrogen and oxygen, and minor components of NO_x and the like and some amount of CO_2 are contained. The off-gas is mixed with a great deal of nitrogen generated by the oxygen generator **10**, and is diffused to the atmosphere from the discharge stack **9**.

[0056] Here, the basic principle of the oxyfuel boiler system will be described. An ordinary coal firing boiler uses air as oxidizer gas, whereas the oxyfuel boiler uses the gas mixture in which major portion of the combustion exhaust gas is taken out from a location along the flue and is mixed thereafter with high purity oxygen generated by the oxygen generator for regulating the oxygen concentration as the oxidizer gas. Thus, final exhaust gas flow rate discharged from the plant is reduced to approximately ¼th compared with other ordinary systems. Further, because the CO_2 concentration of the exhaust gas rises massively, CO_2 can be separated and recovered from the exhaust gas easily.

[0057] For CO_2 emission-free coal-firing oxyfuel boiler system, the main technical objectives are summarized as follows:

[0058] (1) To suppress reduction in power generation efficiency resulting from energy consumption in the oxygen generator and CO_2 separator.

[0059] (2) To establish a plant control method by which the plant can stably respond to various conditions such as starting, stopping and changing loads, and realize the stable operation by cooperation with peripheral facilities (such as oxygen generator and a CO_2 separator).

[0060] (3) To achieve stable burning performance and suppress the formation of trace harmful substance when burning coal with an oxidizer mixture gas of recirculation exhaust gas and oxygen.

[0061] (4) To prevent various problems arising from increased concentrations of components contained in the various exhaust gas resulting from introduction of a configuration in which a large amount of the exhaust gas is recirculated.

[0062] The present embodiment relates mainly to the item (3) above, and is objected to solve the problems related to inhibit the forming amount of NO_x which is the trace harmful substance. Below, the features of the oxyfuel boiler system and the problems related to NO_x reduction will be described.

[0063] If CO_2 recovery from exhaust gas is the only object, burning coal exclusively with oxygen is an effective way. When coal is burned exclusively with oxygen, the major components of the exhaust gas are CO_2 and H_2O. Therefore, by separating and removing the H_2O from the exhaust gas, for example, by cooling the exhaust gas, CO_2 of a high concentration can be readily collected. However, when coal is burned with oxygen only, the temperature of the burning flame is higher than those in air fired boiler system by 500 higher. Therefore, when this oxygen firing is employed in a coal firing plant, expensive heat resistant steels need to be used for metal materials constituting the boiler. Another problem is that the oxidizer gas jet velocity in the burner is relatively low, thus making it difficult to forma stable flame. Also, the amount of the exhaust gas generated is less than ¼th of those in air firing, and therefore the velocity of the exhaust gas flowing through the heat transfer tube of the boiler is extremely slower. Accordingly, the thermal transfer efficiency degrades and the thermal recovery becomes difficult.

[0064] To overcome above problems, the oxyfuel boiler system employs an exhaust gas recirculation system in which a large amount of the exhaust gas is recirculated, mixed with oxygen, and then supplied to the boiler. Specifically, such system is designed so that the flow rate of the oxidizer gas supplied to the burner and the flow rate of the exhaust gas flowing through the boiler are not less than approximately 70% of the flow rate of the air in an air fired boiler. In this manner, high efficiency thermal recovery and electric power generation can be stably achieved without greatly modifying a conventional air fired boiler system.

[0065] In the oxyfuel boiler system with such basic configuration, the problems related to NO_x reduction are as below.

[0066] In the oxyfuel boiler system, nitrogen (N_2) concentration in the exhaust gas is maintained extremely low. Therefore, thermal NO_x formed by reaction of N_2 and oxygen (O_2) in the high temperature zone in the upper part of the boiler is suppressed greatly. As a result, the NO_x forming amount per unit supplied heat amount can be reduced compared with those in the air fired boiler. Accordingly, in order to further reduce the NO_x forming amount in the oxyfuel boiler system, the forming amount of fuel NO_x generated by oxidation of N portion in coal needs to be suppressed.

[0067] The reaction pathway that forms the fuel NO_x from N portion in coal is considered to be an oxidation reaction of ammonia (NH_3) and cyanogen (HCN) generated from the coal. The mechanism of the oxidation reaction of NH_3 and HCN is different in the reductive combustion zone with extremely low O_2 concentration and in the oxidative combustion zone with high O_2 concentration. OH radical mainly contributes to oxidation in the reductive combustion zone, whereas oxidation rests upon O_2 in the oxidative combustion zone. Accordingly, how these oxidation reaction rates are suppressed according to the atmosphere of the combustion zone is a key point for the fuel NO_x reduction.

[0068] Also, as a factor affecting NO_x formation from NH_3 and HCN, the temperature of the combustion zone is also important in addition to the O_2 concentration and the OH radical concentration described above. In the reductive combustion zone, as the combustion temperature becomes higher, the forming rate of the fuel NO_x lowers. The reason is considered that the reaction in which the NO_x generated in the reductive combustion zone reacts with coal, NH_3, HCN and the like again and is reduced to N_2 is promoted in a field with higher temperature. On the other hand, in the oxidative combustion zone, as the combustion temperature becomes lower, the forming rate of the fuel NO_x lowers. The reason is that, out of NH_3, HCN formed in the reductive combustion zone in the lower part of the boiler, those remaining until the oxidative combustion zone in the upper part of the boiler are oxidized in this zone, and the N portion contained is converted to NO_x or N_2, where, when the combustion temperature of the oxidative combustion zone is higher, conversion rate to NO_x rises, whereas when the combustion temperature is lower, conversion rate to N_2 rises.

[0069] To summarize above, in order to suppress formation of the fuel NO_x in the oxyfuel boiler system, it is necessary to lower the OH radical concentration in the reductive combustion zone to the most and to raise the combustion temperature. Also, it is required to lower the O_2 concentration in the oxidative combustion zone while controlling the combustion temperature lower.

[0070] In this connection, in the present embodiment, the oxygen controlling apparatus for oxidizer **25** is provided with a function of regulating the recirculation gas amount supplied to the coal mill **11**, which is a coal supply apparatus, burner **12**, and after-gas port **13** and setting the O_2 concentration of the oxidizer gas independently.

[0071] In the air fired type coal firing boiler, the air excess ratio at the boiler outlet is made approximately 1.15, and the distribution ratio of the combustion air amount supplied to the burner and the combustion air amount supplied to the after-air port is made approximately 0.8:0.35. Therefore, NO_x and unburned portion can be reduced with a good balance. Regulating air excess ratio/distribution ratio of the combustion air amount is equivalent with regulating oxygen excess ratio/distribution ratio of the oxygen contained in the air. Therefore, in the oxyfuel boiler also, it is preferable to set the oxygen amount supplied to the burner and the oxygen amount supplied to the after-gas port as well as the oxygen excess ratio at the furnace outlet using the condition described above for the air firing case. That is, in the present embodiment, the total oxygen amount supplied to the boiler is set to approximately 1.15 times of the oxygen amount required for complete combustion of coal. Also, the distribution ratio of the oxygen amount supplied to the burner **12** and the oxygen amount supplied to the after-gas port **13** is made approximately 0.8:0.35.

[0072] In addition, the oxygen controlling apparatus for oxidizer **25** also has a function of regulating the recirculation gas amount supplied to the burner **12** and after-gas port **13**. Furthermore, the oxygen controlling apparatus for oxidizer **25** sets the O_2 concentration of the oxidizer gas independently. Specifically, the oxygen controlling apparatus for oxidizer **25** makes the concentration of the oxygen supplied to the after-gas port lower than the concentration of the oxygen supplied to the burner. With respect to the regulation target for the O_2 concentration, following values are appropriate.

[0073] It is preferable to set the O_2 concentration of the oxidizer gas in the coal supply pipe **19** and the secondary gas pipe **14***b* connected to the burner between 32% and 36%. FIG. **5** illustrates a calculation result of the combustion temperature in the reductive combustion zone in the boiler **1** in accordance with the present embodiment. In order to obtain the combustion temperature similar to that of the air firing, the O_2 concentration of approximately 30% is needed. Also, it was found that the combustion temperature rose with the increase of the O_2 concentration of the oxidizer gas. As described above, in the reductive combustion zone, the forming rate of the fuel NO_x lowers with the rise of the combustion temperature. Therefore, in order to obtain a stable high temperature flame, O_2 concentration can be made 32% or more.

[0074] On the other hand, when the combustion temperature rises by 150° C. or higher if compared with the time of the air firing, problems occur in the heat resistance performance of the burner and boiler water tube material. Therefore, from this viewpoint, the O_2 concentration should be 36% or less. Based on the above study, in order to reduce the forming amount of the fuel NO_x, the O_2 concentration of the oxidizer gas supplied to the burner can be set in the range between approximately 32% and 36%.

[0075] Next, the O_2 concentration of the oxidizer gas in the after-gas pipe **14***c* connected to the after-gas port can be set between 26% and 28%. FIG. **6** illustrates a calculation result of the combustion temperature in the oxidative combustion zone in the boiler **1** in accordance with the present embodiment. By making the O_2 concentration 30%, the combustion temperature approximately similar to that in the air firing can be obtained.

[0076] As described above, in the oxidative combustion zone, forming rate of the fuel NO_x lowers with the lowering of the combustion temperature. Therefore, in order to obtain a stable temperature lowering effect, the O_2 concentration can be made 28% or less.

[0077] On the other hand, when the combustion temperature lowers by 100° C. or higher, there is a risk that the concentration of the unburned portion at the boiler outlet rises exceeding an allowable range. Therefore, the O_2 concentration should be made 26% or more. Based on the above study, in order to reduce the forming amount of the fuel NO_x, the O_2 concentration of the oxidizer gas supplied to the after-gas port can be set in the range between 26% and 28%.

[0078] Because the CO_2 emission-free oxyfuel boiler system in accordance with the present embodiment can reduce the forming amount of the fuel NO_x generated in the combustion, NO_x reduction effect can be further enhanced. Also, the harmful component emitted to the atmosphere can be reduced substantially. Thus, the apparatuses related to NO_x removal in an exhaust gas treatment system can be substantially miniaturized and simplified, and also the utilities cost of the ammonia solution and the like required for their operation can be reduced.

[0079] Further, setting value of the appropriate O_2 concentration changes also according to the distribution ratio of the oxygen, oxygen excess ratio, boiler structure, kind of coal, and the like. Therefore, the setting value should be decided after each case is assessed, and the values of the appropriate O_2 concentration setting range described above does not limit the scope of the present embodiment.

Second Embodiment

[0080] FIG. **2** illustrates a schematic diagram of the oxyfuel boiler system in accordance with the present embodiment.

[0081] Because the present embodiment comprises many sections constituted of apparatuses having the similar actions as those of the first embodiment, only the points different from the first embodiment will be described below. The apparatuses not described below have the similar action and effect as the first embodiment.

[0082] The point of the present embodiment different from the first embodiment is that the exhaust gas tapping port **22** is disposed downstream of the moisture removing cooler **7**, and the recirculation exhaust gas removed with the dust and moisture can be supplied to the boiler. The moisture removing cooler **7** serves as a moisture removing apparatus. In the configuration in accordance with the first embodiment, the moisture density in the recirculation exhaust gas is approximately 30%. On the other hand, in the configuration in accordance with the present embodiment, the moisture density in the recirculation exhaust gas can be made 5% or less. Because the moisture density in the recirculation exhaust gas lowers, the moisture amount supplied from the burner also decreases. Therefore, OH radical concentration derived from the moisture in the reductive combustion zone greatly lowers. As described above, lowering of the OH radical concentration in the reductive combustion zone is effective in reduction of the fuel NO_x.

[0083] Thus, with the configuration in accordance with the present embodiment, the NO_x reduction effect greater than that of the first embodiment can be obtained.

Third Embodiment

[0084] FIG. **3** illustrates a schematic diagram of the oxyfuel boiler system in accordance with the third embodiment.

[0085] Because the present embodiment comprises many sections constituted of apparatuses having the similar actions as those of the first embodiment and the second embodiment, only the points different from the first embodiment and the second embodiment will be described below. The apparatuses not described below have the similar action and effect as the said embodiments.

[0086] The configuration of the present embodiment is similar to the first embodiment in that the exhaust gas tapping port **22** is disposed downstream of the dry dust-removing apparatus **4** and upstream of the other exhaust gas treatment apparatuses. However, the configuration is different in that the recirculation gas supply pipe **14** branches to two lines before entering the heat exchanger **3**. Out of the recirculation gas supply pipes that branched, the first line is connected to the primary gas pipe **14***a* and the secondary gas pipe **14***b* through the heat exchanger **3** after the moisture in the gas is removed through the recirculation exhaust gas moisture removing cooler **17**. Out of the recirculation gas supply pipes that branched, the second line is connected to the after-gas pipe **14***c* through the heat exchanger **3** without removing the moisture. With the configuration in accordance with the present embodiment, similar to the second embodiment, the OH radical concentration in the reductive combustion zone is substantially reduced. Also, the moisture in the recirculation exhaust gas supplied to the after-gas port which does not affect the NO_x reduction is not removed. Therefore, the thermal loss of the recirculation exhaust gas supplied to the after-gas port decreases, and the total capacity of the moisture removing cooler **7** and the recirculation exhaust gas moisture removing cooler **17** can be reduced. Also, when the wet desulfurization apparatus and the wet dust-removing apparatus are arranged like in the case of the present embodiment, the gas amount flowing through these apparatuses becomes less than ¼th of that of the second embodiment, therefore the apparatuses can be miniaturized.

[0087] Accordingly, with the present embodiment, the oxyfuel boiler system having the NO_x reduction effect greater than that of the first embodiment and with the improved thermal efficiency and with the miniaturized apparatuses when compared with the second embodiment can be realized.

Fourth Embodiment

[0088] FIG. **4** illustrates a schematic diagram of the oxyfuel boiler system in accordance with the fourth embodiment.

[0089] Because the present embodiment comprises many sections constituted of apparatuses having the similar actions as those of the third embodiment, only the points different from the third embodiment will be described below. The apparatuses not described below have the similar action and effect as the third embodiment.

[0090] The point of the present embodiment different from the third embodiment is that the exhaust gas tapping port for the recirculation gas is arranged in two positions of an exhaust gas tapping port **22***a* and an exhaust gas tapping port **22***b*. Similar to the third embodiment, the exhaust gas tapping port **22***a* is disposed immediately after the dry dust-removing apparatus. The exhaust gas taken in from the exhaust gas tapping port **22***a* is sent out to the boiler side by a recirculation fan **21***a* through the heat exchanger **3**, and is supplied to the after-gas pipe **14***c* only. Also, similar to the second embodiment, the exhaust gas tapping port **22***b* is disposed immediately after the moisture removing cooler **7**. The exhaust gas taken in from the exhaust gas tapping port **22***b* is supplied to the boiler side by a recirculation fan **21***b* through the heat exchanger **3**, and is supplied to the primary gas pipe **14***a* and the secondary gas pipe **14***b* only.

[0091] With these configurations, similar to the third embodiment, the OH radical reduction effect in the reductive combustion zone can be obtained without arranging the recirculation exhaust gas moisture removing cooler. That is, because it is not necessary to arrange the moisture removing apparatuses in two positions, layout of equipment and piping is facilitated, therefore the apparatuses can be made more simple and inexpensive.

[0092] According to the embodiments in accordance with the present invention, with configuration of a CO_2 emission-free oxyfuel boiler system, a substantial reduction of the NO_x discharge can be realized by more simple apparatuses, therefore spread of CO_2 emission-free power generation can be promoted contributing to suppressing global warming.

What is claimed is:

1. An oxyfuel boiler system comprising:

an oxygen generator to separate oxygen from air;

a coal mill to dry and pulverize coal;

a burner to burn the dried and pulverized coal with oxygen generated at the oxygen generator;

an after-gas port to which oxygen generated at the oxygen generator is supplied;

a boiler provided with the burner and the after-gas port on its wall;

a flue introducing combustion exhaust gas from the boiler to the outside;

a recirculation gas supply pipe having an exhaust gas tapping port disposed in the midway of the flue and supplying recirculation exhaust gas to the coal mill, the burner, and the after-gas port; and

an oxygen supply pipe supplying oxygen from the oxygen generator to the burner and the after-gas port,

wherein the exhaust gas tapping port is disposed downstream of a dry dust-removing apparatus arranged in the flue, and

there is provided an oxygen controlling apparatus for making a concentration of oxygen to be supplied to the after-gas port lower than that of oxygen to be supplied to the burner.

2. An oxyfuel boiler system according to claim **1**,

wherein the exhaust gas tapping port is disposed downstream of the dry dust-removing apparatus and downstream of a moisture removing cooler.

3. The oxyfuel boiler system according to claim **1**,

wherein the exhaust gas tapping port is disposed downstream of the dry dust-removing apparatus and upstream of a first moisture removing cooler, and

a second moisture removing cooler is provided in the midway of the recirculation gas supply pipe.

4. An oxyfuel boiler system comprising:

an oxygen generator to separate oxygen from air;

a coal mill to dry and pulverize coal;

a burner to burn the dried and pulverized coal with oxygen generated at the oxygen generator;

an after-gas port to which oxygen generated at the oxygen generator is supplied;

a boiler provided with the burner and the after-gas port on its wall;

a flue introducing combustion exhaust gas from the boiler to the outside;

recirculation gas supply pipes having two exhaust gas tapping ports disposed in the midway of the flue and supplying recirculation exhaust gas taken in from the respective exhaust gas tapping ports to the boiler; and

an oxygen supply pipe supplying oxygen from the oxygen generator to the burner and the after-gas port,

wherein the oxyfuel boiler system has:

the first exhaust gas tapping port arranged in the flue and disposed downstream of a dry dust-removing apparatus and the second exhaust gas tapping port arranged in the flue and disposed downstream of a moisture removing cooler;

the recirculation gas supply pipe including a first line supplying exhaust gas taken in from the first exhaust gas tapping port to the after-gas port and a second line supplying exhaust gas taken in from the second exhaust gas tapping port to the burner; and

an oxygen controlling apparatus for oxidizer making a concentration of oxygen to be supplied to the after-gas port lower than that of oxygen supplied to the burner.

5. A method of controlling an oxyfuel boiler system, comprising:

an oxygen generator to separate oxygen from air;

a coal mill to dry and pulverize coal;

a burner to burn the dried and pulverized coal with oxygen generated at the oxygen generator;

an after-gas port to which oxygen generated at the oxygen generator is supplied;

a boiler provided with the burner and the after-gas port on its wall;

a flue introducing combustion exhaust gas from the boiler to the outside;

a recirculation gas supply pipe having an exhaust gas tapping port disposed in the midway of the flue and supplying recirculation exhaust gas to the coal mill, the burner and the after-gas port; and

an oxygen supply pipe supplying oxygen from the oxygen generator to pipes supplying exhaust gas to the coal mill, the burner and the after-gas port by the recirculation gas supply pipe,

the method comprising the steps of:

taking exhaust gas in from downstream of a dry dust-removing apparatus arranged in the flue; and

making a concentration of oxygen to be supplied to the after-gas port lower than that of oxygen to be supplied to the burner.

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