DEVICE AND METHOD FOR BOILER SUPERHEAT TEMPERATURE CONTROL

FIELD OF THE INVENTION

[0001] The present invention concerns steam boilers designed or modified to operate with oxygen and fuel with the absence of normal combustion air and requires a superheated and or reheated steam temperature control employing an advanced method of controlling the superheat and or reheat temperature of steam in the boiler above the conventional combustion region. More particularly the present invention concerns a boiler having at least one additional burner using oxygen and fuel with the absence of normal combustion air in the convection area in order to boost heat and energy at the superheat and or the reheated areas and convection regions as may be required to maintain proper steam temperatures at the outlet of the steam boiler.

BACKGROUND OF THE INVENTION

[0002] Power plants and or steam plants used by utility companies, industries and municipalities for, among other applications, the production of steam and electricity, typically comprise small to giant boiler systems used to produce steam that can be fed to different processes and other applications as well as turbines which in turn run generators and other devices. The boilers, which generally have a basic design dating to the 19th century, comprise myriad tubes with water circulating there through. The boilers typically also include a burner or burners, fed by varieties of carbon based fuels, including fossil fuels, which are ignited and burn in the presence of air. The burners and water tubes are in proximity to each other and the heat produced by the burner or burners heats the water

within the tubes. Hot water rises above the burner section of the boiler, as do the gases heated in the presence of the burners, such that the hot water continues to get hotter as it rises within the myriad tubes. Typically, the tubes are under pressure, such that the water, which boils at about 100° C at atmospheric pressure, does not boil but only continues to get hotter.

[0003] These boilers are typically from several feet high to several stories high and comprise, near their tops, areas where hot water is permitted to escape the confinement of the water tubes and flash to steam. The sudden release of the water and its conversion to steam provides considerable turbine turning power. Such boilers are engineered to produce and/or exceed the heat and energy needs necessary to the task to which the boiler is designated.

[0004] Improvements to these boiler systems have included the inclusion of superheat and reheat areas, which provide a means for the temperature of the steam to be further escalated by passing the steam through superheat and reheat tubes placed in the fast flow of exhaust gases. These devices raise the temperature of the steam above its saturation point using the waste energy of combustion. It has been found that, above the benefits of steam having increased energy, superheated steam is dryer and that dryer steam has fewer deleterious effects on turbine blades than steam having higher moisture content. Dry steam has been found to have more energy per volume than saturated steam.

[0005] In general, boilers are designed such that more energy than needed is produced and this energy is attenuated by cooling the steam to the desired temperature. In prior art systems, using air, which is approximately 18 percent oxygen, the flow of the air must be increased to provide a stoichiometric proportion of oxygen to completely burn the

fuel. The use of air at high flow pressures caused hot gasses to flow rapidly from the burner region of the boiler up and throughout the height of the water tubes. As such, needed heat and energy are available to continue to heat and transfer energy to the water, and steam in superheaters, all the way up to the top of the boiler. However, along with this benefit, it has been found that the burning of fuel in the presence of nitrogen rich air causes the production of nitrogen oxide (NOx), a deleterious greenhouse gas. In prior art boilers, the burning of air in the boilers, and the necessary increased flow of air into the boiler, in order to provide a stoichiometric proportion of oxygen to complete combustion, concomitantly, causing a great amount of flow and produces great quantities of NOx.

[0006] One manner of reducing greenhouse gases, is explained in U.S. Patent No. 6,436,737, entitled: *Oxy-Fuel Combustion System and Uses Therefor*, which is owned by the assignee of the present invention and which is incorporated in its entirety herein, as if set forth in full here. In the '737 patent, a system whereby burners are fed with substantially pure oxygen, such that excess NOx is not produced, is disclosed. Such a system can be used both in new boilers and in the modification of existing boilers.

[0007] However, because use of pure oxygen at an un-pressurized flow rate creates the stoichiometric proportion needed to consume fuel, without the need for the rapid/forced flow used with air, heat and energy are concomitantly not forced (by the pressure otherwise used to pump air into the boiler) up to the heights of the boiler. As a result, for certain boilers, as known by persons having skill in the art, in such oxygen-fed systems, water, in tubes that are not bathed in heated gases at higher levels in the boiler, begins to cool before the appropriate amount of heat and energy are produced. Further, in such boilers, flow of hot gases past superheat elements does not occur to the degree necessary to produce

superheated steam as desired. This results in the failure of such boilers to provide an effective alternative to the prior art greenhouse gas producing furnaces.

[0008] It would be desirable to have the greater amount of quality steam while avoiding the production of NOx.

SUMMARY OF THE INVENTION

[0009] In accordance with the present invention a boiler comprising at least one primary burner using oxygen and fuel with the absence of normal combustion air for initial heating of water, a collection of water tubes, each tube having a first end in proximity to the at least one primary burner and a second end spaced apart from the first end and in proximity to a boiler steam outlet is provided. The boiler further can comprise a superheater and/or reheater in steam transfer connection with the steam outlet. At least one secondary burner is provided above the typical burner position to produce more heat or energy to increase the temperature and quality of the steam in the boiler proper and in the superheat and/or reheat regions of the boiler.

[0010] In one embodiment of the present invention an existing, prior art, boiler is modified to be fed substantially pure oxygen rather than pressurized air. The modification of such a boiler includes the strategic placement of at least one secondary burner above the primary burner region to provide the needed heat and energy to produce desirable quantities and quality of steam. In a preferred embodiment, the secondary burner, whether in a modified prior-art system or a newly designed boiler, is fed with substantially pure oxygen.

[0011] In the operation of the boiler, the primary burner, or burners, heats water flowing in the water tubes, causing the heated water to rise within the boiler. The heated

water flashes to steam in the steam outlet and the steam is transferred to the superheat device. As a result of convection currents, heat is added to the steam in the superheat area, raising the temperature of the steam above the saturation point. The secondary burner provides added heat, permitting a more constant and consistent control over the heating of the steam. In this manner, appropriately heated steam is provided to a turbine, permitting the turbine to work in an efficient and proper way. In other embodiments, more than one secondary burner is provided, such that, when desired, the heat applied to the superheater elements is more carefully controllable. Because of the diminished flow of heated gases in the present embodiment, due to the use of oxygen at typically a lower flow rate than air, energy from the primary burner, or burners, is supplemented by the at least one secondary burner to overcome the insufficient heat and energy. The at least one secondary burners, placed between the level of the primary burner(s) and the steam outlet, provides heat or energy to the water in the tubes, and to the steam in the superheat zone, to provide the energy lost through the use of low flow oxygen.

[0012] In a further embodiment, the secondary burner is fed with oxygen from an oxygen generation system in place of normal combustion air in a stoichiometric proportion with the fuel, such that green house gases are minimized. As normal combustion air consisting of approximately 80% nitrogen consumes considerable heat, which is lost to exhaust, the use of oxygen from an oxygen generation system lessens the heat lost to exhaust and permits the heat of the burner to be applied to the superheater in a more efficient manner. In another embodiment, both the secondary and primary burners are fed with oxygen from an oxygen generation system in stoichiometric proportions.

[0013] The heated water flashes to steam, in the steam outlet, and the steam is

transferred to the superheat device, where the secondary burner continues to provide the added heat and energy to increase the quality of steam produced. Steam from the superheater can then be fed into the turbine. In one embodiment, steam is returned from the turbine to a reheat device, where it is again placed into the presence of the heat and energy provided both by the primary and secondary burners, and is again sent to the turbine. As a result of convection currents produced by the secondary burners, heat or energy is added to the steam in areas where low flow oxygen fed burners typically have heat and energy gaps, which would otherwise allow the water in the boiler to cool. The convection currents raise the temperature of the steam above the saturation point producing desirable quantities and qualities of steam. The secondary burner provides added heat or energy, permitting a more constant and consistent heating of the steam. In this manner, appropriately heated steam is provided to a turbine, permitting the turbine to work in an efficient and proper manner.

[0014] In other embodiments of the present invention, more than one secondary burner is provided, such that, when desired, the heat or energy applied to the superheater elements can be more carefully controlled. Further, in a preferred embodiment a boiler of the present invention can be created so that it can produce greater heat or energy than needed. In such an embodiment cooling and other elements known to persons having skill in the art can be provided to bring, or attenuate, the steam to the desired heat and energy levels. It will be understood by persons having skill in the art that the use of cooling elements to produce steam having desired properties will be more effective than attempting to use heating elements, within a boiler, to heat steam to the desired levels.

[0015] In another embodiment of the invention the burners are used as nozzles or ports to control the superheat temperature of the steam by introducing recycled flue gasses.

It will be understood that the recycled flue gasses are most useful when incorporated with the use of oxygen and carbon based fuels, including fossil fuels, fired burners in the furnace section of the boiler. Due to the reduced volume of flue gasses from the combustion process and the higher radiation heat transfer from the process it may be beneficial to use recycled flue gas to control the temperature of the superheated steam. In this example the recycled flue gasses are used in controlling the steam temperature in the boiler by adding volume or tempering effects to the convective region of the boiler.

[0016] Another method of controlling super heated steam temperature (or super critical) is to introduce the recycled flue gas at the secondary burner tip. Either all of a portion of the required flue gas tempering gasses can be introduced at the secondary burner tip by using the flue gasses as a carrier gas for the pulverized coal or other carbon based fuels, including fossil fuels. This again is in coordination with aspects of oxygen and carbon based fuel fired burners. With those systems it is desirable to negate any introduction of nitrogen.

[0017] In addition, by using recycled flue gas (substantially no nitrogen if used products are from a oxygen and carbon based fuel combustion system) to propel the coal, such a system is able to achieve, once again, super heated steam temperature control. In another embodiment, another portion of flue gasses is introduced in the upper burners or nozzles to finalize control of the systems.

[0018] A more detailed explanation of the invention is provided in the following description and claims and is illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

[0019] Figure 1 is a schematic view of a boiler incorporating the device of the present invention.

DETAILED DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENT

[0020] While the present invention is susceptible of embodiment in various forms, there is shown in the drawings a number of presently preferred embodiments that are discussed in greater detail hereafter. It should be understood that the present disclosure is to be considered as an exemplification of the present invention, and is not intended to limit the invention to the specific embodiments illustrated. It should be further understood that the title of this section of this application ("Detailed Description of an Illustrative Embodiment") relates to a requirement of the United States Patent Office, and should not be found to limit the subject matter disclosed herein.

[0021] Referring to the figure, a boiler 10 comprising a series of water tubes 12, which together comprise a water wall 13, is shown. The boiler 10 further comprises at least one primary burner 14, located in primary burner zone 15, connected to a source of fuel 16 and air 18. In a preferred embodiment of the present invention, instead of using air 18, which must be pumped into the boiler at an increased rate (so as to produce a stoichiometric ratio of fuel to oxygen in the burner), substantially pure oxygen is provided. It will be understood that in the use of oxygen, the pressurized flow is not necessary as a stoichiometric proportion to the fuel can be more easily created. Such a system will require oxygen of only a purity such that the complete burning of the fuel is accomplished. In such a system the production of harmful greenhouse gases is lessened in that nitrogen, a substantial

element of air but not of pure oxygen, is not burned to create NOx. It will be understood that where further lessening of greenhouse gases is desired a greater degree of purity of oxygen will be required. While the term "substantially pure oxygen" has been used in various places herein, it will be understood, by persons having skill in the art, that the degree of purity of oxygen can be varied as needed to provide the correct ratio of fuel and oxygen for the desired burn and by products without departing from the novel scope of the present invention.

[0022] The water wall 13, in boiler 10, is comprised of a myriad of water tubes 13a extending from the primary burner zone 15 to the upper regions of the boiler 10. Boiler 10 can further comprise a superheater 20 and/or reheater 21, of types well known in the art. Such superheaters 20 are generally fed with steam that has been produced in the boiler 10, at a steam transfer area 22. The steam passes within the superheater 20, and convection currents carry heat or energy from combustion, and heat and energy radiated from the water tubes 13a, on and about the superheater 20, heating the steam carried therein. Reheaters 21 are typically fed with steam returning to the boiler from a turbine, that steam requiring further heating before it is returned to the turbine for additional use. This heat or energy is transferred to the steam causing its temperature to rise above the saturation point of the steam; making the steam more suitable for use in turbines. It will be understood that cooling features can be included such that steam having too high a temperature and/or too much energy for the desired task can be attenuated as needed.

[0023] As an added feature, boiler 10 includes a secondary burner 24, which can be placed in locations above the typical burner zone 15 of a boiler 10 and below the steam transfer area 22. In one embodiment, at least one secondary burner 24 is placed in the

superheat area 26. In other embodiments, secondary burners 24 are located in numerous locations about the boiler 10 such that control of heat or energy can be more properly made.

[0024] In this manner, heat or energy is added to produce greater quantities and/or qualities of steam. Further, the addition of a secondary burner 24 in a superheat or reheat area 26 permits higher amounts of the burner energy to be used exclusively to heat steam rather than to heat water. As less energy is required to add heat or energy to steam than to water, the energy of secondary burner 24 is more readily converted to power, in a turbine, than is heat or energy created at or near the zone where the primary burner 14 is placed.

[0025] As will be known by persons having skill in the art, secondary burners 24 can be considerably smaller than primary burners 14; while causing the production of greater quality and amounts of steam, in an oxygen environment, than a larger extra primary burner 14, placed in the primary burner zone 15. It will also be understood that the use of large primary-type burners 14 in both the primary burner zone and above, can be used without departing from the novel scope of the present invention. Further, the numbers of primary and secondary burners, 14 and 24, in the boiler 10 can be varied without departing from the novel scope of the present invention. The type and size and numbers of burners will depend on the application and the desired amount and quality of steam. While Figure 1 shows the use of one burner 24, it will be understood, from the description above, that one burner 24, or any number of burners 24, can be substituted without departing from the novel scope of the present invention. It will be understood that these variations can be made to aid in the control of the temperature such as by adding more heat or energy when it is required and permitting the use of less heat or energy as necessary or desired.

[0026] It will also be understood that in a typical boiler, and in the present invention,

boiler steam can be produced in greater quantities and with greater heat than desired or needed and then cooled to the desired heat, energy and saturation point by using cooling means, such as devices permitting steam carrying conduits to come in contact with cooling waters, as is know to persons having skill in the art, without departing from the novel scope of the present invention.

[0027] In order to control the superheat temperature when the reduction of flue gasses from the use of oxygen and carbon based fuel (such as fossil fuels) combustion or the increased radiation heat transfer rates are too high, recycled flue gas is used to either temper the combustion gas temperature to cool the superheat tubes or provides adequate dispersion by augmentation of flue gas volume in the super heat section. Either application allows for control of the super heated steam temperature in the tubes. Flue gas can, be introduced for the purposes of super heat temperature control at the proposed location 24 of the additional burners (for the case when the superheat temperatures are too low) by use of a nozzle or port device. Or at the fuel source 16, in this example a coal pulverizer, as an additional tool to negate the introduction of nitrogen in an oxygen and carbon based fueled combustion system.

[0028] As those skilled in the art will know, the exact location and the requirement for the amount of additional heating or cooling of the superheated steam tubes will vary on the size and configuration of the boiler. Embodiments of the present invention concentrate on controlling the temperature of the super heated steam by adding or subtracting heat in the convective passes of a boiler. More particularly the use of tempering flue gas or augmented flue gas volumes in the superheat region of the boiler can be beneficial when used in conjunction with oxygen and carbon based fuel combustion systems.

[0029] Although an illustrative embodiment of the invention has been shown and described, it is to be understood that various modifications and substitutions may be made by those skilled in the art without departing from the novel spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. A boiler comprising:

at least one primary burner for initial heating of water, the burner, located in a primary burner zone, being fed by a low flow rate of substantially pure oxygen, the rate of flow being minimally sufficient for causing the combustion of fuel in stoichiometric proportion to produce flue gases having low NOx levels;

a collection of water tubes, each tube having a first end in proximity to the at least one primary burner and a second end, spaced away from the first end and, in proximity to a boiler steam outlet; and

at least one secondary burner in a secondary zone distinct from the primary burner zone and below the boiler steam outlet and in a low NOx region, for producing energy for higher quality steam, including at least one of a superheater and a reheater.

2. The boiler of claim 1, wherein the at least one secondary burner is placed adjacent the superheater.

3. The boiler of claim 1, wherein the at least one secondary burner is placed adjacent the reheater.

4. A boiler comprising:

at least one primary burner for initial heating of water, the burner being fed by a low flow rate of substantially pure oxygen, the rate of flow being minimally sufficient for causing the combustion of fuel in stoichiometric proportion to produce flue gases having low NOx levels;

a collection of water tubes, each tube having a first end in proximity to the at least one primary burner and a second end, spaced away from the first end and, in proximity to a boiler steam outlet;

at least one of a superheater or reheater in steam transfer connection with the steam outlet; and

two secondary burners, placed in a secondary zone distinct from the primary burner area and the steam outlet within the boiler and in a low NOx region, for producing heat or energy for increased quality of steam in the boiler.

5. The boiler of claim 4, wherein the secondary burners are provided with generally pure oxygen, flowing at a similar rate as the oxygen in the primary burner, in stoichiometric proportion to fuel.

6. A method of retrofitting an existing burner to eliminate a substantial portion of greenhouse gases, comprising the steps of:

providing a feed of substantially pure oxygen to the primary burner or burners of the boiler,the oxygen being fed at a rate minimally sufficient for causing the combustion of fuel in stoichiometric proportion, to produce low NOx flue gases;

providing at least one secondary burner for the boiler, the secondary burner being located in a secondary zone distinct from the primary burner zone of the boiler;

providing a superheater in a superheat zone in the boiler and placing the at least one secondary burner adjacent to the superheat zone; and

operating the boiler such that fuel in both the primary and secondary burner is burned in the presence of substantially pure oxygen and low NOx such that the fuel is substantially combusted.

7. A boiler comprising:

at least one primary burner for initial heating of water, the burner, located in a primary burner zone, being fed by a low flow rate of substantially pure oxygen, the rate of flow being minimally sufficient for causing the combustion of fuel in stoichiometric proportion to the boiler fuel so as to produce low NOx flue gases;

a collection of water tubes, each tube having a first end in proximity to the at least one primary burner and a second end, spaced away from the first end and, in proximity to a boiler steam outlet;

a convection type superheater in steam transfer connection with the steam outlet in a secondary burner zone; and

at least one nozzle or port in a secondary zone in proximity to the convection-type superheater, for providing an oxidation agent to control temperatures of steam in the superheater, the secondary zone being a low NOx zone.

8. A boiler comprising:

at least one primary burner for initial heating of water, the burner, located in a primary burner zone, being fed by a low flow rate of substantially pure oxygen, the rate of flow being minimally sufficient for causing the combustion of fuel in stoichiometric proportion to the boiler fuel to produce low NOx flue gases;

a collection of water tubes, each tube having a first end in proximity to the at least one primary burner and a second end, spaced away from the first end and, in proximity to a boiler steam outlet;

a convection type superheater in steam transfer connection with the steam outlet; and

said boiler using highly concentrated CO_2 and nitrogen deficient carrier gasses for fuel conveying as a process to control temperatures of steam in the super heater.

9. A boiler comprising:

at least one primary burner for initial heating of water, the burner, located in a primary burner zone, being fed by a low flow rate of substantially pure oxygen, the rate of flow being minimally sufficient for causing the combustion of fuel in stoichiometric proportion to the boiler fuel to produce low NOx flue gases;

a collection of water tubes, each tube having a first end in proximity to the at least one primary burner and a second end, spaced away from the first end and, in proximity to a boiler steam outlet;

a convection type superheater in steam transfer connection with the steam outlet; and

said boiler using highly concentrated CO_2 and nitrogen deficient carrier gasses for fuel conveying as a process of depriving the introduction of nitrogen into the carrier gasses for the carbon based fuel.