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Greenhut et al.(10) **Pub. No.: US 2012/0160142 A1**(43) **Pub. Date: Jun. 28, 2012**(54) **METHOD OF AND APPARATUS FOR
SELECTIVE CATALYTIC NO_x REDUCTION
IN A POWER BOILER****Publication Classification**

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(57) **ABSTRACT**

A method of selective catalytic NO_x reduction in a power boiler and a power boiler with selective catalytic NO_x reduction. Fuel is combusted in a furnace of the boiler and a flue gas stream that includes NO_x is generated. The flue gas stream is conducted from the furnace along a flue gas channel to a stack. The flue gas stream is cooled in a heat recovery area, including an economizer section, arranged in the flue gas channel. At least a portion of the NO_x is reduced to N₂ in an NO_x catalyst arranged in the flue gas channel downstream of the economizer section. The flue gas is further cooled, and heated air is generated in a gas-to-air heater arranged in the flue gas channel downstream of the economizer section and upstream of the NO_x catalyst. The gas-to-air heater may be a tubular air heater or a heat exchanger with a recirculating heat transfer fluid.

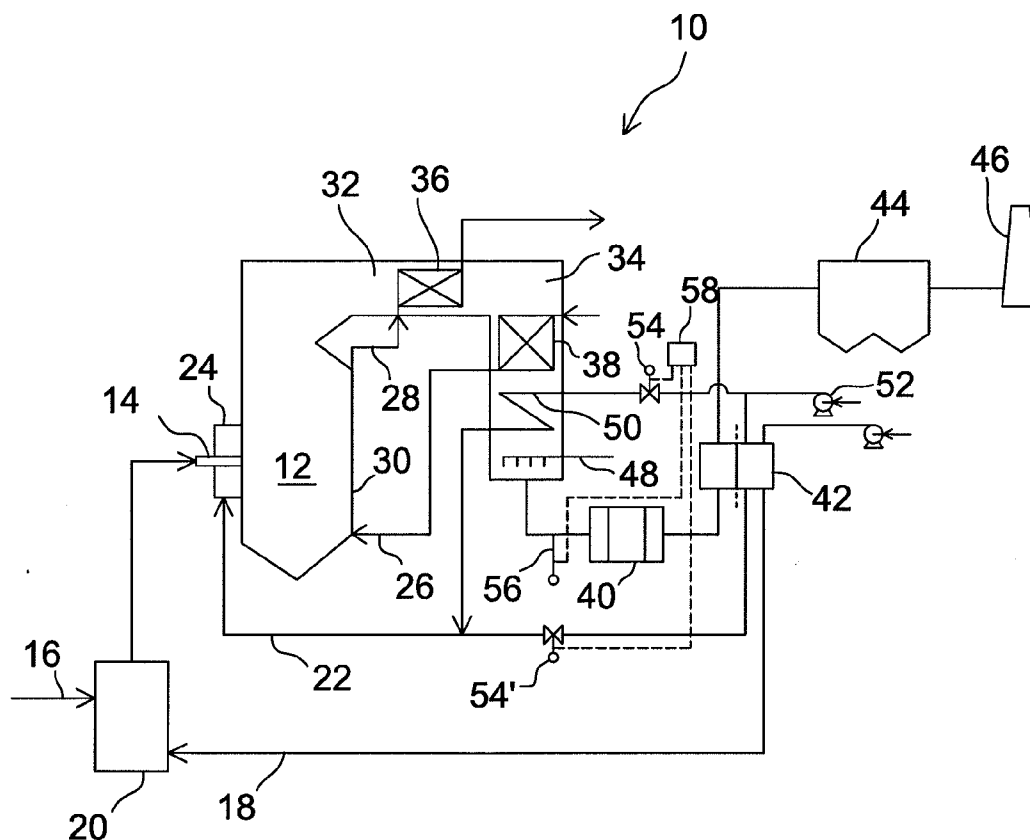


Fig. 1

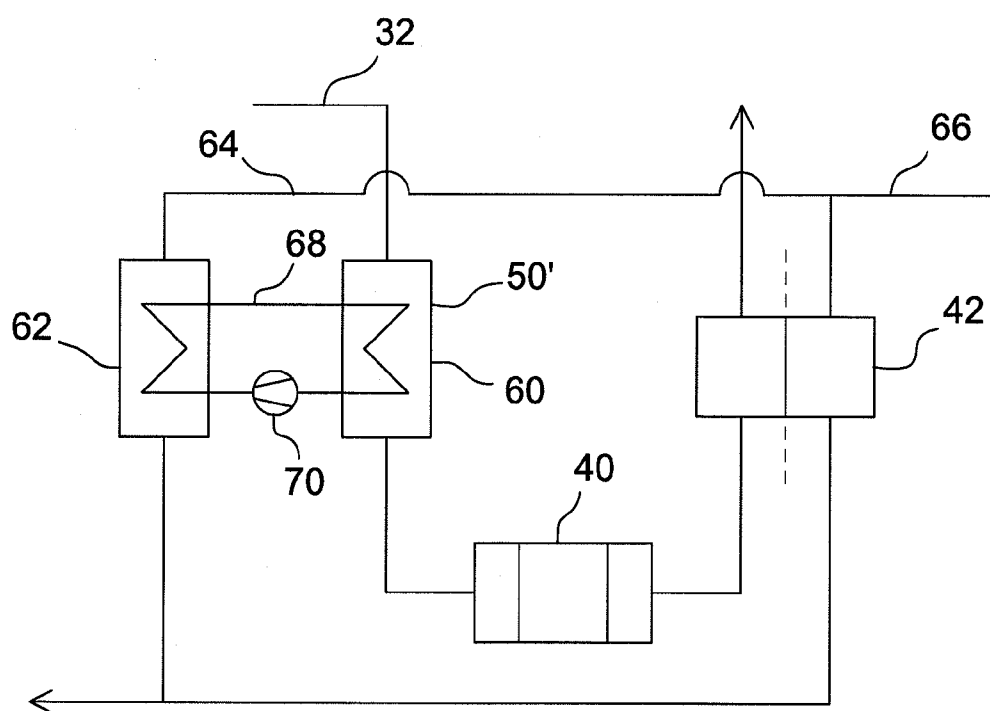


Fig. 2

METHOD OF AND APPARATUS FOR SELECTIVE CATALYTIC NO_x REDUCTION IN A POWER BOILER

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

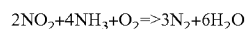
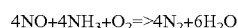
[0002] The present invention relates to a method of and a system for selective catalytic NO_x reduction (SCR) in a solid or a liquid hydrocarbon fuel firing power boiler. More particularly, the present invention relates to controlling the temperature of a flue gas entering an NO_x catalyst of the boiler.

[0003] 2. Description of the Related Art

[0004] Oxides of nitrogen, also known as NO_x, contribute to the generation of acid rain and smog. Due to environmental regulations demanding that NO_x emissions be maintained at acceptable levels, the reduction of NO_x both during and after the combustion process is of a major concern in the design and operation of modern power plants.

[0005] Oxides of nitrogen are a byproduct of the combustion of solid and liquid hydrocarbon fuels, such as pulverized coal or oil, and are found in two main forms. If the nitrogen originates from the combustion air, the NO_x is referred to as "thermal NO_x". Thermal NO_x forms when molecular nitrogen (N₂) is subjected to temperatures above about 1500° C. causing it to break down into elemental nitrogen (N), which can then combine with elemental or molecular oxygen to form NO or NO₂. If the nitrogen originates from organically bound nitrogen in the fuel, the NO_x is referred to as "fuel NO_x".

[0006] Various methods are used to control nitrogen oxide emissions. One method is selective catalytic reduction (SCR), which uses a catalyst and a reductant, typically, gaseous ammonia, to dissociate NO_x to nitrogen gas and water according to the following reactions:



[0007] Since NO_x is approximately ninety-five percent NO, the first reaction dominates the process. The ideal operating temperature range for SCR is generally from about 300 to about 400° C. When operating conditions fall much below 300° C., the potential for ammonium bisulfate formation and sulfur trioxide deposits on the catalyst surface increases. This can cause permanent catalyst activity loss. Above 400° C., ammonia may dissociate, reducing the effectiveness of the process. If temperatures exceed about 450° C., the catalyst activity might be permanently impaired due to sintering.

[0008] A typical power boiler utilizing SCR as an NO_x reduction technique comprises a furnace in fluid communication with a flue gas channel. Combustion of hydrocarbon fuels occurs in the furnace generating hot flue gases that rise within the furnace, giving up a portion of their energy to generate steam in the evaporator surfaces at the walls of the furnace. The flue gases are then directed through a heat recovery area (HRA) of the flue gas channel, wherein they give up additional energy to superheat the steam and to heat feed water in the economizer surfaces. Flue gases exiting the economizer section are directed through an NO_x catalyst, an air preheater and possible flue gas cleaning systems, and finally, via a stack to the atmosphere.

[0009] In a typical SCR system, at some point in the flue gas channel upstream of the catalyst section, a reactant, such as gaseous ammonia or a solution of urea in water, is introduced into and mixed with the flue gas stream. The mixture of the reactant and flue gas then enters the catalyst section wherein

catalytic reduction of NO_x takes place between the reactant and excess oxygen in the flue gas.

[0010] The catalyst typically includes multiple layers of solid catalytic material lying within the path of the flue gas stream. The most common types of catalytic material in use and the approximate temperature ranges of the flue gas over which they are effective as catalysts are: titanium dioxide (270-400° C.), zeolite (300-430° C.), iron oxide (380-430° C.) and activated coal/coke (100-150° C.).

[0011] U.S. Pat. No. 5,555,849 discloses a fossil fuel power plant with an economizer system upstream of an NO_x catalyst, wherein the economizer system comprises a water-side bypass line in order to maintain a desired flue gas temperature in the NO_x catalyst even at low load conditions.

[0012] European patent publication EP 0 753 701 A1 discloses a boiler with an NO_x catalyst disposed in the flue gas channel between two economizers and having a flue gas bypass channel for the economizer upstream of the NO_x catalyst.

[0013] U.S. Pat. No. 6,405,791 discloses a tubular air heater with an inlet plenum which permits retrofit installation of a selective catalytic reduction (SCR) system upstream of the air heater in an existing boiler.

[0014] In addition to the problem addressed by U.S. Pat. No. 5,555,849, it has been observed that, especially in retrofit installations of an NO_x catalyst in an existing power boiler, the flue gas temperature at the NO_x catalyst may, especially at high loads, tend to be too high. Due to, for example, changes in the fuel or operation mode of the boiler, or even poor design of the boiler, the economizer outlet temperature may be in excess of 430° C., i.e., above the optimal temperature range of existing NO_x catalysts.

[0015] Therefore, the adding of an SCR downstream of the economizer to reduce NO_x may require the use of a special catalyst. Another solution to this problem is to install additional economizer surfaces in the heat recovery area (HRA) of the boiler. This method, however, increases the feed water temperature and, if the temperature rises close to the saturation temperature of the steam drum, it will have negative effects on the water circulation of the boiler and ultimately, reduce boiler performance.

SUMMARY OF THE INVENTION

[0016] An object of the present invention is to provide a method of selective catalytic NO_x reduction in a power boiler by which problems of the prior art described above can be minimized.

[0017] Another object of the present invention is to provide an apparatus for selective catalytic NO_x reduction in a power boiler by which problems of the prior art described above can be minimized.

[0018] According to one aspect, the present invention provides a method of selective catalytic NO_x reduction in a power boiler, the method comprising the steps of (a) combusting fuel in a furnace of the boiler and generating a flue gas stream that includes NO_x, (b) conducting the flue gas stream from the furnace along a flue gas channel to a stack, (c) cooling the flue gas stream in a heat recovery area, including an economizer section, arranged in the flue gas channel, (d) reducing at least a portion of the NO_x to N₂ in an NO_x catalyst arranged in the flue gas channel downstream of the economizer section, and (e) further cooling the flue gas and generating heated air in a gas-to-air heater arranged in the flue gas channel downstream of the economizer section and upstream of the NO_x catalyst.

[0019] According to another aspect, the present invention provides a power boiler, with selective catalytic NO_x reduc-

tion, the boiler including (a) a combustor for combusting fuel in a furnace of the boiler so as to generate a flue gas stream including NO_x , (b) a flue gas channel for conducting the flue gas stream from the furnace to a stack, (c) a heat recovery area, including an economizer section, arranged in the flue gas channel for cooling the flue gas stream, (d) an NO_x catalyst arranged in the flue gas channel downstream of the economizer section for reducing at least a portion of the NO_x to N_2 , and (e) a gas-to-air heater arranged in the flue gas channel downstream of the economizer section and upstream of the NO_x catalyst for further cooling the flue gas and for generating heated air.

[0020] The present invention, i.e., the arranging of a gas-to-air heater upstream of the NO_x -catalyst to cool the flue gas, provides the advantage of rendering possible the installation of a conventional NO_x catalyst using a standard catalyst material. The gas-to-air heater is preferably a tubular air heater, but may, in some cases, also be of other types of heat exchangers that transfer heat from the flue gas to combustion air of the boiler. According to another preferred embodiment of the present invention, the gas-to-air heater is a heat exchanger with a recirculating heat transfer fluid. The gas-to-air heater may, in some applications, alternatively be of another suitable type, for example, a heat pipe.

[0021] Advantageously, the power boiler comprises a burner, or, in practice, a set of burners, for combusting the fuel carried to the burners by a stream of primary air. According to a first embodiment of the present invention, the combustion air heated in the gas-to-air heater is conducted as secondary air to the burners. Due to the use of the secondary air as the cooling medium, the method does not have a risk of overheating the cooling medium, as the case may be when using feed water as the cooling medium. Moreover, because the heat transferred to the secondary air can be fully recovered in the boiler, the method does not affect the operation or efficiency of the existing boiler. The combustion air heated in the gas-to-air heater can also alternatively be of other types of combustion air, for example, primary air, to be conducted to the furnace.

[0022] When using a method in accordance with the present invention in different load conditions of the boiler, the flow of air through the gas-to-air heater can be modulated, or shut off, to maintain a desired temperature of the flue gas entering into the catalyst. The flow of air can thus advantageously be controlled directly on the basis of the load conditions of the boiler, or on the basis of a measured temperature of the flue gas entering the NO_x catalyst. Thus, the present invention provides a simple method to provide optimized operation of the catalyst in different load conditions, without, for example, a need to provide an economizer with a flue gas by-pass, or water side by-pass, for low load operation. The present invention thus provides a wide range of temperature control, without requiring any change in the flue gas or steam/water circuitry of the boiler. The invention is thus especially useful in retrofit applications, but it can be applied in new units as well, for example, to control the temperature of the flue gas entering the NO_x catalyst.

[0023] The above brief description, as well as further objects, features, and advantages of the present invention will be more fully appreciated by reference to the following detailed description of the currently preferred, but nonetheless illustrative, embodiments of the present invention, taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

[0024] FIG. 1 is a schematic diagram of an exemplary power boiler in accordance with the present invention.

[0025] FIG. 2 shows a portion of a flue gas channel of a power boiler according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0026] FIG. 1 is a schematic diagram of a pulverized coal combustor power boiler 10 in accordance with the present invention. The boiler comprises a furnace 12 with a burner 14 for injecting a mixture of pulverized coal 16 and primary air 18 from a coal mill 20 to the furnace. Usually, a power boiler comprises multiple burners but, for the sake of simplicity, only one burner is shown in FIG. 1. The fuel is combusted in the furnace with the primary air and secondary air 22, injected to the furnace via a windbox 24 adjacent to the burner, and hot flue gas is generated. The combustion may in practice be completed by tertiary air and/or overfire air injected in the furnace downstream of the burners, but, for the sake of simplicity, injection of tertiary air and/or overfire air is not shown in FIG. 1. Generated hot flue gases rise within the furnace, giving up a portion of their energy in evaporator surfaces 30 at the walls of the furnace to evaporate feed water 26 to steam 28. The flue gas is discharged from the furnace along a flue gas channel 32 connected to the upper portion of the furnace. [0027] The flue gases are then directed through a heat recovery area (HRA) 34 of the flue gas channel, wherein they give up additional energy in superheater surfaces 36 to superheat the evaporated steam and in economizer surfaces 38, to preheat feed water to be fed to the evaporator surfaces. Typically, the HRA comprises multiple superheater and reheater surfaces, but because they are not important for the present invention, only one superheater 36 is shown in FIG. 1.

[0028] Flue gases exiting the economizer 38 are directed through an NO_x catalyst 40, an air preheater 42, a flue gas cleaning system 44, and a stack 46 to the atmosphere. The flue gas channel 32 also comprises an injector 48 for injecting NO_x reductant, such as ammonia, upstream of the catalyst 40. The catalyst 40 preferably comprises conventional catalyst material, such as titanium oxide or iron oxide. Typically, the flue gas cleaning system comprises several flue gas cleaning units, such as a dust separator and a desulfurizer, but because they are not important for the present invention, only one schematic gas cleaning system 44 is shown in FIG. 1.

[0029] In accordance with the present invention, the flue gas channel comprises a gas-to-air heater, in this case, a tubular air heater 50, arranged upstream of the NO_x catalyst 40. By the tubular air heater, it is possible to cool the flue gas, as desired, to an optimal temperature range for the catalyst, for example, to below about 400° C.

[0030] The tubular air heater 50 is advantageously connected so as to render possible additional heating of the secondary air 22. In some embodiments, it is also possible to use the tubular air heater to heat the primary air 18, or tertiary air or overfire air, not shown in FIG. 1. According to a preferred embodiment of the present invention, the tubular air heater 50 is connected in parallel with the air heater 42, which is here also called a second air heater, arranged in the flue gas channel 32 downstream of the NO_x catalyst 40. Thus, the stream of secondary air from the secondary air blower 52 can be divided, by using control devices, such as control valves 54, 54', between the tubular air heater 50 and the air heater 42 downstream of the catalyst 40.

[0031] The ratio of the air flows through the tubular air heater 50 and the air heater 42 downstream of the catalyst 40 can advantageously be determined on the basis of the boiler load, or on the basis of the flue gas temperature upstream of the catalyst, as measured by a temperature measuring device, such as a thermometer 56. Thus, the system advantageously

comprises a controller **58** for controlling the control valves **54**, **54'** on the basis of the measured temperature.

[0032] Typically, at high loads, when the temperature of the flue gas upstream of the catalyst tends to rise above the optimal operating temperature of the catalyst, a larger portion of the secondary air is conducted through the tubular air heater **50** by at least partially closing the valve **54'** arranged in the branch of the secondary air line leading through the air heater **42** arranged downstream of the catalyst **40**. Correspondingly, at low loads, a smaller portion of the secondary air is conducted through the tubular air heater by at least partially closing the valve **54** arranged in the branch of the secondary air feeding line leading through the tubular air heater **50**. Thus, by controlling the division of the air stream between the tubular air heater **50** and the air heater **42** downstream of the NO_x catalyst **40**, it is possible to optimize the temperature of the flue gas entering the NO_x catalyst at different load conditions.

[0033] FIG. 2 shows a portion of the flue gas channel **32** of a power boiler according to another embodiment of the present invention. A gas-to-air heater **50'** is arranged in the flue gas channel upstream of a catalyst section **40** and a conventional air heater **42** is arranged downstream of the catalyst section **40**. According to this embodiment, the gas-to-air heater **50'** comprises a flue gas cooler **60** in the flue gas channel **32** and a separate air heater **62** in a branch **64** of an air feeding line **66**. The flue gas cooler **60** and the air heater **62** are connected by a pipe **68** for circulating a heat transfer fluid with a pump **70**.

[0034] While the invention has been described herein by way of examples in connection with what are at present considered to be the most preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but is intended to cover various combinations or modifications of its features and several other applications included within the scope of the invention as defined in the appended claims.

We claim:

1. A method of selective catalytic NO_x reduction in a power boiler, the method comprising the steps of:

- (a) combusting fuel in a furnace of the boiler and generating a flue gas stream that includes NO_x ;
- (b) conducting the flue gas stream from the furnace along a flue gas channel to a stack;
- (c) cooling the flue gas stream in a heat recovery area, including an economizer section, arranged in the flue gas channel;
- (d) reducing at least a portion of the NO_x to N_2 in an NO_x catalyst arranged in the flue gas channel downstream of the economizer section; and
- (e) further cooling the flue gas and generating heated air in a gas-to-air heater arranged in the flue gas channel downstream of the economizer section and upstream of the NO_x catalyst.

2. The method according to claim 1, wherein the gas-to-air heater is connected to an air flow to provide heated air to be conducted as secondary air to a burner arranged in the furnace.

3. The method according to claim 1, further comprising an additional air heater arranged in the flue gas channel downstream of the NO_x catalyst.

4. The method according to claim 3, wherein the gas-to-air heater and the additional air heater are connected in parallel to an air flow.

5. The method according to claim 4, further comprising the step of controlling the flow of air entering into the gas-to-air heater on the basis of the load conditions of the power boiler.

6. The method according to claim 4, further comprising the steps of measuring the temperature of the flue gas entering into the NO_x catalyst, and controlling the flow of air entering into the gas-to-air heater on the basis of the measured temperature.

7. The method according to claim 1, wherein the gas-to-air heater is a tubular air heater.

8. The method according to claim 1, wherein the gas-to-air heater is a heat exchanger with a recirculating heat transfer fluid.

9. A power boiler with selective catalytic NO_x reduction, the boiler comprising:

- (a) a combustor for combusting fuel in a furnace of the boiler so as to generate a flue gas stream including NO_x ;
- (b) a flue gas channel for conducting the flue gas stream from the furnace to a stack;
- (b) a heat recovery area, including an economizer section, arranged in the flue gas channel for cooling the flue gas stream;
- (d) an NO_x catalyst arranged in the flue gas channel downstream of the economizer section for reducing at least a portion of the NO_x to N_2 ; and
- (e) a gas-to-air heater arranged in the flue gas channel downstream of the economizer section and upstream of the NO_x catalyst for further cooling the flue gas and for generating heated air.

10. The power boiler according to claim 9, wherein the combustor for combusting fuel comprises a burner, and the gas-to-air heater is connected to an air channel for conducting the heated air to the furnace as secondary air adjacent to the burner.

11. The power boiler according to claim 9, further comprising an additional air heater arranged in the flue gas channel downstream of the NO_x catalyst.

12. The power boiler according to claim 11, wherein the gas-to-air heater and the additional air heater are connected in parallel to an air channel.

13. The power boiler according to claim 9, further comprising a controller for controlling the flow of air entering into the gas-to-air heater on the basis of the load conditions of the power boiler.

14. The power boiler according to claim 9, further comprising a temperature gauge for measuring the temperature of the flue gas entering into the NO_x catalyst, and a controller for controlling the flow of air entering into the gas-to-air heater on the basis of the measured temperature.

15. The power boiler according to claim 9, wherein the gas-to-air heater is a tubular air heater.

16. The power boiler according to claim 9, wherein the gas-to-air heater is a heat exchanger with a recirculating heat transfer fluid.

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