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(54) Regenerative air preheater design to reduce cold end fouling

(57) An air preheater 100 is described having an air damper assembly 162 that partially restricts an air inlet 130 and a flue gas damper assembly 152 that partially restricts flue gas inlet 124 during periods of reduced boiler load. Restricting the flue gas inlet 124 reduces the effective surface area of the preheater causing more heat to pass to the cold end of the air preheater 100, reducing acid condensation and fouling. Restricting the gas inlet 124, increases gas velocity, thereby eroding accumulations in the air preheater 100, also reducing fouling. Restricting the air inlet 130 reduces the effective heat transfer surface area of the air preheater, which raises the gas temperature in the cold end of the air preheater and thereby reduces acid condensation and fouling.

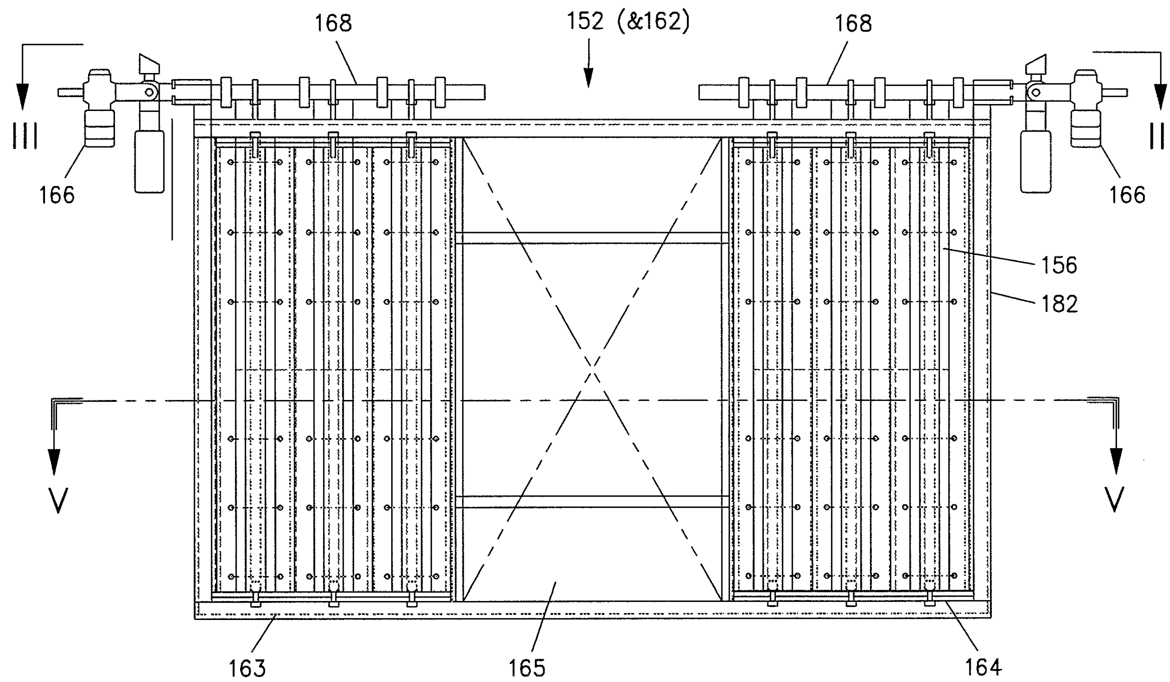

Figure 3

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Description

BACKGROUND OF THE INVENTION

1. Field of The Invention

[0001] This invention relates generally to a steam generating system having a fossil fuel fired boiler and a regenerative air preheater. More particularly, the present invention relates to a steam generating system having a fossil fuel fired boiler and a rotary regenerative air preheater that exhibits reduced fouling during varying boiler operating levels.

2. Discussion of Prior Art

[0002] During the combustion process in the boiler, the sulfur in the fuel is oxidized to SO_2. After the combustion process, some amount of SO_2 is further oxidized to SO_3 with typical amounts on the order of 1 to 2% going to SO_3. The presence of iron oxide, vanadium and other metals at the proper temperature range produces this oxidation. Selective catalytic reduction (SCR) is also widely known to oxidize a portion of the SO_2 in the flue gas to SO_3. The catalyst formulation (primarily the amount of vanadium in catalyst) impacts the amount of oxidation, with rates ranging from 0.5% to over 1.5%. Most typical is around 1%. Therefore plants firing a high sulfur coal with a new SCR can see a large increase in the SO_3 emissions, which produce a visible plume, local acidic ground level problems and other environmental issues.

[0003] Rotary regenerator heat exchangers are commonly used on a large fossil fuel fired boiler to transfer heat from the hot flue gasses to the cooler input air that is provided to a combustion chamber of the boiler. This type of heat exchanger is typically referred to as an air preheater. The purpose of an air preheater is to increase the efficiency of the fossil fueled boiler. Fundamentally, a rotary regenerative air preheater consists of a large cylinder packed with a plurality of spaced sheets of metal. The sheets are separated from one another to allow hot flue gases to flow over the surface of each plate parallel to the axis of the cylinder, heating them. The hot sheets are rotated into the cooler input air stream to heat the input air. The flue gases and input air usually flow through the air preheater in opposite directions. The entire cylinder is continually rotated around its axis so that the hot gas and the cold air flow alternately over the same metal sheets.

[0004] The products of combustion of a fossil fuel often contain both sulfur trioxide (SO_3) and water vapor (H_2O) so that when the exhaust gas is cooled to a sufficient degree within the air preheater, the SO_3 combines with water vapor and condenses into liquid sulfuric acid (H_2SO_4). This occurs when the temperature of surfaces, such as a heat exchange element of an air preheater, is below the dew point of sulfuric acid. When ash particles and sulfuric acid are both deposited on the metal surfaces in the air preheater, they stick to the metal surfaces and cause a phenomenon called fouling. Fouling degrades the efficiency of the air preheater by restricting the amount of air and gas flowing through the air preheater.

[0005] High velocity jets of steam or air are periodically directed at the metal surfaces to remove the ash/acid deposits in a process known as sootblowing. Sootblowing removes some, but not all, of the deposit from the metal sheets.

[0006] The cold ends of regenerative air preheaters are often below the dew point of the H_2SO_4 in the flue gas, causing a portion of the H_2SO_4 to condense on the surfaces of the heat exchange elements. As the condensed ash and H_2SO_4 accumulate, they create a pressure drop in the flow through the heat exchanger 100. The pressure drop becomes larger over time as solids such as ash or other solid material from the combustion of the fuel also accumulate on the heat exchange elements. If the fouling is severe enough, the flow passages between metal sheets may become plugged. In this event, heat transfer surface area is lost and the fan may be incapable of moving the necessary amount of combustion air through the air preheater.

[0007] The cold end of an air preheater, by nature of the lower gas temperature, has a higher gas density and hence a lower flow velocity. Typically the cold end flow velocity is only about 60% of the hot end flow velocity. Lower gas velocities also result in more fouling.

[0008] Other factors also add to fouling, such as low boiler load. Low boiler load causes the velocity to drop to a velocity that can be as low as 25% of hot end maximum continuous rating (MCR).

[0009] Currently, there is a need for an air preheater that resists fouling under varying combustion conditions.

SUMMARY OF THE INVENTION

[0010] Briefly stated, the invention in a preferred form is an air preheater that is more resistant to 'fouling' under varying boiler loads.

[0011] It is an object of the invention to provide an air preheater that is more resistant to corrosion.

[0012] It is an object of the invention to provide an air preheater that adjusts to varying boiler loads.

[0013] It is an object of the invention to provide an air preheater that adjusts flue gas velocity under varying boiler loads.

[0014] Other objects and advantages of the invention will become apparent from the drawings and specification.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The present invention may be better understood and its numerous objects and advantages will become apparent to those skilled in the art by reference to the accompanying drawings in which:
[0016] Figure 1 is a perspective, partial sectional view of a conventional rotary regenerative air preheater;
[0017] Figure 2 is a schematic view of a steam generating system having a regenerative air preheater arrangement in accordance with the present invention;
[0018] Figure 3 is a side elevational view of the damper manifold of Figure 2;
[0019] Figure 4 is top plan view of the damper manifold of Figure 3;
[0020] Figure 5 is a cross section view taken along line V-V of Figure 3; and
[0021] Figure 6 is an enlarged view of Area VI of Figure 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0022] The majority of steam-generating systems utilize stationary or rotary regenerative air preheaters to increase the boiler efficiency. The most common being rotary regenerative air preheaters. This type of air preheater features rotating heat exchange elements. The present invention relates to boiler systems equipped with either type of regenerative air preheater. To facilitate discussion, the inventive arrangement will be discussed in combination with a rotary regenerative air preheater.
[0023] With reference to Figure 1 of the drawings, a conventional rotary regenerative preheater 10 is shown. The air preheater 100 has a rotor 112 rotatably mounted in a housing 114. The rotor 112 is formed of diaphragms or partitions 116 extending radially from a rotor post 118 to the outer periphery of the rotor 112. The partitions 116 define compartments 20 therebetween for containing heat exchange element basket assemblies 122.
[0024] In a typical rotary regenerative heat exchanger 100, the flue gas stream 224 and the combustion air inlet stream 230 enter the rotor 112 from opposite ends and pass in opposite directions over the heat exchange elements 142 housed within the heat exchange element basket assemblies 122. Consequently, the cold air inlet 130 and the cooled flue gas outlet 126 are at one end of the heat exchanger, referred to as the cold end 144, and the hot flue gas inlet 124 and the heated air outlet 126 are at the opposite end of the air preheater 100, referred to as the hot end 146. Sector plates 136 extend across the housing 114 adjacent the upper and lower faces of the rotor 112. The sector plates 136 divide the air preheater 100 into an air sector 138 and a flue gas sector 140.
[0025] The arrows of Figure 1 indicate the direction of the flue gas stream 224 and the air stream 230 through the rotor 112. The flue gas stream 224 entering through the flue gas inlet 124 transfers heat to the heat exchange elements 142 in the heat exchange element basket assemblies 122 mounted in the compartments 120 positioned in the flue gas sector 140. The heated heat exchange elements 142 are then rotated to the air sector 138 of the air preheater 100. The stored heat of the heat exchange element basket assemblies 122 is then transferred to the air stream 230 entering through the air inlet 130. The cold flue gas outlet stream 226 exits the preheater 100 through the flue gas outlet 126 and the heated air outlet stream 232 exits the preheater 100 through the air outlet 132.
[0026] As stated above, additional acidic fouling of the cold end 144 of the air preheater 100 creates a larger pressure drop across the air preheater 100. Particulate matter carried in the flue gas also accumulates over time on the surfaces of the heat exchange elements 142, and the presence of these deposits adds to the pressure drop of the air preheater. This particulate matter tends to accumulate predominantly in localized areas of low flow velocity.
[0027] Therefore, fouling is due to two problems:
[0028]

1) condensation of acids that accumulate fly ash and other particulates; and

[0029]

2) regions of low velocity flow that become lower at low boiler loads.

[0030] There have been attempts to overcome each of the problems in different ways. One device functioned to partially block only the flue gas inlet. This had disappointing results. At that time all of the factors leading to fouling were not recognized and addressed.
[0031] The present invention addresses both the acid condensation problem and the velocity-related fouling problem. High velocity streams of particles erode solid materials in a process similar to sand blasting. The rate of erosion is proportional to the velocity raised to a power greater than 1. Our experience is that fly ash erosion is proportional to the

flow velocity raised to the 3.4 power.

[0032] Therefore, it would be beneficial to increase the flow velocity in the gas sector to reduce the amount of deposit on the heat exchange elements 142. Increasing the flow velocity in the air sector does not appreciably aid in removing deposits because there is little to no particulate matter in the air sector. However, reducing the amount of heat transfer surface in the air sector does serve to raise the gas temperature in the gas sector, which results in less acid condensation and therefore less fouling.

[0033] The air flow into the boiler is related to the operating level of the boiler. Therefore, a boiler running at 60% of its maximum continuous rating (MCR) would require and take in less combustion air than the same boiler running at 90% of MCR. Consequently, a boiler running at 60% MCR would exhaust less flue gas than one running at 90% MCR. The smaller amount of flue gases exiting through the same cross section with approximately the same density, would exit at a lower velocity.

[0034] Also, when the boiler is running at 60% MCR. vs. 90% MCR, it produces flue gases that exit with a lower temperature. Therefore, boiler operation level affects the input air velocity into the boiler, the exhaust flue gas flow velocity out of the boiler and temperature of the exiting flue gases.

[0035] Referring now to Figure 2, the present invention includes damper assemblies 152, 162 at the immediate inlets to the air preheater 100. These are attached as close as possible to minimize leakage between the damper assemblies 152, 162 and the air preheater 100. A controller 158 can be used to partially close dampers assemblies 152, 162 during periods of reduced boiler load conditions. This effectively reduces the flow area and hence increases the flow velocities.

[0036] By restricting flow into both the flue gas inlet 124 and the air inlet 130 of the air preheater, a smaller effective area for heat transfer will result in less heat exchanged. This causes a greater portion of the metal surfaces to have a temperature above the sulfuric acid dew point, thereby reducing fouling of the metal surfaces. Also, the flow velocity in the gas sector is increased, which facilitates the erosion of any accumulated deposit.

[0037] Furthermore, if the cold air flowing into the air preheater is heated by another heat exchanger in order to keep the metal temperatures above the acid dew point, then obstructing flow of both the air and gas side of the air preheater 100, the amount of heat required from the other heat exchanger will be reduced. This will save energy overall since obstructing a portion of the metal surfaces on the air side requires a negligibly small amount of energy compared to the amount that would be needed to heat the cold air to a sufficient degree.

[0038] Figure 2 is a schematic view of a steam generating system having a regenerative air preheater arrangement in accordance with the present invention. The system includes a flue damper assembly 152 positioned inside the hot flue gas inlet 124, as closely as possible to the face of the element basket assemblies 122. A flue gas duct 154 connects the boiler 148 to the air preheater 100. The dampers (156 of Figure 3) of the flue gas damper assembly 152 can be shut at reduced load conditions to effectively reduce the flow area of the flue gas inlet 124. This increases the velocity of the flue gases flowing over the heat exchange elements 142. This also decreases the effective surface area for heat transfer from the flue gas.

[0039] The damper system 50 also includes an air damper assembly 162 positioned inside the preheater cold air inlet 130, as close to the face of the elements in the basket assemblies 122 as possible to minimize air leakage. Air damper assembly 162 can be partially closed at reduced load conditions of boiler 148 to effectively reduce the flow area of the air inlet 130 and thereby decrease the effective surface area for heat transfer to the air flowing into the air preheater 100. This means that there is less cooling of the cold end (144 of Figure 1) of the preheater 100.

[0040] Due to the increased flow velocity in the flue gas sector (140 of Figure 1), the fly ash carried in the flue gas erodes the deposit on the surface of the heat exchange elements 142 in the air preheater 100. The rate of erosion is proportional to the velocity raised to a power specific to the eroding agent. Such power for fly ash is 3.4.

[0041] Also, since less surface area is used to extract heat from the flue gases, the flue gases passing through the air preheater to the cold end are hotter and therefore a larger percentage of the plates in the cold end are maintained above the H_2SO_4 dew point. This results in less condensation of H_2SO_4 on the heat exchange elements (142 of Fig. 1).

[0042] Controller 158, preferably a programmable logic controller ("PLC") with preprogrammed control logic, monitors the load of the boiler 148 and controls the actuation of the damper blades in the damper assemblies 152, 162.

[0043] In a preferred embodiment, the controller 158 receives a signal from the plant distributed control system (DCS) 160. The DCS 160 can determine the operating load of the boiler 148, based on the monitored parameters, and can be programmed to send a signal indicating the boiler load to the controller 158. Upon receiving the signal, the controller 158 will calculate the boiler load and actuate dampers assemblies 152, 162 accordingly.

[0044] Now with respect to both Figures 1 and 2, alternatively, the temperature at various locations within the air preheater may be monitored. If any structures within the flue gas sector 140 fall below the dew point for various acids within the flue gas, liquid acids condense on these structures. The liquid acids accumulate and hold fly ash accelerating fouling of the air preheater. Usually, the flue gas outlet 132 has the lowest temperature of the flue gas sector 140 and is most prone to acid condensation. Therefore, the controller 158 will receive temperature readings and determine if the flue gas inlet should be closed more than it is to increase flue gas velocity, thereby reducing the surface area of heat exchange element 142 that is exposed to the flue gases. The combination of increased flue gas velocity and reduced heat exchanger surface area reduces the amount of heat taken from the flue gases, elevating the temperature of the flue gas stream 226 exiting the air preheater 100.

[0045] Similarly, as the air damper assembly 162 closes more of the air inlet 130, the velocity of the inlet air stream 230 increases. Closing more of the air inlet 130 also reduces the surface area of the heat exchange elements 142 that are exposed to the air inlet stream 230. This results in less heat being absorbed by the air inlet stream 230, again causing flue gas outlet stream 226 to have higher temperatures exiting the air preheater.

[0046] The increased velocity of the flue gas passing through the air preheater 100 tends to erode accumulated deposit in the air preheater at a rate based upon the velocity raised to the 3.4 power. The controller may operate the flue gas damper 152 and the air damper 162 to maximize the erosion of accumulation, however, the damper assemblies may not be closed to the degree that allows the exiting flue gas to exceed a maximum allowable temperature. This temperature may be predetermined based upon the maximum temperatures that the downstream equipment can safely tolerate along with a desired margin of safety.

[0047] With reference to Figures 3-6, the air damper assembly 162 includes a frame 182 and multiple dampers 156 positioned within the frame 182. Preferably, the dampers 156 are grouped in a number of damper panel 163, 164. In addition to the associated dampers 156, each damper panel 163, 164 includes an actuator 166 and a drive 168 connecting the actuator 166 to each of the dampers 156.

[0048] As shown in Figure 3, the air damper assembly 162 may divide the flue gas inlet (124 of Figure 2) into sections. The dampers 156 of the damper sections 163, 164 being positioned to control flow within flue gas inlet 124. Another section 174 of the flue gas inlet 124 being left open with no damper assembly or dampers.

[0049] Flue gas damper assembly 152 has the same parts and operates in the same manner as that described for air damper assembly 162. Therefore, the description above applies equally for flue gas damper assembly 152 as applied to the flue gas inlet instead of the air inlet.

[0050] The controller 158 operates the actuator 166 of the damper sections 163, 164 to partially restrict flow in certain areas of the flue gas inlet (124 of Figure 2).

[0051] It should be appreciated that a regenerative air preheater 100 in accordance with the invention may include more, or fewer damper assemblies 152, 162 shown in Figures 3-6. In addition, a smaller or a greater portion of the flue gas inlet 124 may be left with no damper assembly to control flow through it.

[0052] Figure 6 is an enlarged view of a portion of Figure 5. It shows damper 156 being rotatable about an axis 176 between an 'open' and 'closed' position. A flat bar seal 178 mounted to both sides of each damper 156. Bar seals 178 overlap and contact a portion of the bar seal 179 of an adjacent damper to prevent the flow of flue gas between the dampers. The bar seal 178 of the damper closest the frame 182 contacts a portion of the frame 182 to prevent the flow of flue gas between the frame 182 and the damper 156.

[0053] Referring now to Figure 3, for vertical flow air preheaters, the controller (158 of Figure 2) may be programmed to periodically open the dampers 156 of a "closed" damper panel 163 while closing the dampers 156 of an "open" damper assembly 164, maintaining a substantially constant flow area. Such operation allows the dampers 156 of the "closed' damper assembly 164 to shed any ash deposits that might accumulate on top of the dampers 156.

[0054] Referring now to Figure 2, restricting the flow area of the flue gas inlet 124 increases the velocity of the flue gas flow, thereby causing fly ash carried in the flue gas to erode the cold end deposit. However, the higher velocity with a reduced area for heat transfer produces a higher than normal flue gas outlet temperature. That is, closing off portions of the flue gas inlet effectively prevents flue gas flow through portions of the installed heat exchange elements (142 of Fig. 1), reducing the effective heat transfer surface area and raising the flue gas temperature leaving the air preheater 100.

[0055] In addition, a larger pressure drop at 100% power would require a higher capital cost for higher-pressure air and gas fans 188 and higher operating costs for running the larger motors that these larger fans 188 would require. For all but the worst coals, the plant data measurement system does not show an increase in pressure drop at full load over the 8 hours of time between soot blowing cycles. The fouling that is observed is either hot end fouling from large particles of "popcorn" or slag that has formed on some hotter upstream surface, dislodged and is carried by the flue gas stream, or cold end fouling which may be acidic fouling and/or particulate fouling in low velocity and low turbulence zones.

[0056] However, at low load conditions the gas outlet temperature is always lower than the gas outlet temperature for the MCR design point. This is due to two factors. At lower boiler load conditions, the temperature of the flue gas entering the air preheater 100 is lower than at the design point. The air preheater 100 is also more efficient, since the flue gas velocity is also lower and the resultant decrease in heat transfer coefficient has a lesser effect than the reduction in flow for the existing surface area, therefore producing a greater reduction in flue gas temperature. Often the lower temperature that occurs at low loads is sufficiently low to result in the condensation of sulfuric acid. Some plants use steam air heating to raise the inlet air temperature, and therefore the exit gas temperature and element plate temperatures to avoid condensing acid. However, the accumulation of dust due to the reduced velocity is not mitigated by this procedure.

Table 1						
	Gas Side Flow Area Ratio	**Air Side Flow Area Ratio**	**Change in Gas Exiting Temp. (Avg.) (°F)**	**Change in Coldest Element Temp. (°F)**	**Percent Change in Avg. CE Gas Velocity (=$V_{ce,avg}$) (ft/s)**	**Percent Change in Avg. CE Gas Velocity to 3.4 Power (=$V_{ce,avg}^{3.4}$)**
Existing Design						
70% Load relative to MCR	1	1	-29	-7	-21%	-56%
30% Load relative to MCR	1	1	-70	-15	-59%	-95%
New Design						
70% Load relative to MCR	1	1	-7	7	59%	382%
30% Load relative to MCR	1	1	-53	-6	-17%	-48%

[0057] Table 1 compares flue gas velocity of the present invention against a conventional air preheater during a thirty percent (30%) load condition, a seventy percent (70%) load condition and MRC. Damper assemblies 152, 162 according to the present invention are used to effect a fifty percent (50%) reduction in the flue gas inlet flow area to produce significant increases in the velocity of the flue gas flow. As can be seen, doubling the inlet velocity of the flue gas doubles the outlet velocity of the flue gas, with a proportional increase in the average flue gas outlet velocity to the 3.4 power. A ratio of the average flue gas outlet velocities to the 3.4 power at 70% power and MCR of 3.54 is achieved with the subject invention compared to a ratio of 0.32 for a conventional air preheater. For a 30% power level the ratio for the subject invention is 0.43 compared to 0.04 for a conventional air preheater. Closure of additional dampers 56 would provide even higher cold end velocities and cleaning effect (velocity to 3.4 power) at the 30% load case. The conditions of this example are not necessarily optimal conditions but merely illustrate the principle of the invention.

[0058] In alternative embodiments, the dampers may be actuated by gear drives, belt drive, chain mechanisms, solenoids or other known actuator mechanisms. These all fall under the scope of the present invention.

[0059] While preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

Claims

1. An air preheater having a flue gas inlet for receiving flue gases from a boiler, a flue gas outlet for exhausting flue gases, an air inlet for receiving air to preheat and an air outlet for providing preheated air to the boiler, the air preheater exhibiting reduced fouling under varying boiler operation levels, comprising:

a. an air damper assembly adapted to adjust an opening of said air inlet, the air damper assembly fitting tightly against the air inlet to minimize and air leakage between the damper assembly and the air inlet;
b. a flue gas damper assembly adapted to adjust an opening of said flue gas inlet, the flue gas damper assembly fitting tightly said against flue gas inlet to minimize and air leakage between the flue gas damper assembly and the flue gas inlet;

c. a controller coupled to the air damper assembly adapted to operate the air damper and the flue gas damper assembly during varying boiler operation levels to maintain desired air and gas flow velocities to reduce fouling.

2. The air preheater of claim 1, wherein controller is adapted to receive input regarding the boiler operation level and interactively control at least one of the flue gas damper assembly and the air damper assembly based upon the received input.

3. The air preheater of claim 1, wherein controller is adapted to receive input regarding temperature of flue gases exiting flue gas outlet and interactively control at least one of the flue gas damper assembly and the air damper assembly based upon the received input.

4. The air preheater of claim 1, wherein controller is adapted to receive input regarding a velocity of flue gases exiting the flue gas outlet and interactively control at least one of the flue gas damper assembly and the air damper assembly based upon the received input.

5. The air preheater of claim 1, wherein controller is adapted to:

a. receive input regarding a maximum allowable flue gas outlet temperature;
b. measure a temperature of a flue gas outlet stream; and
c. control at least one of the flue gas damper assembly and the air damper assembly to maximize a velocity of air flowing into the air inlet while keeping the measure temperature of the flue gas outlet stream below the maximum allowable flue gas temperature.

6. The air preheater of claim 1, wherein controller is adapted to receive input regarding the flue gas outlet velocity and interactively control at least one of the flue gas damper assembly or the air damper assembly based upon the received input.

7. The air preheater of claim 1, wherein the controller is further adapted to adjust the flue gas damper assembly and the air damper assembly to reduce the amount of acid condensation within the air preheater.

8. The air preheater of claim 1, wherein the air damper assembly comprises:

a plurality of dampers adapted to adjustably close at least a portion of the air inlet.

9. The air preheater of claim 1, wherein the flue gas damper assembly comprises:

a plurality of dampers adapted to adjustably close at least a portion of the flue gas inlet.

10. The air preheater of claim 1, wherein the dampers are pivotable and are pivoted by a drive bar attached to the dampers.

11. The air preheater of claim 10, wherein an actuator moves the drive bar to cause the dampers to pivot.

12. A method of reducing fouling in an air preheater having an air inlet and a flue gas inlet during periods of reduced boiler operation comprising the steps of:

a. measuring a temperature of flue gas outlet stream exiting the preheater;
b. determining if the measured gas outlet temperature is lower than a predetermined threshold;
c. calculating an amount to close at least one of the flue gas inlet and the air inlet to increase the flue gas outlet stream temperature to be above the threshold temperature, when the measured temperature is below the predetermined threshold; and
d. closing the flue gas inlet and the air inlet by the calculated amount when the measured gas outlet temperature is below the predetermined threshold to result in increased flue gas outlet stream temperature, thereby reducing acid condensation and fouling.

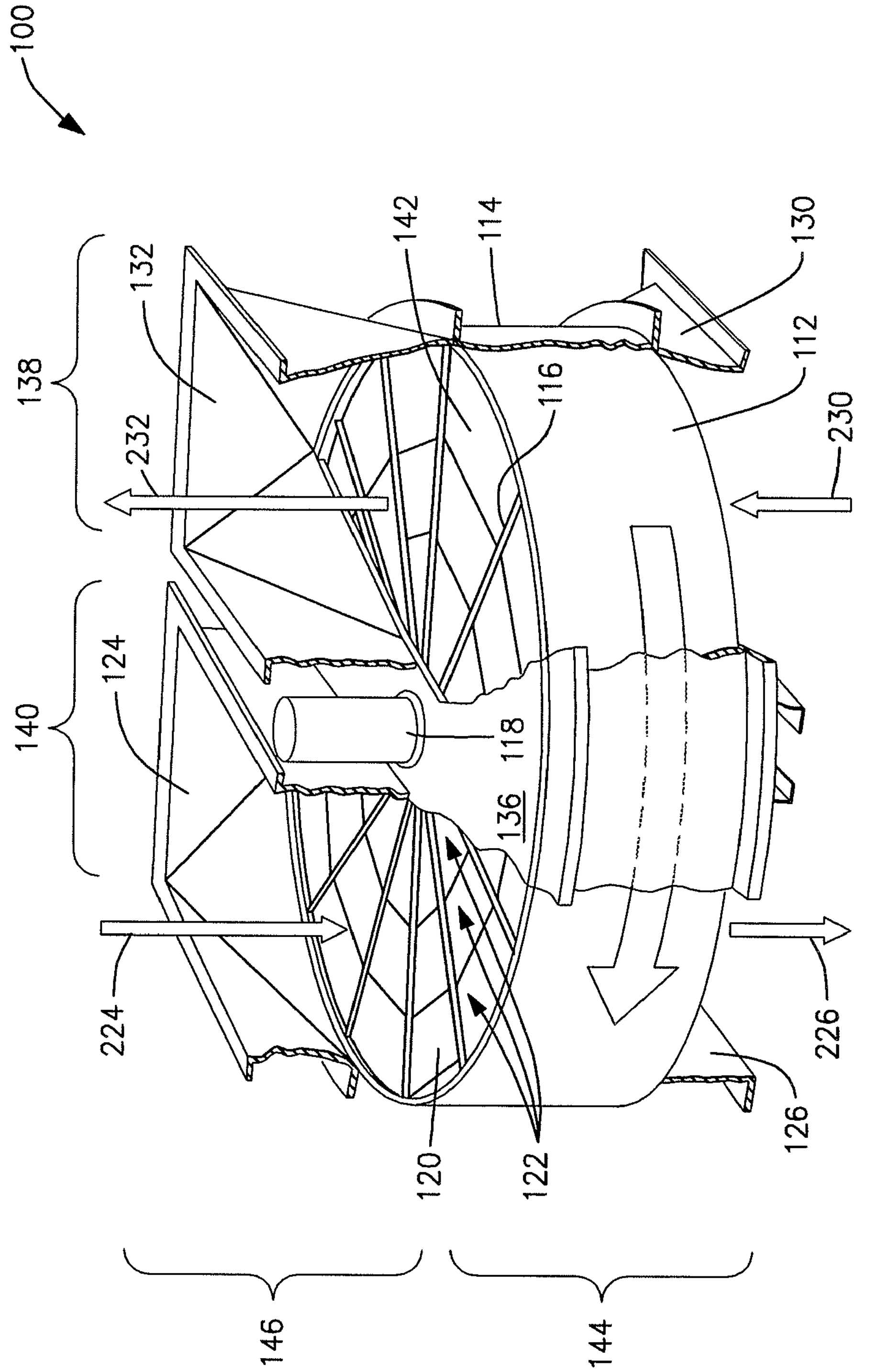
13. The method of reducing fouling of claim 12 wherein the predetermined threshold temperature is the condensation temperature of an acid present in the flue gases plus a safety margin.

14. A method of reducing fouling in an air preheater having an air inlet and a flue gas inlet, during periods of reduced boiler operation comprising the steps of:

a. measuring velocity of at least one of the flue gases and air passing through the preheater;
b. determining a difference between the measured velocity and a desired velocity;
c. calculating an amount to adjust at least one of a flue gas inlet opening and an air inlet opening to minimize the difference between the measured velocity and the desired velocity; and
d. adjusting at least one of the flue gas inlet and the air inlet opening by the calculated amount to result in adjusted outlet velocity, thereby increasing erosion of any accumulations and fouling.

15. The method of reducing fouling of claim 14 further comprising the steps of:

a. receiving maximum flue gas outlet stream temperature;
b. measuring flue gas outlet stream temperature, and
c. limiting the step of adjusting to insure that the measured flue gas outlet stream temperature is below the maximum flue gas outlet stream temperature.


100
138
140
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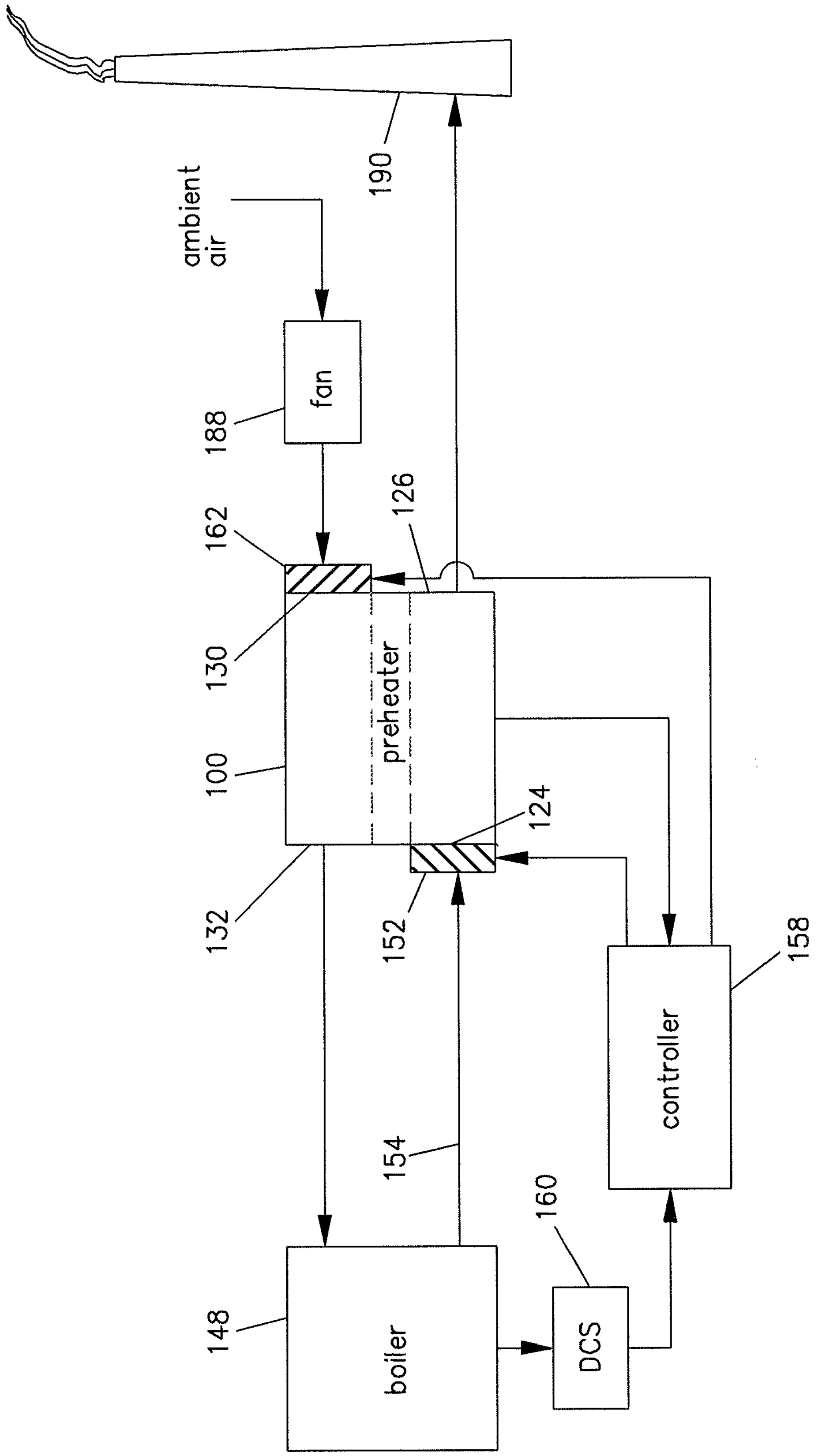
144

Figure 1


ambient air
fan
preheater
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DCS
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124
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Figure 2

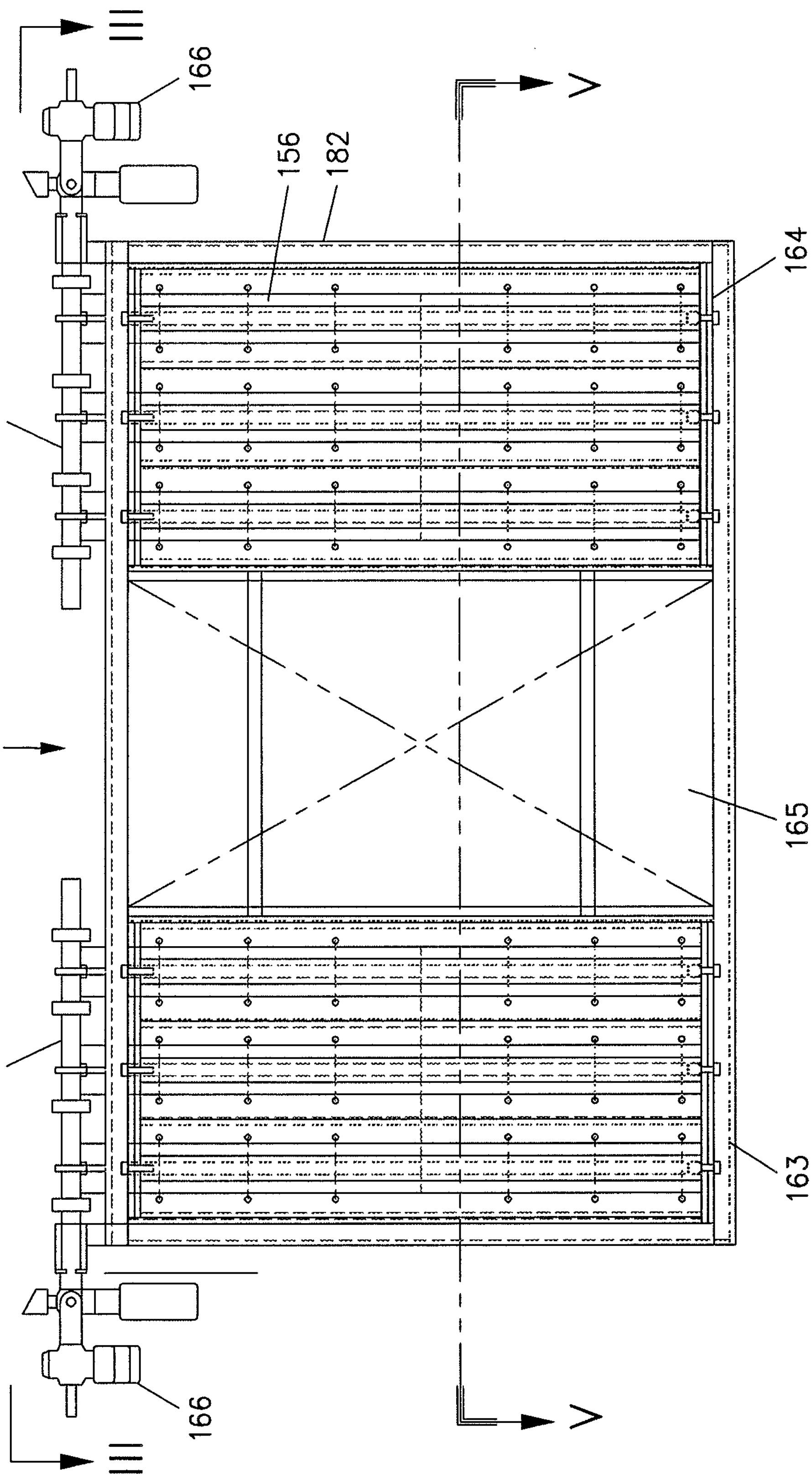

Figure 3

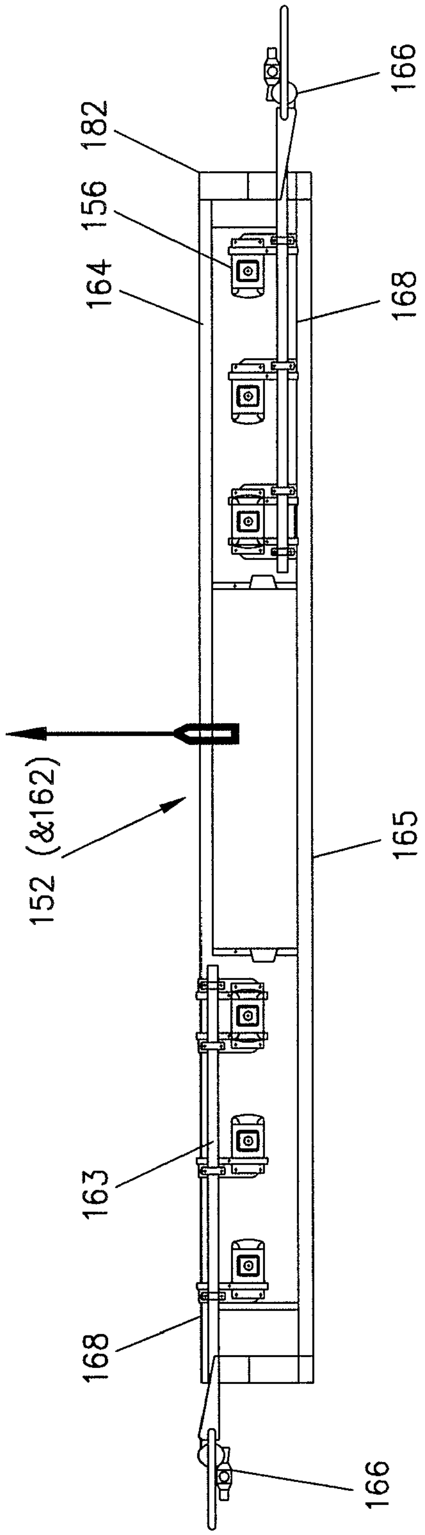

Figure 4

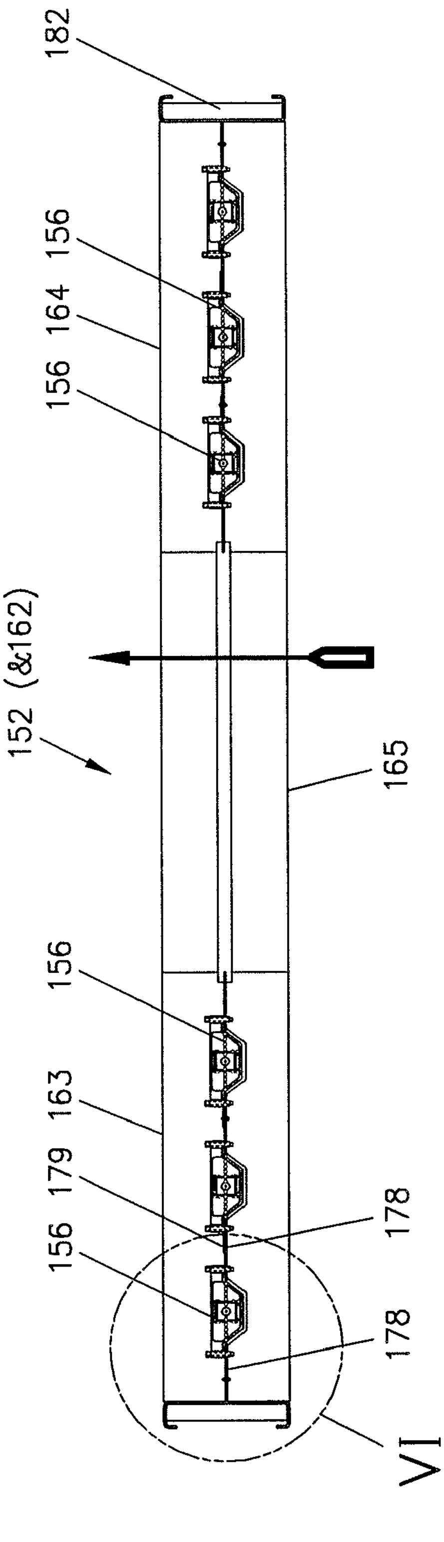

Figure 5

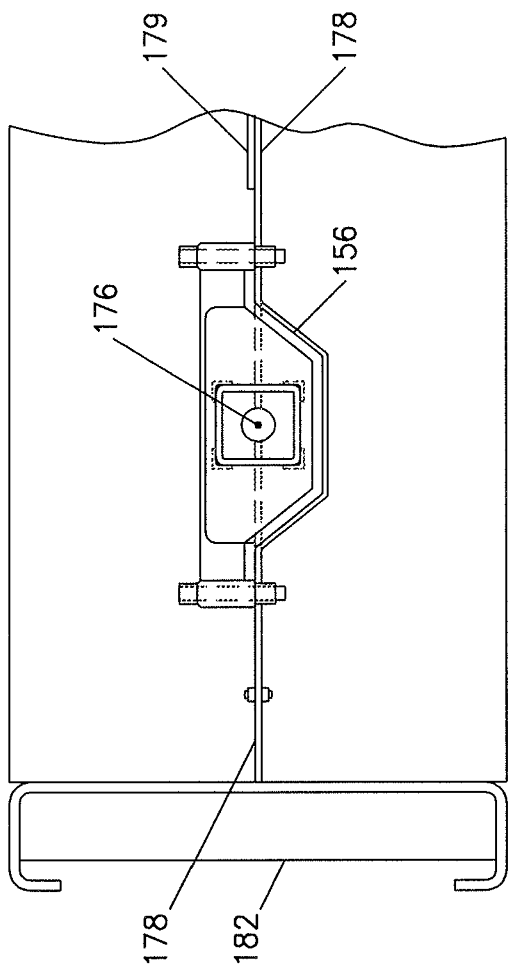

Figure 6