SYSTEM OF CLOSE COUPLED RAPID MIX BURNER CELLS

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ABSTRACT

A burner system that utilizes a plurality of single stage rapid mix burner cells which are organized into one or more self-stabilizing matrices. The assemblage combines the advantageous operating characteristics of nozzle mix and premixed type burners and achieves extremely low NOx, CO, and hydrocarbon emissions.
SYSTEM OF CLOSE COUPLED RAPID MIX BURNER CELLS

RELATED APPLICATION

This application claims priority from U.S. provisional patent application Ser. No. 60/962,304, filed on Jul. 27, 2007.

FIELD OF INVENTION

This invention relates generally to combustion apparatus, and more specifically relates to a burner system that utilizes a plurality of single stage Rapid Mix Burner cells, which are organized into one or more self-stabilizing matrices. The assemblage combines the advantageous operating characteristics of nozzle mix and premixed type burners and achieves extremely low NOx, CO, and hydrocarbon emissions.

BACKGROUND OF INVENTION

In the gas burner invention of my U.S. Pat. No. 5,407,347 (the disclosure of which is hereby incorporated by reference) extremely low NOx, CO, and hydrocarbon emissions are achieved, while maintaining the desirable features of a nozzle mix burner. This is accomplished by injecting the fuel gas, such as natural gas, in a position that would be typical for a nozzle mix burner, while generating such rapid mixing that, effectively, premixed conditions are created upstream of the ignition point.

In such burner apparatus (hereinafter referred to as “the basic rapid mix burner”, or “single stage RMB”, or simply “RMB”) an outer shell is provided which includes a windbox and a constricted tubular section in fluid communication therewith. A generally cylindrical body is mounted in the shell, coaxially with and spaced inwardly from the tubular section so that an annular flow channel or throat is defined between the body and the inner wall of the tubular section. Oxidant gases are flowed under pressure from the windbox to the throat, and exit from a downstream outlet end. A divergent quarl is adjoined to the outlet end of the throat and defines a combustion zone for the burner. A plurality of curved axial swirl vanes are mounted in the annular flow channel to impart swirl to the oxidant gases flowing downstream in the throat. Fuel gas injector means are provided in the annular flow channel proximate or contiguous to the swirl vanes for injecting the fuel gas into the flow of oxidant gases at a point upstream of the outlet end. The fuel gas injection means comprise a plurality of spaced gas injectors, each being defined by a gas ejection hole and means to feed the gas thereto. The ratio of the number of gas ejection holes to the projected (i.e. transverse cross-sectional) area of the annular flow channel which is fed fuel gas by the injector means is at least 200/ft².

One or more turbulence enhancing means may optionally be mounted in the throat at least one of the upstream or downstream sides of the swirl vanes. These serve to induce fine scale turbulence into the flow to promote microscale mixing of the oxidant and fuel gases prior to combustion at the quarl. The gas injectors can be located at the leading or trailing edges of the swirl vanes, and inject the fuel gas in the direction of the tangential component of the flow imparted by the swirl vanes. The gas injectors can also be disposed on a plurality of hollow concentric rings which are mounted in the throat downstream of the swirl vanes. The injectors can similarly comprise openings disposed in opposed concentric bands on the walls which define the inner and outer radii of the annular flow channel. The gas injectors can also be located at the surfaces of the swirl vanes, with the vanes being hollow structures fed by a suitable manifold. Preferably the geometry of the burner is such that the product of the swirl number S and the quarl outlet to inlet diameter ratio C/B is in the range of 1.0 to 3.0.

FIG. 1 is a prior art showing which is actually FIG. 17 of my aforementioned U.S. Pat. No. 5,407,347 patent, and is included here to illustrate a typical prior art single stage RMB which may be utilized in the present invention. FIG. 1 is a plan view of such a device 110. The view is somewhat simplified and schematic in nature. Windbox 112 is fed combustion air and flue gas in the direction 114 (by pressurizing means not shown). The entirety of the windbox is not shown, but is rather broken away at its upper end. The arrangement of apparatus 110 enables a more compact device than certain other embodiments of the prior art apparatus. Specifically, it will be seen that a constricted tubular section 115 is provided, which is in direct communication with the interior of wind box 112 through the open end defined by diverging flange 116. The flange 116, while shown to diverge linearly, can also be dish-shaped to assist in air flow. Combustion air proceeds through the annular space 118 defined between tubular member 115 and the generally cylindrical body 120 mounted coaxially with said member. Cylindrical body 120 consists of a central tube 122 within which is received an oil gun 124 terminating in a nozzle 126. Oil is provided to gun 124 by port 125. A combustible gas feed may alternatively or additionally be used. More generally, cylindrical body 120 functions as a bluff body and may take the form of or include an oil gun (which gives the burner both gas and oil firing capabilities); or can simply be an open or closed end tube in the case of a gas only burner. Tube 122 in turn is surrounded by a spaced tubular member 130. The spacing between tube 130 and tube 122 defines an annular space 132 a possible function of which is discussed in my earlier patent. Tube 130 is, in turn, surrounded toward its forward end by a further cylinder 134, which is closed at each end and defines within same an annular fuel receiving manifold 136. Fuel for manifold 136 is fed via a connector 138. The gas injector means in the device 110 comprises a series of prism-like hollow members 139 which are mounted transversely to cylinder 134 and intersect and are open to the interior manifold space 136 within same. The members 139 are provided on their lateral faces with openings 140. The members 139 are directly in contact with and contiguous with the leading edges of swirl vanes 142, so that the gas is injected directly at such leading edge. As discussed previously, a diverging quarl 144 is provided at the outlet end of burner throat 118.

As is known in the art, an igniter is only used for start-up. Once the main flame is established, the igniter is removed and the flame is self-stabilizing. The ignition point is determined by the temperature and mass flow rate of the internal recirculation gases, which in turn is determined by the burner geometry and the amount of external FGR that is used.

Pursuant to another aspect of my U.S. Pat. No. 5,407,347, a method is provided for injection of gaseous fuel in a forced draft burner of the type which includes an annular throat of outer diameter B, having an inlet connected to receive a forced flow of air and recirculated flue gases, and an outlet adjoined to a divergent quarl. The gaseous fuel is
injected at an axial coordinate which is spaced less than B in the upstream direction from the axial coordinate at which the swirl divergence begins; and sufficient mixing of the gaseous fuel with the air and recirculated flue gases is provided that these components are well-mixed down to a molecular scale at the axial coordinate of ignition. This procedure results in extremely low NOx, CO, and hydrocarbon emissions from the burner.

[0009] In a further aspect of my U.S. Pat. No. 5,407,347 invention, the swirl vanes, which are mounted with their leading edges parallel to the axial flow of fuel and oxidant gases, and then slowly curve to the final desired angle, have a constant radius of curvature along the curved portion of the vane, whereby the curved portion is a section of a cylinder. This shape simplifies manufacturing using conventional metal fabricating techniques.

[0010] Also to be noted is that in accordance with the invention in my further U.S. Pat. No. 5,470,224 (the disclosure of which is also incorporated herein by reference), a two stage rapid mix burner design (herein referred to as times as the “D-RMB”) provides apparatus and method which both significantly reduces the burner size of a rapid mix burner, and/or the burner pressure drop, while maintaining the rapid mix feature and stability of the basic rapid mix design. The two stage rapid mix burner design can also be easily altered to fit in non-circular geometries, such as a corner or tangential fired boiler.

[0011] The D-RMB burner uses a circular basic rapid mix burner located internally inside a larger burner which can be non-circular. The inner burner provides the flow of hot gases which stabilizes the outer burner. In effect, the combustion gases produced in the inner burner replace the strong internal recirculation flow generated by the basic RMB as an ignition source for the outer burner flow. The inner burner uses the same type swirler, burner and swirl geometry as the basic RMB burner described in my previous applications and consequently has the desired stability and NOx, CO and HC performance. The outer portion of the burner uses a rapid mix injection grid and consequently also has the desired NOx, CO and HC performance. Since the flame stability is provided by the inner burner, swirl vanes or a divergent swirl for the outer portion of the burner are not required. It may also be noted that in FIGS. 11 and 12 of the U.S. Pat. No. 5,470,224 patent a D-RMB is shown having a rectangular outer burner portion. This geometry corresponds to corner (or tangentially fired boilers), which make up a significant fraction of the large industrial and utility boiler market. FIG. 13 also shows a view of 6 burners, as they would appear in one corner of a typical corner fired boiler application. The inner burner is conceptually the same as the annular two stage burner described e.g. in FIGS. 7 through 10 of the patent. The swirl of the inner burner has the same outside diameter as the smaller dimension of the rectangular boundary comprising the outer burner.

[0012] These two versions of the rapid mix burners (RMB and D-RMB) have been in commercial use for a number of years, with approximately 200 burners installed thus far, and have been meeting NOx emissions of 0.011 lb/MMBtu (9 ppm @ 3% O2) and CO emissions of less than 0.04 lb/MMBtu (50 ppm @ 3% O2). However, in certain regions of the country, including California’s Central Valley, some boilers and furnaces are required to meet NOx emissions less than 0.007 lb/MMBtu (6 ppm @ 3% O2), while maintaining CO emissions of 0.04 lb/MMBtu, or lower. The existing versions of the RMB and D-RMB tend to generate high CO emissions (well above 0.04 lb/MMBtu) as the NOx level approaches 0.007 lb/MMBtu, and in some cases the flames will become unstable. The CO emissions are typically created at the outer edges of the flame, as relatively cold furnace gases are entrained into the flame quenching combustion reactions leaving unburned combustion products at the flame exit. As more and more of the combustion reactions are quenched, the flame eventually no longer generates enough heat to self stabilize.

SUMMARY OF INVENTION

[0013] Now in accordance with the present invention a burner system is disclosed that utilizes a plurality of single stage Rapid Mix Burner cells which are configured into one or more self-stabilizing matrices. Any number of RMB cells, two or more, may be organized into such a matrix. The assemblage combines the advantageous operating characteristics of nozzle mix and premixed type burners and achieves extremely low NOx, CO, and hydrocarbon emissions. This invention is referred to herein as a Cell Rapid Mix Burner or “C-RMB”. The C-RMB is so effective that it may be operated at NOx levels below 0.007 lb/MMBtu while maintaining a stable flame with CO emission below 0.04 lb/MMBtu. The C-RMB concept is applicable to any package or field erected boiler, so long as the front wall meets certain dimensional requirements and the front wall is refractory.

BRIEF DESCRIPTION OF DRAWINGS

[0014] The invention is diagrammatically illustrated, by way of example, in the drawings appended hereto, in which:

[0015] FIG. 1 is a prior art showing (FIG. 17 of my aforementioned U.S. Pat. No. 5,407,347 patent), and illustrates a typical prior art single stage RMB which may be utilized in the present invention:

[0016] FIG. 2 is a longitudinal cross-sectional view, schematic in nature, of a two element C-RMB in accordance with the invention;

[0017] FIG. 3 is a front schematic end view of the apparatus of FIG. 2;

[0018] FIG. 4 is a further schematic longitudinal cross-sectional view, of a four element C-RMB in accordance with the invention; and

[0019] FIG. 5 is a front schematic end view of the apparatus of FIG. 4.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0020] Typical preferred embodiments of the invention are shown in FIGS. 2, 3, 4, and 5. The single stage RMBs used in the two cell arrangement of FIGS. 2 and 3, and in the four cell arrangement of FIGS. 4 and 5, are substantially those of FIG. 1, and accordingly corresponding components to the prior art showing of FIG. 1 are identified by the same reference numerals.

[0021] The invention is used in combination with a boiler or furnace having a refractory bound wall opening for receiving one or more burners. The burner system 102 (FIGS. 2 and 3) is mounted at the wall opening 108 of front wall refractory 112 and includes a plurality of rapid mix burner cells (here two in number) which are configured into a self-stabilizing matrix of side-by-side cells. Air and recirculated flue gases are provided under pressure by conventional fan means (not shown) via a conduit 90 to a burner windbox 92 from which
as shown by arrows 94 they proceed into annular space or throat 118 as in FIG. 1. As in FIG. 1, tube 130 is, in turn, surrounded toward its forward end by a further cylinder 134, which is closed at each end and defines within same an annular fuel receiving manifold 136. Fuel for manifold 136 is fed via an inlet 138. The gas injector means in the cells 104 and 106 again comprises a series of hollow members 139 which are mounted transversely to cylinder 134 and intersect and are open to the interior manifold space 136 within same. The members 139 are provided with openings 140. The members 139 are directly in contact with and contiguous with the leading edges of swirl vanes 142, so that the gas is injected directly at such leading edge. The central tube 122 in each burner cell is provided with combustible gas via an inlet 125 and is open at its forward end to provide center firing for the burner. The individual burner cells 104 and 106 each terminate in a divergent refractory quartz 143 and 144, and are positioned in the matrix so that the centerlines of adjacent cells are no more than 1.6 burner throat diameters apart (dimension S) both vertically and horizontally. A common refractory section 110 is formed into the front wall 112 of the burner system and borders the matrix. The flame from each cell exits into the common refractory section, promoting flame-to-flame self stabilization and increasing the flame 114 residence time in an environment in which the entrainment of cold furnace gases into the flame is limited. The total axial spacing resulting from the refractory quartz at the distal end of each burner cell, plus the said common refractory section, should be at least 20° before the flame is exposed to externally recirculated furnace gases. Preferably as well each burner cell includes means for swirling the air flow from each cell in the same direction. The rotating burner flow brings combustion products from the outer portion of the flame, that may have mixed with relatively cold furnace gases, into the reacting zone between the flames from each burner cell, thereby causing the gases rotated between the flames to be reheated and further oxidation of unburned fuel to occur.

Retreating, the individual burner cells that make up a matrix are thus placed so that the burner centerlines are no more than 1.6 burner throat diameters apart both vertically and horizontally (S/D<1.6 in FIG. 2). The flame from each C-RMB cell exits into a common refractory section formed into the front wall, promoting flame-to-flame self stabilization and increasing the flame residence time in an environment in which the entrainment of cold furnace gases into the flame is limited. And as indicated, the total axial extending length of each burner cell refractory plus the common refractory section provides a total refractory length of at least 20° before the flame is exposed to externally recirculated furnace gases (dimension L in FIG. 2).

The air flow from each burner cell is swirled in the same direction. The rotating burner flow brings combustion products from the outer portion of the flame, that may have mixed with relatively cold furnace gases, into the reacting zone between the flames from each burner cell. This causes the gases rotated between the flames to be reheated and further oxidation of unburned fuel to occur. The swirl direction can be either clockwise or counterclockwise but is the same for all burner cells.

Each cell of the C-RMB system is thus seen to consist of a single stage RMB having a structure in accordance with my U.S. Pat. No. 5,407,347, typically with center fire gas and with the burner refractory angle and dimensions modified from the standard single stage RMB design criteria to meet the S/D<1.6 and L>20°C-RMB requirements.

The burner systems 202 shown in FIGS. 4 and 5 is based on four single stage cell RMBs, arranged in a rectangle or square, where each of the individual cell burners 204, 206, 208, and 210 correspond to the burners in FIGS. 2 and 3 and operate in similar fashion.

The C-RMB system of the invention is further illustrated and its unexpected advantages shown by the following Example:

Example

A C-RMB system in accordance with the invention was tested in a 30,000 lb/hr water tube boiler. FIGS. 2 and 3 schematically illustrate the C-RMB used for the testing. The C-RMB system thus consisted of a two cell RMB matrix burner, similar to the C-RMB arrangement shown in FIGS. 2 and 3. Data from the testing is shown in Table 1.

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
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<tbody>
<tr>
<td>FUEL</td>
</tr>
<tr>
<td>% CO</td>
</tr>
<tr>
<td>NOx</td>
</tr>
<tr>
<td>PPM @ 3% O2</td>
</tr>
<tr>
<td>PPM @ 3% O2</td>
</tr>
<tr>
<td>NOx</td>
</tr>
<tr>
<td>LB/MMBTU</td>
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<tr>
<td>MMBTU</td>
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</tbody>
</table>

The data shows NOx emissions well below the target value of 0.007 lb/MMBTu can be achieved with CO emissions below the target value of 0.04 lb/MMBTu, using the C-RMB concept.

While the present invention has been particular set forth in terms of specific embodiments thereof, it will be understood in view of the present disclosure, that numerous variations on the invention are now enabled to those skilled in the art, which variations yet reside within the scope of the present teaching. Accordingly, the invention is to be broadly construed and limited only by the scope and spirit of the disclosure and of the claims now appended hereto.

1. In combination with a boiler or furnace having a refractory bound wall opening for receiving one or more burners; a burner system for mounting at said wall opening that combines the advantageous operating characteristics of nozzle mix and premixed type burners and achieves extremely low NOx, CO, and hydrocarbon emissions; said burner system comprising:

   a plurality of rapid mix burner cells which are configured into a self-stabilizing matrix of side-by-side cells; the individual burner cells terminating in a divergent refractory quartz, and being positioned in said matrix so that the centerlines of adjacent cells are no more than 1.6 burner throat diameters apart both vertically and horizontally; a common refractory section being formed into the front wall of said system and bordering said matrix, and the flame from each cell exiting into said common refractory section, promoting flame to flame self stabilization
and increasing the flame residence time in an environment in which the entrainment of cold furnace gases into the flame is limited; and the total axial spacing resulting from the said refractory quarl of each burner cell plus the said common refractory section, being at least 20° before the flame is exposed to externally recirculated furnace gases.

2. A system in accordance with claim 1, wherein each burner cell includes means for swirling the air flow from each cell in the same direction; the rotating burner flow bringing combustion products from the outer portion of the flame, that may have mixed with relatively cold furnace gases, into the reacting zone between the flames from each burner cell, thereby causing the gases rotated between the flames to be reheated and further oxidation of unburned fuel to occur.

3. A device in accordance with claim 2, wherein the said matrix includes two or more of said cells arranged in a single row or column.

4. A device in accordance with claim 3, wherein said matrix includes at least one row and one column of said burner cells, the total number of cells being at least four.

5. A system in accordance with claim 2, wherein each cell of the matrix is a single stage rapid mix burner apparatus comprising:

an outer shell including a windbox and a first hollow cylinder having an outlet, and an inlet which is in fluid communication with said windbox;

a second hollow cylinder mounted in said shell coaxially with and spaced inwardly from said first cylinder, an annular flow channel being defined between said first and second cylinder, said channel constituting a throat for oxidant gases provided thereto from said windbox, and having a downstream outlet end for said gases;

means for providing a flow of said oxidant gases to said throat from said windbox;

a divergent quarl being adjoined to said outlet end of said throat and defining a combustion zone for said burner;

a plurality of curved axial swirl vanes being mounted in said annular flow channel to impart swirl to said oxidant gases flowing downstream in said throat;

fuel gas injection means being provided in said annular flow channel proximate to said swirl vanes for injecting said gas into the flow of oxidant gases at a point upstream of said outlet end; and

said fuel gas injection means comprising a plurality of spaced gas injectors, each being defined by a gas ejection hole and means to feed the gas thereto; the ratio of the number of gas ejection holes to the transverse cross-sectional area of the annular flow channel which are fed fuel gas by said injector means being at least 200/ft.sup. 2.

6. Apparatus in accordance with claim 5, further including a third hollow cylinder mounted coaxially within and spaced from said second cylinder, the annular space between said second at third cylinder comprising a manifold for said fuel gas, and said fuel injector means being in communication with said manifold.

7. Apparatus in accordance with claim 6, wherein said swirl vanes are mounted with their leading edges parallel to the axial flow of fuel and oxidant gases, and have a constant radius of curvature along the curved portion of the vanes, whereby said curved portion is a section of a cylinder.

8. Apparatus in accordance with claim 6, wherein the product of the swirl number S and the quarl outlet to inlet diameter ratio C/B is in the range of 1.0 to 3.0.

9. Apparatus in accordance with claim 6, in which said gas injectors are located at the leading edges of said swirl vanes, and inject said fuel gas in the direction of the tangential component of the flow imparted by the swirl vanes.

10. Apparatus in accordance with claim 6, in which said gas injectors are located at the trailing edges of said swirl vanes, and inject said fuel gas in the direction of the tangential component of the flow imparted by the swirl vanes.

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