ABSTRACT

A method of providing oxygen enriched fuel into a combustion atmosphere of a furnace includes injecting a fuel stream into the combustion atmosphere, and providing oxygen into the fuel stream during the injecting of the fuel stream into the combustion atmosphere. A fluid injection apparatus for a combustion atmosphere of a furnace is also provided and includes a housing having a space therein and a discharge orifice in communication with the space, a lance for oxygen disposed in the space and in communication with the discharge orifice, and an inlet duct for a fuel stream in communication with the space external to the lance.
FIG. 9
BURNER UTILIZING OXYGEN LANCE FOR FLAME CONTROL AND NOX REDUCTION

BACKGROUND

[0001] The present embodiments relate to burners and lances that provide oxygen surrounded by a gas shroud to a furnace or melter.

[0002] Known oxy-fuel burners use fuel and oxygen streams. Fuel injectors or burners are also used in regenerative glass melting furnaces. The burners, such as gas burners, are typically pipes or lances with single hole nozzles. Low nitrous oxide (NOx) burners were developed which provided a dual impulse type function. That is, a central conduit with a higher velocity impulse jet has an outer annular jet at a slower velocity. Distribution of the jets is controlled by either of external or internal valves or adjustments of the two nozzles for the burners.

[0003] A higher velocity impulse of the burner provides more turbulence and rapid mixing of the gases, which thus shortens the flame and accordingly provides the flame with a higher concentration of NOx. Conversely, a lower velocity impulse produces less turbulence, less mixing and therefore a longer staged burner and flame which results in lower NOx emissions. These types of burners typically produce NOx at about or in excess of 850 mg/Nm³ at 8% O₂, if no other NOx reduction equipment is employed. It is also common to use cooling air for off-side cooling on a non-firing side of the furnace regenerator.

[0004] What would be desirable to have, however, is burners producing NOx lower than 850 mg/Nm³ at 8% O₂ with adjustable flame shape and higher heat transfer.

BRIEF DESCRIPTION OF THE DRAWING

[0005] For a more complete understanding of the present embodiments, reference may be had to the following description taken in conjunction with the drawing Figures, of which:

[0006] FIGS. 1-5 show cross-section side views of embodiments of a burner lance of the present invention;

[0007] FIG. 6 shows a cross-section side view of another embodiment of a burner lance of the present invention;

[0008] FIG. 7 shows a cross-section end view of a burner lance embodiment used with a cross-fired regenerative furnace;

[0009] FIG. 8 shows a cross-section partial end view of another burner lance embodiment used under-port of a regenerative furnace; and

[0010] FIG. 9 shows a cross-section partial end view of the burner lance embodiment disposed off-side with respect to the regenerative furnace.

DETAILED DESCRIPTION OF THE INVENTION

[0011] Before describing the present inventive embodiments in detail, it is to be understood that the inventive embodiments are not limited in their application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also, it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation. The inventive embodiments can be used with all types of regenerative furnaces such as for example cross-fired and end-fired furnaces; under-port, side-port and through-port; recuperative furnaces; a hundred percent oxy-fuel furnaces; and air fuel furnaces including regenerative and recuperative furnaces which are partially boosted by oxy-fuel burners. As further examples, the embodiments can be used with a regenerative furnace such that injecting a fuel stream and providing oxygen can occur beneath at least one port of the regenerative furnace, or such can occur at a side of at least one port of the furnace; or the embodiments can be used in a recuperative burner hot air stream for a recuperative furnace.

[0012] Referring to FIG. 1, an embodiment of a fuel injector with integral oxygen injector apparatus of the present invention is shown generally at 10 and which may be used with a furnace, such as for example a regenerative furnace (see FIG. 7). The injector 10 includes a body portion 12 having a sidewall 11 defining a space 14 or passageway for a fuel, such as gas, within the body portion and in which to receive an oxygen lance 16 or pipe through an end wall 20 of the body portion 12. Another end wall 22 or distal end of the body portion 12 is open-ended to provide a discharge orifice 23. The space 14 extends between the end wall 20 and the distal end 22. The oxygen lance 16 includes a sidewall 24 defining an internal passageway 26 of the lance through which oxygen, as a stream for example, is provided as shown by arrow 17. A hole 28 is provided in the sidewall between the end wall 20 and the distal end 22. An inlet duct 30 or pipe is in fluid communication with the space 14 of the body portion 12 via the hole 28 so that injected gas, such as natural gas, as a fuel and indicated by arrow 32 can be introduced or injected into the space. The actual mixing of the fuel 32 and the oxygen 17 will occur at the discharge end external to the oxygen injector apparatus 10.

[0013] The injector body portion 12 can be made of steel, while the oxygen lance 16 is made of stainless steel, copper or a combination thereof. The fuel 32 can be selected from natural gas, producer gas, coke oven gas, syngas, methane, ethane, propane, butane, pentane, low calorific biomass, or any other commercially available fuel.

[0014] Referring still to FIG. 1, the apparatus 10 may be used in a regenerative furnace, for example, in either an under-port or side-port location. The oxygen stream 17 can be used to cool a tip of the body portion 12 proximate the discharge orifice 23 during a non-firing mode of the apparatus. At the end of the furnace reversal, as the injected fuel 32 is introduced into the space 14, a flame will form rapidly at an interface of the gas and the oxygen stream 17. As the injected gas flow 32 increases above that of the flow of the oxygen 17, the flame will be surrounded by a zone of injected gas 32 which will burn in a combustion region of the furnace, similar to that which occurs with known burners. Combustion of the oxygen 17 and gas 32 internal to the flame (but external to the apparatus 10) will create a much hotter flame that will disassociate (crack) the natural gas to form carbon soot particles and OH radicals which will increase heat transfer through improved flame luminosity and lower NOx through staged combustion in the combustion region of the furnace. An increase in the oxygen 17 and/or a higher velocity of the oxygen will increase mixing and shortening of the flame length. Conversely, a lesser amount and/or lower velocity of the oxygen will produce a longer flame length.

[0015] The apparatus 10 provides for the flame to be external to the lance but disposed internal to a shroud of the gas 32. The oxygen 17 is injected into the fuel stream 32 and may be injected into an interior or central region of the fuel stream.
Other exemplary embodiments of the present invention are illustrated in FIGS. 2-6, respectively. Elements illustrated in FIGS. 2-6 which correspond to the elements described above with respect to FIG. 1 have been designated by corresponding reference numerals increased by 100, 200, 300, etc., respectively. The embodiments of FIGS. 2-6 are designed for use in the same manner as the embodiment of FIG. 1, unless otherwise stated.

Referring to FIG. 2, another embodiment of an oxygen injector apparatus 110 is shown. The apparatus 110 includes an injector nozzle 42 at the distal end 22. The nozzle 42 has an end portion 44 which converges as shown in FIG. 2 to reduce a size of the discharge orifice 123. The body portion 12 of the injector apparatus 110 also includes a seal 46 or gasket at the end wall 120 where the oxygen lance 116 extends through the end wall into the space 114.

Still referring to FIG. 2, the oxygen lance 116 is movably positionable and adjustable with respect to the nozzle 42 which will, in effect, control the velocity of the injected gas 312. Arrows 40 represent movement of the oxygen lance 116 in the space 114. The lance 116 is movable along its longitudinal axis substantially parallel to a longitudinal axis of the body portion 112 extending along the space 114.

In FIG. 3, the oxygen injection apparatus 210 is essentially the same as that provided above in FIG. 2, with the addition of a vortex element 50 or member disposed in the space 214 to increase mixing of the injected gas 232 with the injected oxygen 217. The vortex element 50 may include a swirler vane, for example.

In FIG. 4, a vortex element 52 or member is disposed in the internal passageway 326 of the oxygen lance 316 to provide turbulence to the oxygen stream 317 to increase mixing of same with the injected gas 332. The vortex element 52 may include a swirler vane, for example.

Referring to FIG. 5, the oxygen injection apparatus 410 includes both vortex elements 50, 52 in the space 414 and the passageway 426, respectively. Such construction provides the greatest amount of turbulence to facilitate mixing the injected oxygen 417 with the injected gas 432. The elements 50, 52 may be moved with respect to each other so as to increase or decrease an overall velocity of the flame resulting from the burner in which the apparatus 10 is used. It is also possible to use the elements 50, 52 so that they move in co- or counter-directions with respect to each other to adjust the amount of turbulence created or mixing of the oxygen 17 and the injected gas 32.

The present apparatus 10 can be used with a recuperative burner and can have application in glass industries, as well as secondary steel/metal or cement industries. The oxygen injector apparatus 10 can be retrofitted to side-port and through-port regenerative furnaces.

FIG. 6 shows another embodiment of the oxygen injection apparatus shown generally at 510 and having a construction similar to that of FIG. 1, but instead delivering up to 20% of oxygen through the lance. In the embodiment of FIG. 6, the apparatus 510 can have up to 100% of the oxygen 517 surrounded by the gas 532 shroud. In effect, what is provided by the apparatus 510, as well as the apparatus 10-410, is a "inside-out" burner. Such a burner is ignited by introducing a portion of the oxygen stream 517 prior to injecting the gas 532 to ensure that when the gas is introduced into the space 514 there is a sufficient flame front established immediately external to the burner with the oxygen then fully introduced and brought up to full power into the passageway 526. It is necessary to provide a sufficient amount of the injected gas 532 to provide for cooling of the block prior to the flame being established from the burner. A majority of the oxygen passing through the burner is consumed within the inner flame envelope. Any injected gas 532 immediately adjacent or tangential to the flame is cracked to form carbon (C) and OH radicals. By consuming the oxygen internal to the flame the release of free radical oxygen is limited and hence the formation of NOx is also limited. By injecting gas 517 encapsulating the oxygen in the gas shroud, formation of glass foam is substantially minimized, and the carbon (soot) formation will further reduce the glass foam layer in the melt.

The injected gas 32-532 can be provided to the oxygen stream 17-517 prior to the oxygen stream entering a regenerator or a furnace.

The oxygen injector apparatus 10-510 can be used individually or in combination with furnaces, such as glass melting furnaces either alone or with a regenerator(s) mounted to the furnaces.

The fuel 132-532 can also be selected from natural gas, producer gas, coke oven gas, syngas, methanle, ethane, propane, butane, pentane, low calorific biomas or any other commercially available fuel.

Referring to FIGS. 7-9, the oxygen injector apparatus 10-510 is shown for use with certain types of furnaces.

Referring to FIG. 7, an oxygen injector apparatus 10 is shown for use with a furnace 60, which happens to be a regenerative furnace, due to generators 62-64 disposed at sidewalls of the furnace. A glass bath 61 or melt is at a bottom of the furnace 60. Port 72 is in communication with and interconnects the regenerator 62 with the furnace 60, while the port 74 interconnects and is in communication with the regenerator 64 and the furnace 60. The regenerator 62 includes checker brick 66, while the regenerator 64 includes checker brick 68. The furnace 60 includes a combustion region 70 which is in fluid communication with the ports 72, 74.

By way of example, the oxygen injector apparatus 10 is shown mounted for a cross-fired application with respect to the regenerator furnace 60. Each one of the apparatus 10 provides an oxygen-gas flame front 80 which is surrounded by an air-fuel flame front 82.

In FIG. 8, the oxygen injector apparatus 10 includes an oxygen envelope 84 surrounded by an oxygen-gas flame front 80 for providing the air-fuel flame front 82. During reversal of the regenerators 62-64, oxygen 17 only will be flowing and upon ignition, the injected gas 32 will ignite. The oxygen envelope 84 will be enclosed as the oxygen-gate flame front 80 increases to full flow from the apparatus 10. The present embodiment of FIG. 8 can be used with cross-fired and end-port furnaces.

Referring to FIG. 9, there is shown the off-side firing mode of the furnace 60, wherein the oxygen injector apparatus 10 provides the oxygen envelope 84 for post-combustion of the air-fuel flame front 82.

FIGS. 7-9 show operation in a cross-fired regenerative furnace. However the apparatus 10-510 could also be used in an end-fired furnace under similar principals of operation. Combustion air 78 is pre-heated by the regenerator 64. The amount of air required will be less than required in a conventional regenerator, since there are two points of additional oxygen injection 17 to the apparatus 10, one at a firing side in FIG. 8 and one at an exhaust side of FIG. 9. In a
cross-fired furnace, the port fuel distribution and concentration of oxygen per port can be different. Note that for each port 72.74 there can be from one to four injector apparatus 10. The oxygen and fuel can therefore be profiled across the particular port with different fuel and oxygen in each burner to meet the combustion needs of the furnace 60. Depending upon the type of furnace 60 and condition of the regenerator 64 for example, varying quantities of oxygen may be provided to each port 74. Similarly, if each port 74 has a plurality of burners (for example, four) then fuel flow profiles could also be used which would therefore call for different quantities of oxygen to be provided. On the firing side in FIG. 8, the oxygen stream 17 creates the oxygen envelope 84 which combusts to create the flame front 80 inside the main air fuel flame 82. The flame 80 will crack and dissociate the fuel 32 to increase flame luminosity, resulting in improved heat transfer to the furnace 60 and the glass bath 61. The quantity and velocity of the oxygen 17 relative to the fuel 32 will adjust the flame mixing and a resulting shape of the flame.

Referring FIG. 9, the air-fuel flame front 82 will require oxidant to complete the combustion and this is provided via the off-side/exhaust oxygen envelope 84. The oxygen flow on the firing side can be the same as on the exhaust side. In certain applications it is desirable to have more oxygen on the firing side in order to shorten the flame. In other applications there may be an excess of carbon monoxide and therefore it is desirable to have more oxygen on the exhaust side. This method of overall flame staging will increase heat transfer and reduce the formation of NOX when implemented. During reversal of the regenerators 62,64 for the furnace there will be a possibility to reduce oxygen flow to a minimum in order to provide cooling of the furnace.

All of the elements of the oxygen injector apparatus 10-510 are constructed of metal, except for the seal 46. In many applications, the injected gas 32-532 will be provided, for example injected, into the oxygen stream 17-517, which may also be injected, before entering into a furnace or a regenerator.

It will be understood that the embodiments described herein are merely exemplary, and that one skilled in the art may make variations and modifications without departing from the spirit and scope of the invention. All such variations and modifications are intended to be included within the scope of the invention as described and claimed herein. Further, all embodiments disclosed are not necessarily in the alternative, as various embodiments of the invention may be combined to provide the desired result.

What is claimed is:

1. A method of providing oxygen enriched fuel into a combustion atmosphere of a furnace, comprising:
   injecting a fuel stream into the combustion atmosphere; and
   providing oxygen into the fuel stream during the injecting of the fuel stream into the combustion atmosphere.

2. The method of claim 1, wherein the providing oxygen comprises injecting the oxygen into the fuel stream.

3. The method of claim 1, further comprising mixing the oxygen and the fuel stream.

4. The method of claim 1, further comprising creating turbulence in the fuel stream for mixing with the oxygen.

5. The method of claim 1, further comprising creating turbulence in the oxygen for mixing with the fuel stream.

6. The method of claim 1, further comprising adjusting a flow rate of the oxygen for controlling a flow rate of the fuel stream to be responsive to a flow rate of the oxygen.

7. The method of claim 1, wherein the injecting the fuel stream into the combustion atmosphere occurs prior to the oxygen entering the furnace.

8. The method of claim 1, wherein the oxygen is to an interior of the fuel stream.

9. The method of claim 1, wherein the furnace is a regenerative furnace and the injecting and the providing occur beneath at least one port of said regenerative furnace.

10. The method of claim 1, wherein the furnace is a regenerative furnace and the injecting and the providing occur at a side of at least one port of said furnace.

11. The method of claim 1, wherein the furnace is a regenerative furnace and the injecting and the providing occur in a middle of at least one port of said furnace.

12. The method of claim 1, wherein the furnace is a recuperative furnace and the injection and the providing occur in a recuperative burner hot air stream for said furnace.

13. The method of claim 1, wherein the furnace is an oxy-fuel furnace and the oxygen provided to the fuel stream is in an amount up to a hundred percent (100%) of the oxygen being provided into the fuel stream.

14. A fluid injection apparatus for a combustion atmosphere of a furnace, comprising:
   a housing having a space therein and a discharge orifice in communication with the space;
   an in-fuel oxygen disposed in the space and in communication with the discharge orifice; and
   an inlet duct for a fuel stream in communication with the space external to the lance.

15. The apparatus of claim 14, further comprising a nozzle mounted to the housing at the discharge orifice.

16. The apparatus of claim 14, wherein the lance is adjustable moveable within the space to control a flow of the oxygen and the fuel stream into the combustion atmosphere.

17. The apparatus of claim 14, wherein the housing is mounted to at least one of an end wall, a sidewall, a crown, and a peep site hole of the furnace and the discharge opening is in communication with the combustion chamber of the furnace.

18. The apparatus of claim 14, further comprising a vortex member disposed in the space for creating turbulence of the fuel stream.

19. The apparatus of claim 18, wherein the vortex member comprises a swirler vane.

20. The apparatus of claim 14, further comprising a vortex member disposed at an interior of the oxygen lance for creating turbulence of the oxygen.

21. The apparatus of claim 20, wherein the vortex member comprises a swirler vane.

22. The apparatus of claim 14, wherein the fuel stream is selected from the group consisting of natural gas, producer gas, coke oven gas, syngas, methane, ethane, propane, butane, pentane, low calorific biomas or any other commercially available fuel.

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