The invention uses an input signal directly from a fuel flow device to control the amount of ammonia injected into a flue gas stream for NOx reduction for boilers. The control system receives a signal directly from a fuel flow device that indicates the amount of fuel flow and corresponding NOx emissions. The signal is processed using an algorithm with a multi-loop controller and an ammonia mass flow control valve with temperature and pressure corrections to determine how much ammonia must be injected into the flue gas in the presence of a catalyst to achieve the desired NOx emissions reductions. A dilution air blower transports ammonia to an injection grid and subsequently, the ammonia reacts with the flue gas in the presence of a catalyst to reduce the amount of NOx emissions to the desired level.

A bias function that allows a boiler operator to manually increase or decrease the flow of ammonia in order to vary the amount of NOx reduction is included and can be used as an alternate to automatic operation, thus allowing an operator to dictate the amount of ammonia to be injected into the system. Air temperature and pressure correction functions are also included to adjust the ammonia flow based on a given temperature and fuel flow.
FIG. 4

- AINU2
- AIN1
- DIN1
- NOR1
- MTH1
- HLD2
- SUB1
- SCL1
- ODC
- LMT1
- HLD1
- AOUT1

Blocks and connections labeled with numbers.
NOX REDUCTION CONTROL SYSTEM FOR BOILERS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not Applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable

REFERENCE TO SEQUENCE LISTING, A TABLE, OR A COMPUTER PROGRAM LISTING COMPACT DISK APPENDIX

[0003] Not Applicable

BACKGROUND OF THE INVENTION

[0004] The embodiment is in the technical field of boiler steam generation emissions control. More particularly, the present invention is in the technical field of controlling the amount of NH₃ (ammonia) present as part of a selective catalytic reduction (SCR) system. Selective catalytic reduction is a post-combustion control technology that involves the injection of ammonia in the boiler exhaust gases in the presence of a catalyst to significantly reduce and control airborne contaminants of NOx, the cumulative emissions of nitric oxide (NO) and nitrogen dioxide (NO₂) and trace quantities of other nitrogen-bearing species generated during combustion. Ammonia must be present for the selective catalytic reduction process to occur, however if not controlled, it can lead to what is known as "ammonia slip"; the term used when ammonia is not consumed in the reaction and passed through the atmosphere.

[0005] The federal Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) that set forth maximum allowable concentrations of pollutants in the ambient air. Through the NAAQS, areas of the United States are designated as either being in attainment or nonattainment. It is the responsibility of each state to regulate addressing individual pollution sources in order to achieve the pollutant reductions necessary to comply with NAAQS.

[0006] Boiler NOx formation is produced from the boiler burner, which uses combustion to produce heat. Under high temperatures of combustion, thermal NOx is formed. The amount of NOx formed varies with the fuel/air ratio. Ambient temperature, which affects the density of air, impacts the fuel/air ratio.

[0007] Several NOx reduction control systems exist today by a number of manufacturers and equipment integrators. Unlike prior art which are neither self contained nor skid mounted, this embodiment fulfills the need for a self contained system that is easy to install (new or retrofit) as a complete package. This embodiment is also unique in that it can be installed without requiring changes to existing boiler controls or combustion settings in order to receive signals to the control system. This is an advantage because the invention is easy to install and operate, with very little operator intervention.

[0008] Unlike prior art, this embodiment also performs ammonia flow trimming, based on ambient temperature. Ammonia flow is accurately adjusted based on ambient temperature to maintain NOx emissions and ammonia slip within acceptable limits. This is an advantage because current air quality regulations are enforced to tightly control the amount of allowable NOx and ammonia slip and this embodiment maintains these within the acceptable limit.

[0009] Unlike prior art, this embodiment does not require a separate and costly continuous emissions monitoring system (CEMS) device for emission control. A continuous emissions monitoring system is the total equipment necessary for the determination of a gas or particulate matter concentration or emission rate using pollutant analyzer measurements and a conversion equation, graph, or computer program to produce results in units of the applicable emission limitation or standards. CEMS are required under some regulations for either continual compliance determinations or determination of emissions exceedances of the standards. Many current selective catalytic reduction systems require a CEMS for their control.

[0010] In addition, the control signals used in this embodiment are feed forward signals that are received directly from a fuel flow device. This function eliminates the need for the boiler system to have additional emission monitoring equipment or devices that are needed to receive a signal and it allows the boiler to stay in compliance with regulated NOx emission levels during normal and changing load operating conditions.

[0011] An advantage of this embodiment is that it includes a bias function that allows a boiler operator to manually increase or decrease the flow of ammonia in order to vary the amount of NOx reduction. This function allows added control of the ammonia flow to the selective catalytic reduction system and adjusts the ammonia flow curve automatically, thus allowing an operator to compensate for NOx variations without shutting down and re-setting the ammonia flow algorithm.

BRIEF SUMMARY OF THE INVENTION

[0012] The present invention is a NOx reduction control system designed to control the amount of ammonia used with a NOx reduction catalyst as part of a selective catalytic reduction system for boilers (package boilers, whether firetube and watertube type, indicating that the boiler is shipped to an end user completely assembled and includes a burner and controls, thus the NOx control system described here is ideal for package type boilers). This approach can be applied to new boiler application or as a retrofit to an existing boiler system in order to improve the overall operation of ammonia flow control and NOx reduction capabilities.

[0013] A fuel flow measuring device, with an analog signal, is processed with a multi-loop, configurable controller and a mass flow control valve designed with temperature and pressure correction to determine the amount of ammonia to inject into the flue gas stream based on an algorithmic calculation. This reduces NOx to the acceptable limit, based on ambient temperature and fuel flow, with bias operation for manual control.

[0014] This invention also includes ambient air temperature correction, a method of controlling the NOx formed by measuring the ambient air temperature and adjusting the ammonia flow based on an ambient air temperature calculation which provides an accurate NOx reduction (up to 99%) with precise ammonia flow control.

BRIEF DESCRIPTION OF THE FIGURES 1 TO 6

[0015] FIG. 1 is a perspective view of a typical industrial watertube boiler and the present invention.
FIG. 2 is a perspective view of a typical industrial firetube boiler and the present invention. FIG. 3 is a perspective view of the present invention control panel showing input and output signals. FIG. 4 is a perspective view of an ammonia flow control configuration (ammonia flow control loop) of the present invention. FIG. 5 is a perspective view of an ammonia flow control configuration temperature limit (ammonia flow start, ammonia flow stop, boiler shutdown). FIG. 6 is a perspective view of an ammonia flow control configuration (ammonia flow loop) of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The invention uses an analog signal directly from a fuel flow device (or similar fuel flow measuring device) to control ammonia for NOx reduction. The control system can also use an alternate analog load signal from the boiler master control, plant master or plant digital control system (better known as a plant or boiler DCS). With the boiler in either manual or automatic operation, the control system receives a signal directly from the fuel flow device indicating the amount of fuel burning and corresponding NOx emissions. The signal is processed using an algorithm with a multi-loop, configurable controller and a mass flow control valve designed with temperature and pressure correction to determine the accurate amount of ammonia to be injected into the flue gas to achieve the desired performance. Air transports the ammonia to an injection grid and subsequent, a mixture of ammonia and flue gas is passed over a catalyst bed, which performs a chemical reaction and reduces NOx emissions to the desired result (typically less than 5 ppmv).

Referring now to FIG. 1 there is shown an industrial watertube boiler 10 mounted on the ground, having a fuel supply line 12 mounted on the boiler, with a fuel flow device 14 connection. Duct work 16 which connects watertube boiler 10 to the ammonia injection grid 18. Mounted directly atop ammonia injection grid 18 is catalyst reactor housing 20. Stack 22 provides an outlet for flue gas flow 24 and is mounted atop and connected to catalyst reactor housing 20. Further, NOx reduction control system 26 is wired to fuel flow device 14 and ammonia flow control valve 28. Nitrogen air blower 32 is placed on ground level next to anhydrous ammonia tank 30 which is connected to ammonia flow control valve 28.

Still referring to FIG. 1 the industrial watertube boiler when in operation receives fuel from fuel supply line 12 and an analog signal from fuel flow device 14 sends a signal to NOx reduction control system 26 indicating the amount of fuel being consumed by watertube boiler 10. The signal is processed in NOx reduction control system 26 using an algorithm with a multi-loop, configurable controller and ammonia flow control valve 28 (later described in FIG. 3) to determine the proper amount of ammonia from anhydrous ammonia tank 30 to inject. Dilution air blower 32 transports ammonia through the ammonia injection grid 18. A chemical reaction occurs when the ammonia flow passes through the catalyst and converts NOx to water and nitrogen.

NOx reduction control system 26 as shown includes the sub components described in FIG. 3. The connection material between firetube boiler 52, ammonia injection grid 18, catalyst reactor housing 20, and stack 22 must be sufficiently mounted, bolted and secure in order to prevent energy loss and safe operation. NOx reduction control system 26 is wired to fuel flow device 14 and watertube boiler 10.

In FIG. 2 there is shown an industrial firetube boiler 52 mounted on the ground, having a fuel supply line 12 with a fuel flow device 14 connection. Mounted atop firetube boiler 52 is ammonia injection grid 18. Mounted directly atop ammonia injection grid 18 is catalyst reactor housing 20. Stack 22 provides an outlet for flue gas flow 24 and is mounted and connected to catalyst reactor housing 20. Further, ammonia flow control valve 28 is wired to fuel flow device 14 and NOx reduction control system 26. Dilution air blower 32 is placed on ground level next to anhydrous ammonia tank 30 which is connected to ammonia flow control valve 28.

Still referring to FIG. 2 the industrial firetube boiler when in operation receives fuel from an external fuel line. The fuel passes through fuel supply line 12 and an analog signal from fuel flow device 14 sends a signal to NOx reduction control system 26 indicating the amount of fuel being consumed by firetube boiler 52. The signal is processed in NOx reduction control system 26 using an algorithm with a multi-loop, configurable controller and a mass flow control valve 14 (later described in FIG. 3) to determine the proper amount of ammonia from anhydrous ammonia tank 30 to inject. Dilution air blower 32 transports ammonia through ammonia injection grid 18. A chemical reaction occurs when the ammonia flue gas mixture passes through the catalyst and converts NOx to water and nitrogen.

In FIG. 2, NOx reduction control system 26 as shown includes the sub components described in FIG. 3. The connection material between firetube boiler 52, ammonia injection grid 18, catalyst reactor housing 20, and stack 22 must be sufficiently mounted, bolted and secure in order to prevent energy loss and safe operation. NOx reduction control system 26 is wired to fuel flow device 14 and firetube boiler 52.

In FIG. 3 there is shown the main inputs and output signals to and from multi-loop, configurable controller with bias control 54, mounted on the face of control panel box 56. Input signals include fuel flow device input signal 58 and ambient air temperature signal 60, boiler on/off signal 53, flue gas temperature 57 and interlocking devices 55 (low ammonia, high ammonia, low dilution air, low instrument air (as required to drive valves and controls)). Output signal 62 is directly linked to ammonia flow control valve 28 which connects to the anhydrous ammonia tank 30.

Still referring to FIG. 3, included with interlocking devices 55 is optional auxiliary dry contact output for boiler shutdown or remote alarms 63. Optional auxiliary dry contact for boiler shutdown or remote alarms 63 may include additional monitoring capabilities via Ethernet.

Also in FIG. 3 the industrial watertube boiler 10 (from FIG. 1) or firetube boiler 52 (from FIG. 2) when in operation sends fuel flow device signal 58, ambient air temperature signal 60, flue gas temperature 57, interlocking device signals 55, and boiler on/off signal 53 to bias control 54 which calculates the signal and sends output signal 62 to ammonia mass flow control valve 28. Based on the signal input, a varying amount of ammonia is injected into the system from anhydrous ammonia tank 30 based on the calculated input signals and the ammonia is sent to the ammonia injection grid 18 (from FIG. 1) via ammonia output 66.
In order for bias control 54 to receive boiler on/off signal 53, fuel flow device signal 58, and ambient air temperature signal 60, the connections between boiler on/off signal 53, bias control 54, fuel flow device 58 and ambient air temperature 60 must be sufficiently secure and weather protected.

Referring now to FIG. 4 there is shown a universal analog input 76, subtraction function 72, hold function 74, scaler 78, analog input 80, characterizer 82, math function 84, bias control 86, signal input 94, logic block 96, hold function 98, auto manual station 99, limit function 100, signal output 102 and operator display 70.

Still referring to FIG. 4 there is shown a complete ammonia flow control configuration (ammonia flow control loop). Signal input 94 uses binary code to allow ammonia flow based on boiler run status. Logic block 96 inverts signal input 94 as hold function 98 holds ammonia control output at zero percent (at “0” or “off”) when ammonia demand is satisfied. Analog input 80 measures gas flow, 4-20 mA signal from gas flow transmitter, characterizer 82 sets ammonia flow curve based on gas flow. Math function 84 performs ammonia flow correction based on ambient temperature. Bias control 86 allows for operator intervention to bias the ammonia flow curve within a negative to positive percentage based on minimum and maximum ammonia flow. Auto manual station 88 puts the control in standby based on signal input 94 and logic block 96. Limit function 100 limits the output to an operating range of 0-100 percent. Signal output 102 sends ammonia flow set point to the ammonia flow control valve.

Universal analog input 76 measures ambient air temperature that is based on a Rankine thermodynamic (absolute) temperature scale. Scaler 78 sets the decimal point in the ambient temperature display. Subtraction process 72 converts ambient air temperature from Rankine to Fahrenheit for the display, only viewed on operator display 70. Hold 74 holds the value of absolute zero for absolute temperature correction. Operator display 70 allows operator to view individual loops.

Referring now to FIG. 5 there is shown universal signal input 102, comparator 104, delay timer 106, delay timer 108, relay output 110, delay timer 114, delay timer 116, relay output 118 and operator display 100.

Still referring to FIG. 5 there is shown a complete ammonia flow control configuration selective catalytic reduction flue gas inlet temperature loop. Universal signal input 102 receives a signal input signal from selective catalytic reduction inlet flue gas temperature measuring device. Comparator 104 is typically set to turn on when the flue gas inlet temperature is greater than a set-point of three hundred and twenty five degrees Fahrenheit. Timer 106 is typically set for a 30 second “off delay” low stack temperature, whereas delay timer function 108 is typically set for a 60 second “on delay” for off of a low selective catalytic reduction flue gas inlet temperature, both used to eliminate cycling relay output 110. Relay output 110 will open or close based on the selective catalytic reduction inlet flue gas temperature. When the flue gas inlet temperature is less than a set-point of three hundred and twenty five degrees Fahrenheit of ammonia flow, relay output 110 is typically set to turn off. When the flue gas inlet temperature is greater than a set-point of three hundred and twenty five degrees Fahrenheit of ammonia flow, relay output 110 is typically set to turn on.

Comparator 112 is the high selective catalytic reduction inlet flue gas temperature set-point, typically set to shutdown at seven hundred degrees Fahrenheit. Delay timer 114 is typically set for a 30 second “off delay” for high selective catalytic reduction inlet flue gas temperature, whereas delay timer 116 is typically set for a 60 second “on delay” for high selective catalytic reduction inlet flue gas temperature.

Relay output 118 is typically set to open the boiler limit circuit to shutdown of the boiler when selective catalytic reduction inlet flue gas temperature is above a set-point of seven hundred degrees Fahrenheit. When flue gas inlet temperature is less than a set-point of seven hundred degrees Fahrenheit, relay output 118 is typically set to turn on. When flue gas inlet temperature is greater than a set-point of seven hundred degrees Fahrenheit of ammonia flow, relay output 118 is typically set to turn off. Operator display 100 allows operator to view individual loops.

Referring now to FIG. 6 there is shown operator display 120 analog input 122 and analog output 124.

Still referring to FIG. 6, analog input 122 reads the actual ammonia flow from the control valve. Analog output 124 is an option to monitor ammonia flow remotely and is programmed to send data to an external reader (if applicable). Operator display 120 allows the operator to view individual loops.

In broad embodiment, the invention is a multi-loop, configurable control system of any manufacture type which receives a signal for fuel flow or boiler load and receives a signal from the ambient air temperature and allows for manual bias operation, which then outputs a signal to a control valve, allowing for a precise amount of ammonia to be passed through an injection grid.

While the foregoing written description enables one of ordinary skill to make and use what is considered presently to be the best mode thereof, those of ordinary skill will understand and appreciate the existence of variations, combinations, and equivalents of the specific embodiment, method, and examples herein. It should therefore not be limited by the above described embodiment, method, and examples, but by all embodiments and methods within the scope and spirit as claimed.

We claim:

1. A control system, as part of a boiler system, for a selective catalytic reduction system, comprising a device to give a fuel flow input signal from the boiler and a device to give an ambient air temperature input signal, being processed and corrected by a configurable controller which sends an output signal to an ammonia mass flow control valve that sets a specific amount of ammonia to be injected to the ammonia injection skid and catalyst for NOX emissions reductions.

2. In accordance with claim 1, a control system with the option of bias operation.

3. In accordance with claim 1, wherein the control system can be set to hold ammonia control output at zero percent until ammonia demand is satisfied.

4. In accordance with claim 1, wherein the control system includes relay outputs for shutting off of the ammonia when selective catalytic reduction inlet flue gas temperature is below or above a given temperature set-point.

5. In accordance with claim 1, wherein the control system has an algorithm that sets the ammonia flow based on the boiler fuel flow or the boiler load signal.

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