

FLUE GAS RECIRCULATION FOR NO_x REDUCTION IN PREMIX BURNERSBACKGROUND OF THE INVENTION1. Field Of The Invention

5 This invention is related to an apparatus and method for reducing NO_x emissions from premix burners, without altering critical heat distribution from the burners. This invention may be employed in high temperature furnaces, for example, for steam cracking hydrocarbons.

2. Description Of Background And Relevant Information

10 Various nitrogen oxides, i.e., NO_x compounds, are formed in air at high temperatures; these include, but are not limited to, nitric oxide and nitrogen dioxide. Reduction of NO_x emissions is a desired goal in order to decrease air pollution and meet government regulations.

15 Burners may use either liquid fuel or gas. Liquid fuel burners may mix the fuel with steam prior to combustion to atomize the fuel to enable more complete combustion, and combustion air is mixed with the fuel at the point of combustion.

20 Gas fired burners are classified as either raw gas or premix, depending on the method used to combine the combustion air and fuel. These burners differ in configuration, and in the type of burner tip used.

25 Raw gas burners inject fuel directly into the combustion air stream, and the mixing of fuel and air occurs simultaneously with combustion.

30 Premix burners mix the fuel with some or all of the combustion air prior to combustion. Premixing is accomplished by using the energy of the fuel stream so that air flow is generally proportional to fuel flow. Therefore, frequent adjustment is not required and the achievement of desired flame characteristics is facilitated.

This Sheet Has Been Replaced



REPLACED SHEETS		SG
☒	Description: 1 page to page 18	
☒	Claim(s): 1 page to page 15	
☒	Drawing(s): 1 page to page 5	
☐	Other: 1 page to page 1	
DATE RECEIVED		

Floor-fired premix burners are used in many steam crackers and reformers, mainly for their ability to produce relatively uniform heat distribution in the tall radiant sections of these furnaces. Flames are non-luminous, permitting tube metal temperatures to be readily monitored. Due to these properties, premix burners are widely used in various steam cracking furnace configurations.

MICHELSON et al., U.S. Patent No. 4,629,413, discloses a low NO_x premix burner and discusses the advantages of premix burners and methods to reduce NO_x emissions; this patent is incorporated herein in its entirety, by reference thereto. The premix burner of MICHELSON et al. lowers NO_x emissions by delaying the mixing of secondary air with the flame and allowing some cooled flue gas to recirculate with the secondary air.

BRAZIER et al., U.S. Patent No. 4,708,638, discloses a fluid fuel burner, in which NO_x emissions are reduced by lowering the flame temperature. A venturi in a combustion air supply passage, upstream of a swirler, induces the flow of flue gas into the combustion air supply passage from ducts opening into the furnace. A swirler is located at the free end of a fuel pipe and mixes the flue gas with the primary combustion air.

FERGUSON, U.S. Patent No. 2,813,578, discloses a heavy liquid fuel burner, which mixes the fuel with steam prior to combustion. The aspirating effect of the fuel and steam draws hot furnace gases into a duct and into the burner block to aid in heating the burner block and the fuel and steam passing through a bore in the block. This arrangement is disclosed as being effective to prevent coke deposits on the burner block and also to prevent any dripping of the oil. Since the flame temperature is raised, this arrangement would not aid



in reducing NO_x emissions.

JANSSEN, U.S. Patent No. 4,230,445, discloses a fluid fuel burner, which reduces NO_x emissions by supplying a flue gas/air mixture through several passages. Flue gas is drawn
5 from the combustion chamber by a blower.

ZINK et al., U.S. Patent No. 4,004,875, discloses a low NO_x burner, in which combusted fuel and air is cooled and recirculated back into the combustion zone. The recirculated combusted fuel and air is formed in a zone with a deficiency
10 of air.

OPPENBERG et al., U.S. Patent No. 4,575,332 discloses a burner having both oil and gas burner lances, in which NO_x emissions are reduced by discontinuously mixing combustion air into the oil or gas flame to decelerate combustion and lower
15 the temperature of the flame.

GRIFFIN, U.S. Patent No. 2,918,117, discloses a heavy liquid fuel burner, which includes a venturi to draw products of combustion into the primary air to heat the incoming air stream to therefore completely vaporize the fuel.

20 In addition to MICHELSON et al., the other patents discussed above are also incorporated herein in their entireties, by reference thereto.

SUMMARY OF THE INVENTION

An object of the present invention is to provide means
25 for retrofitting an existing premix burner to lower NO_x emissions, and thereby decrease air pollution and satisfy government standards. Retrofitting an existing premix burner utilizing the present invention is estimated to cost approximately \$2,000 per burner. In comparison, replacing an
30 existing premix burner with a new low NO_x premix burner would cost approximately \$8,000 to \$10,000 per burner. Because a steam cracking furnace may have 50 burners, for example, retrofitting the furnace utilizing the present invention would

This Sheet Has Been Replaced



therefore present considerable savings over replacing the burners of the furnace.

5 A premix burner for the combustion of fuel gas and air with reduced NO_x emissions is located adjacent a first opening in a furnace, and includes a burner tube having a downstream end and an upstream end. A burner tip is mounted on the downstream end of the burner tube adjacent the first opening in the furnace, and combustion of the fuel gas and air takes place at the burner tip.

10 A gas spud is located adjacent the upstream end of the burner tube in a primary air chamber for introducing fuel gas into the burner tube. Air also is introduced into the upstream end of the burner tube. According to the present invention, at least one passageway has one end at a second opening in the furnace and a second end adjacent the upstream end of the burner tube.

15 Flue gas is drawn from the furnace, through the passageway, in response to fuel gas and air flowing towards the downstream end of the burner tube, whereby the flue gas is mixed with the air at the upstream end of the burner tube prior to the point of combustion of the fuel gas and air, to thereby reduce NO_x emissions.

20 According to one aspect of the invention the flue gas is drawn from the furnace into the passageway in response to fuel gas flowing through a venturi portion in the burner tube. The passageway includes a duct extending into a second opening in the furnace at one end and into the primary air chamber at the other end. At least one adjustable damper opens into the primary air chamber from the ambient to restrict the amount of ambient air entering into the primary air chamber, thereby providing a vacuum to draw flue gas from the furnace.

25 According to another aspect of the invention, the passageway includes two ducts. Each duct may be substantially

This Sheet Has Been Replaced



L-shaped, and further includes flexible seal means at one or both ends of the duct. The respective seal means are adapted to be connected to a portion of the furnace and to the duct.

5 The premix burner further includes at least one staged air port opening into the furnace. Ambient air passes into the furnace through the at least one staged air port, and is drawn into the at least one duct to lower the temperature of the gas flowing through the duct.

10 Another object of the invention is to provide a method of retrofitting an existing premix burner in a furnace to reduce NO_x emissions, wherein the premix burner includes a burner tube having a downstream end and an upstream end, with a burner tip being mounted on the downstream end of the burner tube where combustion of fuel gas and air takes place. Fuel
15 gas is introduced into the upstream end of the burner tube in a primary air chamber, so that air is mixed with the fuel gas in the primary air chamber prior to the point of combustion.

The method includes the following steps:

20 A passageway is installed between the furnace and the primary air chamber. Flue gas is drawn from the furnace through the passageway in response to fuel gas and air flowing towards the downstream end of the burner tube. Flue gas is mixed with the air in the primary air chamber, prior to the point of combustion, so that NO_x emissions are reduced.

25 Either one or two pipes may be installed between the furnace and the primary air chamber. Flexible seals are attached to each of the end portions of the pipes, and to a portion of the furnace.

30 According to another aspect of the invention, the burner tube includes a venturi portion, and flue gas is drawn from the furnace by the aspirating effect of the fuel gas and air passing through the venturi portion. The amount of ambient air drawn into the primary air chamber may be adjustably

This Sheet Has Been Replaced



restricted to provide the vacuum necessary to draw flue gas from the furnace.

According to another aspect of the invention, the pipes are installed by forming openings in the floor of the furnace and in a wall of the primary air chamber, and inserting one
5 end of at least one pipe in the opening in the floor and the other end of the pipe in the opening in the wall. The pipe may then be wrapped with a ceramic fiber blanket.

Another object of the invention is to provide a method
10 for reducing NO_x emissions in a premix burner. The premix burner is located adjacent a first opening in a furnace, and the method includes the steps of: combining fuel gas and air in a primary air chamber; providing combustion of the fuel gas and air at a combustion point downstream of the step of
15 combining the fuel gas and air; and drawing flue gas from the furnace in response to fuel gas and air flowing towards the combustion point, whereby the flue gas mixes with the air in the primary air chamber prior to the point of combustion to thereby reduce NO_x emissions.

The drawing step may include passing the fuel gas and
20 air through a venturi, whereby the aspirating effect of the fuel gas and air flowing through the venturi draws the flue gas from the furnace. Ambient air, which is at a lower temperature than the flue gas, passes into the furnace, and
25 then the lower temperature air, as well as the flue gas, are both drawn to the primary air chamber from the furnace; as a result, the temperature of the drawn flue gas is lowered. The ambient air may be fresh air having an ambient temperature, although the temperature may be in the range between a
30 temperature colder than the ambient temperature and a temperature slightly below the temperature of the flue gas in the furnace.

This Sheet Has Been Replaced



BRIEF DESCRIPTION OF THE DRAWINGS

The invention is further explained in the description which follows with reference to the drawings illustrating, by way of non-limiting examples, various embodiments of the invention wherein:

Fig. 1 illustrates an elevation partly in section of an embodiment of the premix burner of the present invention;

Fig. 1A is a partial elevation of a premix burner similar to Fig. 1, and includes a secondary air port instead of staged air ports.

Fig. 2 is an elevation partly in section taken along line 2-2 of Fig. 1;

Fig. 3 is a plan view taken along line 3-3 of Fig. 1;

Fig. 4 is a plan view taken along line 4-4 of Fig. 1;

Fig. 5 is a second embodiment of the premix burner of the present invention;

Fig. 6 is an elevation partly in section of the recirculation pipe of the present invention;

Fig. 7 is an elevation partly in section of a third embodiment of the premix burner of the present invention;

Fig. 8 is an elevation partly in section taken along line 8-8 of Fig. 7; and

Fig. 9 is a plan view taken along line 9-9 of Fig. 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring particularly to Figs. 1-4, a premix burner includes a freestanding burner tube 12 located in a well in a furnace floor 14. Burner tube 12 includes an upstream end 16, a downstream end 18 and a venturi portion 19. Burner tip 20 is located at downstream end 18 and is surrounded by an annular tile 22. Gas spud 24 is located at upstream end 16 and introduces fuel gas into burner tube 12. Fresh or ambient air is introduced into primary air chamber 26 through adjustable damper 28 to mix with the fuel gas at upstream end

This Sheet Has Been Replaced



16 of burner tube 12. Combustion of the fuel gas and fresh air occurs at burner tip 20.

5 A plurality of air ports 30 originate in secondary air chamber 32 and pass through furnace floor 14 into the furnace. Fresh air enters secondary air chamber 32 through adjustable dampers 34 and passes through staged air ports 30 or through secondary air port 90 into the furnace to provide secondary or staged combustion and to dilute the oxygen concentration of flue gas, as described in MICHELSON et al.

10 In order to recirculate flue gas from the furnace to the primary air chamber, ducts or pipes 36, 38 extend from openings 40, 42, respectively, in the floor of the furnace to openings 44, 46, respectively, in burner plenum 48. Flue gas containing, for example, 6-10% O₂, is drawn through pipes 36,
15 38 by the aspirating effect of fuel gas passing through venturi portion 19 of burner tube 12. In this manner, the primary air and flue gas are mixed in primary air chamber 26, which is prior to the point of combustion. Therefore, the oxygen concentration of the primary air is diluted prior to
20 the point of combustion, thereby slowing down the combustion, and as a result, reducing NO_x emissions. This is in contrast to a liquid fuel burner, such as that of FERGUSON et al., in which the combustion air is mixed with the fuel at the point of combustion, rather than prior to the point of combustion.

25 Closing damper 28 restricts the amount of fresh air that can be drawn into the primary air chamber and thereby provides the vacuum necessary to draw flue gas from the furnace floor.

Unmixed low temperature ambient air, having entered secondary air chamber 32 through dampers 34, and having passed
30 through air ports 30 into the furnace, is also drawn through pipes 36, 38 into the primary air chamber by the aspirating effect of the fuel gas passing through venturi portion 19. The ambient air may be fresh air as discussed above. The mixing

This Sheet Has Been Replaced



of the ambient air with the flue gas lowers the temperature of the hot flue gas flowing through pipes 36, 38 and thereby substantially increases the life of the pipes and allows use of this type burner to reduce NO_x emission in high temperature cracking furnaces having flue gas temperature above 1900°F in the radiant section of the furnace.

Advantageously, a mixture of approximately 50% flue gas and approximately 50% ambient air should be drawn through pipes 36, 38. The desired proportions of flue gas and ambient air may be achieved by proper placement and/or design of pipes 36, 38 in relation to air ports 30. That is, the geometry of the air ports, including but not limited to their distance from the burner tube, the number of air ports, and the size of the air ports, may be varied to obtain the desired percentages of flue gas and ambient air.

A sight and lighting port 50 is provided in the burner plenum 48, both to allow inspection of the interior of the burner assembly, and to provide access for lighting of the burner. The burner plenum may be covered with mineral wool soundproofing 52 and wire mesh screening 54 to provide insulation therefor.

An alternate embodiment of premix burner 10 is shown in Fig. 5, wherein like reference numbers indicate like parts. The main difference between the embodiment of Figs. 1-4, and that of Fig. 5, is that the latter employs only one recirculation pipe 56. For example, one 6 inch diameter pipe may be used instead of two 4 inch pipes.

The recycle pipe 56 of Fig. 5, or the recycle pipes 36, 38 of Figs. 1-4, may be retrofitted into an existing premix burner. Referring to Fig. 6, an opening 58 is formed in furnace floor 14, and an opening 60 is formed in a wall of burner plenum 48. Pipe 56 is then inserted, so that its respective ends extend into openings 58 and 60. Pipe 56 may

This Sheet Has Been Replaced



be covered by insulation portions 62, 64, which may be ceramic fiber blankets.

5 Flange 66 is attached to furnace floor casing plate 68, and flange 70 is attached to burner plenum 48. Seal bag 72 is attached at one end to flange 66, and at the other end to insulation portion 62. Seal bag 74 is attached to flange 70 at one end, and to insulation portion 62 at the other end. The seal bags 72, 74 may be flexible and be made of any suitable heat-resistant material. Alternately, one or both
10 seal bags may be eliminated and the recycle pipe may be seal welded to floor casing plate 68 or burner plenum 48.

The flue gas recycling system of the present invention may also be applied to a new low NO_x burner such as illustrated in Figs. 7, 8 and 9, wherein like reference
15 numbers indicate like parts. A flue gas recirculation passageway 76 is formed in furnace floor 14 and extends to primary air chamber 78, so that flue gas is mixed with fresh air drawn into the primary air chamber from opening 80. The external surface of passageway 76 may be wrapped with
20 insulation 82, which may be a ceramic fiber blanket. Sight and lighting port 84 provides access to the interior of burner plenum 86 for pilot lighting element 88. It is noted that a similar pilot lighting element may also be used in the embodiments of Figs. 1 and 5.

25 Premix burners, according to the present invention may be used under a wide range of operating conditions. An example is described below with reference to Fig. 5.

Fuel gas at 190 lbs./hr. is introduced into burner tube 12 from gas spud 24. Fresh air at 620 lbs./hr. and 60°F. flows through damper 28 into primary air chamber 26. Air at
30 2760 lbs./hr. and 60°F. flows through damper 34 into secondary air chamber 32 and passes through air ports 30 at 2,400 lbs./hr. and 60°F. As a result, fuel and flue gas are

This Sheet Has Been Replaced



provided at 1,550 lbs./hr. and 2,100°F. at burner tip 20. The air ports 30 and pipe 56 are arranged such that flue gas at 380 lbs./hr. and 1,840°F. and air from air ports 30 at 360 lbs./hr. are drawn into pipe 56, to result in a flue gas and air mixture at 740 lbs./hr. which contains 9.4% O₂ and is at 1,025°F. in pipe 56.

As discussed above, the cooling of the flue gas by the fresh air increases the service life of the recycling pipe 56. The recycled flue gas dilutes the concentration of O₂ in the combustion air, which lowers the flame temperature, and thereby reduces NO_x emissions.

Although the premix burners of this invention have been described in connection with floor-fired hydrocarbon cracking furnaces, they may also be used on the side walls of such furnaces or in furnaces for carrying out other reactions or functions.

Thus, it can be seen that, by use of this invention, NO_x emissions may be reduced in a premix burner without the use of fans or special burners. The flue gas recirculation system of the invention can also easily be retrofitted to existing premix burners.

Although the invention has been described with reference to particular means, materials and embodiments, it is to be understood that the invention is not limited to the particulars disclosed and extends to all equivalents within the scope of the claims.

This Sheet Has Been Replaced



CLAIMS:

1. A premix burner for obtaining reduced NO_x emissions in the combustion of fuel gas, said premix burner being located adjacent a first opening in a furnace, said premix burner comprising:

(a) a burner tube having a downstream end, and having an upstream end for receiving air and fuel gas, a burner tip being mounted on the downstream end of said burner tube adjacent the first opening in the furnace, so that combustion of the fuel gas takes place at said burner tip;

(b) a gas spud located adjacent the upstream end of said burner tube, for introducing fuel gas into said burner tube;

(c) at least one passageway having a first end at a second opening in the furnace and a second end adjacent the upstream end of said burner tube; and

(d) means for drawing flue gas from said furnace, through said passageway, in response to fuel gas and air flowing through said burner tube from its upstream end towards its downstream end, whereby the flue gas is mixed with air at said upstream end of said burner tube prior to the point of combustion of the fuel gas and air.

2. The premix burner according to claim 1, wherein said means for drawing flue gas from said furnace comprises a venturi portion in said burner tube.

3. The premix burner according to claim 1, comprising a primary air chamber, wherein said at least one passageway comprises a duct having a first end and a second end, said first end extending into a second opening in the furnace, and said second end extending into said primary air chamber.

4. The premix burner according to claim 2, comprising a primary air chamber, comprising at least one adjustable damper opening into said primary air chamber to restrict the





amount of ambient air entering into said primary air chamber, and thereby to provide a vacuum to draw flue gas from the furnace.

5. The premix burner according to claim 3, wherein said at least one passageway comprises two of said ducts.

6. The premix burner according to claim 3, wherein said duct is substantially L-shaped.

7. The premix burner according to claim 3, further including flexible seal means at at least one of said first end and said second end of said duct.

8. The premix burner according to claim 7, wherein said seal means at said first end of said duct is for connection to a portion of the furnace and said duct, and wherein said seal means at said second end of said duct is connected to said duct and said primary air chamber.

9. The premix burner according to claim 1, further comprising at least one air opening into the furnace, for allowing air to be passed therethrough into said furnace, and thereafter to be drawn into said at least one passageway.

10. A method of retrofitting an existing premix burner in a furnace to reduce NO_x emissions, said premix burner including a burner tube, having a downstream end and an upstream end, a burner tip being mounted on the downstream end of said burner tube where combustion of fuel gas takes place, means for introducing fuel gas into the upstream end of said burner tube in a primary air chamber, so that air is mixed with the fuel gas in the primary air chamber prior to the point of combustion; said method comprising the step of installing a passageway between the furnace and the primary air chamber for drawing flue gas from the furnace through the passageway in response to fuel gas and air flowing towards the downstream end of said burner tube.

11. The method of retrofitting an existing premix burner





according to claim 10, wherein said step of installing said at least one passageway comprises installing at least one pipe between the furnace and the primary air chamber.

12. The method of retrofitting an existing premix burner according to claim 10, wherein said step of installing said at least one passageway comprises installing two pipes between the furnace and the primary air chamber.

13. The method of retrofitting an existing premix burner according to claim 11, further comprising attaching flexible sealing means to each end portion of said at least one pipe, and also attaching said sealing means to a portion of the furnace.

14. The method of retrofitting an existing premix burner according to claim 10, wherein said burner tube includes a venturi portion, wherein the drawing of flue gas from the furnace is caused by the aspirating effect of the fuel gas and air passing through said venturi portion.

15. The method of retrofitting an existing premix burner according to claim 14, in which said premix burner comprises means for adjustably restricting the amount of ambient air drawn into the primary air chamber to provide the vacuum necessary to draw flue gas from the furnace.

16. The method of retrofitting an existing premix burner according to claim 11, comprising forming openings in the floor of the furnace and in a wall of the primary air chamber, and inserting one end of said at least one pipe in the opening in said floor and the other end of said pipe in said wall.

17. The method of retrofitting an existing burner according to claim 11, comprising wrapping said at least one pipe with a ceramic fiber blanket.

18. A method for reducing NO_x emissions in a premix burner, said premix burner being located adjacent a first opening in a furnace, said method comprising the steps of:



(a) combining fuel gas and air at a predetermined location;

(b) combusting said fuel gas at a combustion point downstream of said predetermined location; and

(c) drawing flue gas from the furnace in response to fuel gas and air flowing towards said combustion point, said flue gas mixing with said air at said predetermined location upstream of said point of combustion.

19. The method for reducing NO_x emissions according to claim 18, wherein said drawing step includes passing the fuel gas and air through a venturi, whereby the aspirating effect of the fuel gas and air flowing through said venturi draws the flue gas from the furnace.

20. The method for reducing NO_x emissions according to claim 18, further comprising passing into the furnace, air having a temperature lower than the temperature of the flue gas, and then drawing said lower temperature air, along with said flue gas, to said predetermined location, to thereby lower the temperature of the drawn flue gas.

This Sheet Has Been Replaced



* C L N S *

This Sheet Has Been Replaced

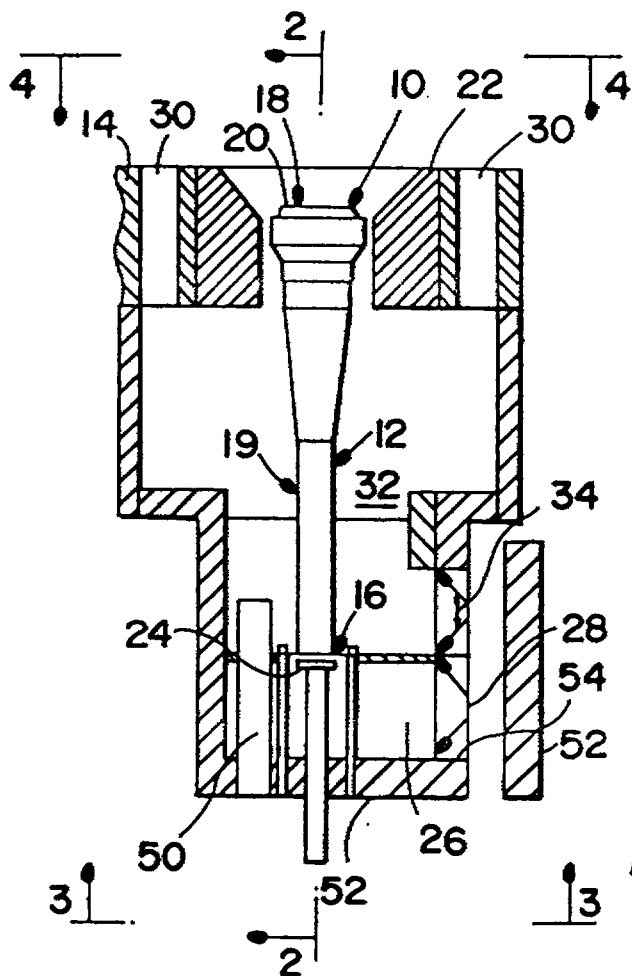


FIG- 1

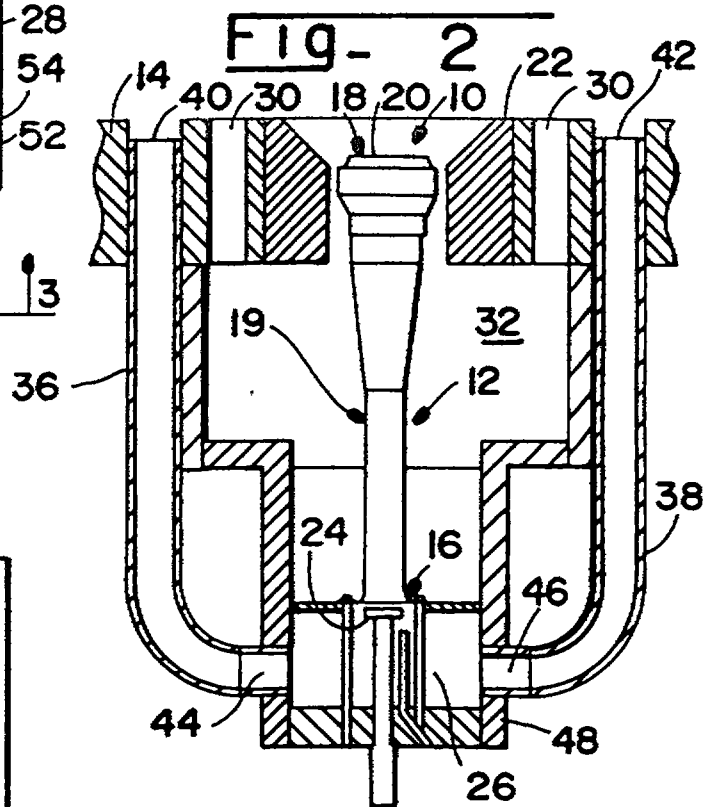


FIG- 2

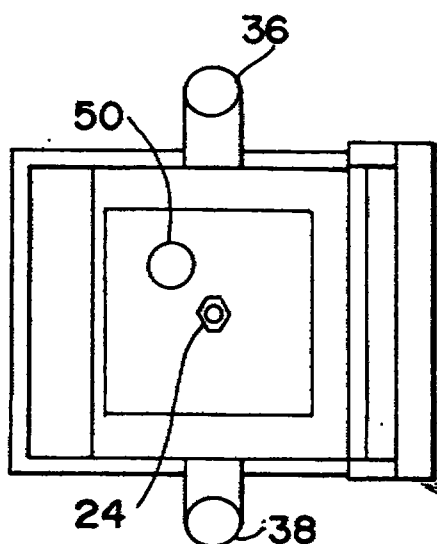
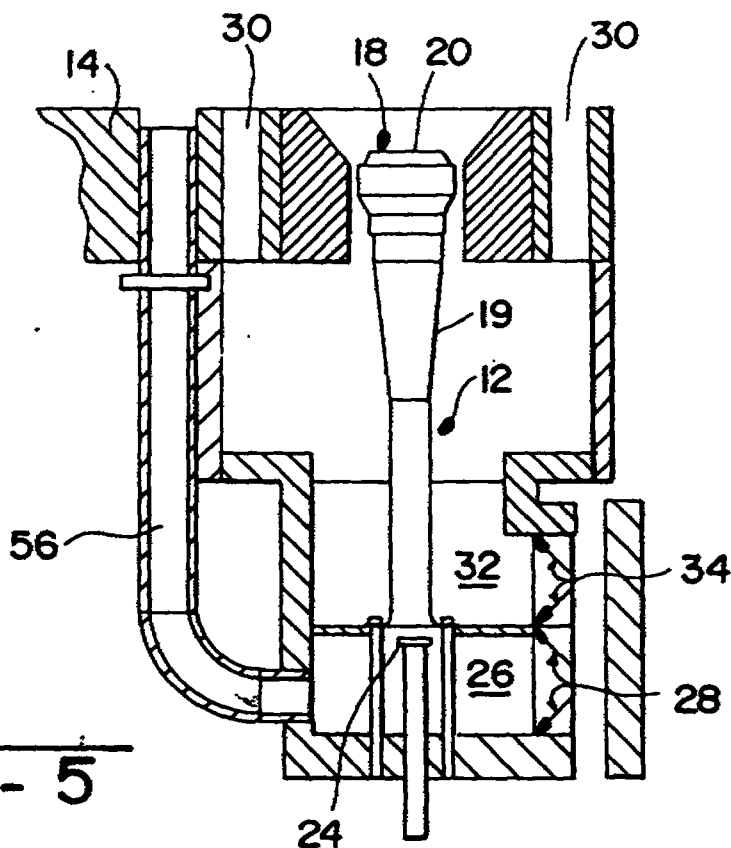
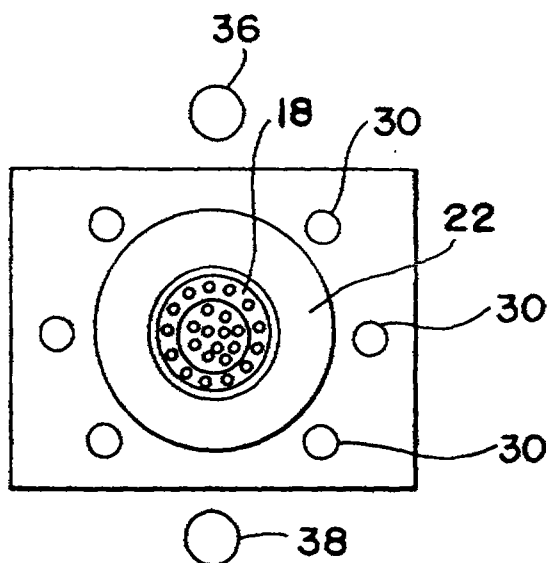
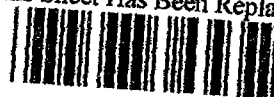
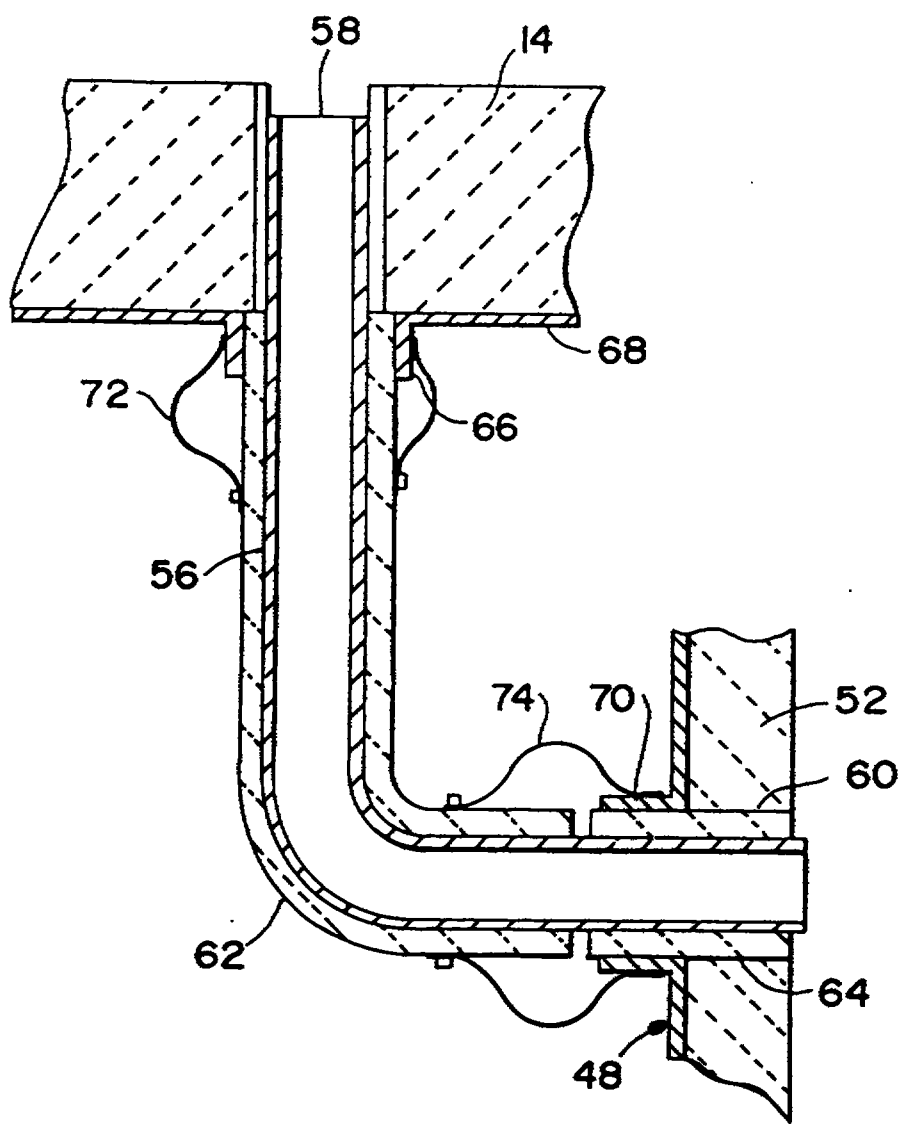


FIG- 3

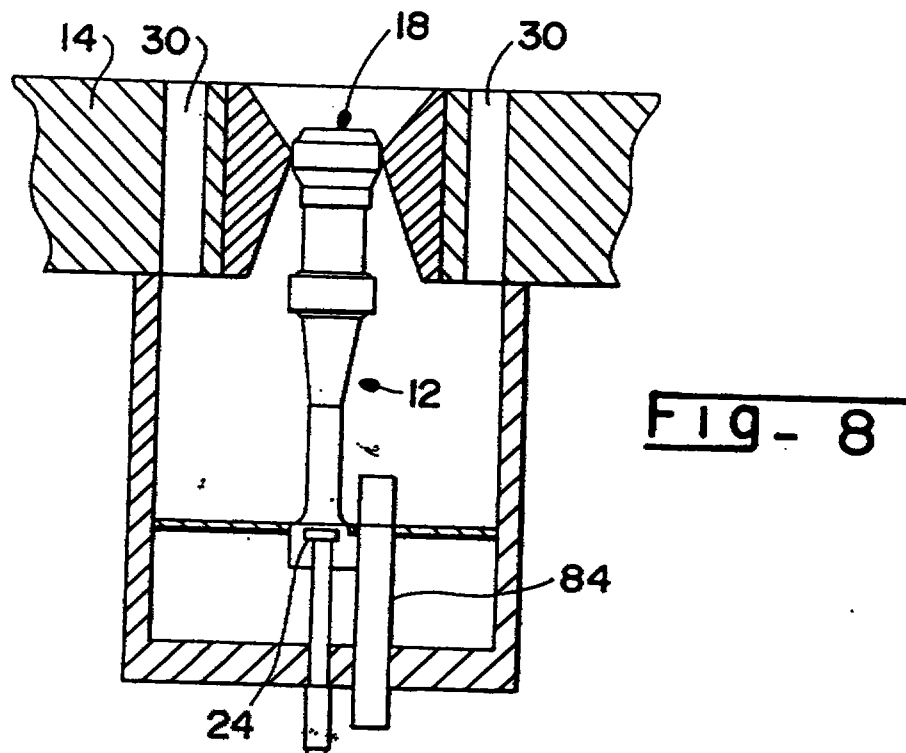
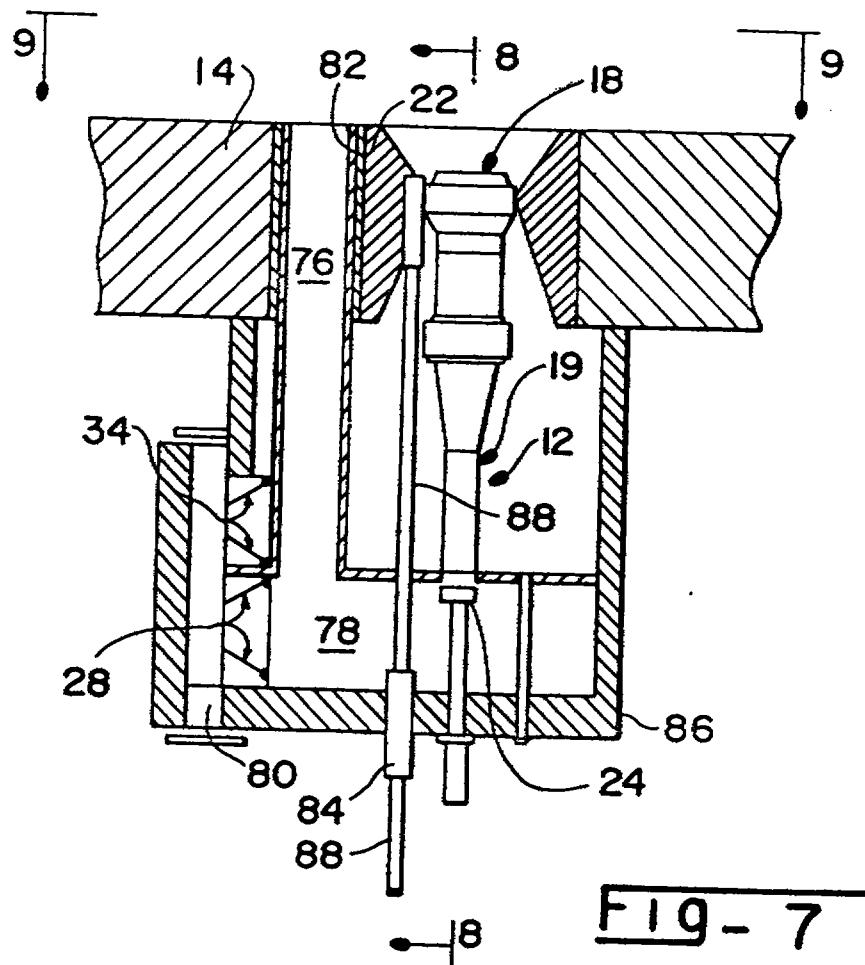
This Sheet Has Been Replaced



This Sheet Has Been Replaced

**Fig. 6**

SUBSTITUTE SHEET



This Sheet Has Been Replaced



SUBSTITUTE SHEET

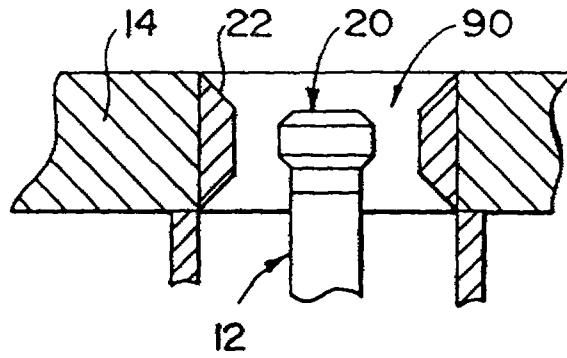


Fig- 1A

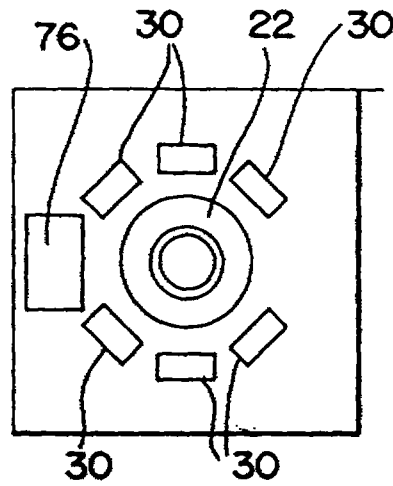


Fig- 9

This Sheet Has Been Replaced



SUBSTITUTE SHEET



FLUE GAS RECIRCULATION FOR NO_x REDUCTION IN PREMIX BURNERS

BACKGROUND OF THE INVENTION

1. Field Of The Invention

This invention is related to an apparatus and method for reducing NO_x emissions from premix burners, without altering critical heat distribution from the burners. This invention may be employed in high temperature furnaces, for example, for steam cracking hydrocarbons.

2. Description Of Background And Relevant Information

Various nitrogen oxides, i.e., NO_x compounds, are formed in air at high temperatures; these include, but are not limited to, nitric oxide and nitrogen dioxide. Reduction of NO_x emissions is a desired goal in order to decrease air pollution and meet government regulations.

Burners may use either liquid fuel or gas. Liquid fuel burners may mix the fuel with steam prior to combustion to atomize the fuel to enable more complete combustion, and combustion air is mixed with the fuel at the point of combustion.

Gas fired burners are classified as either raw gas or premix, depending on the method used to combine the combustion air and fuel. These burners differ in configuration, and in the type of burner tip used.

Raw gas burners inject fuel directly into the combustion air stream, and the mixing of fuel and air occurs simultaneously with combustion.

Premix burners mix the fuel with some or all of the combustion air prior to combustion. Premixing is accomplished by using the energy of the fuel stream so that air flow is generally proportional to fuel flow. Therefore, frequent adjustment is not required and the achievement of desired flame characteristics is facilitated.

REPLACED SHEETS	SG
☒ Description : paged ...1... to paged ...11...	
☒ Claim(s) : paged ...2... to paged ...15...	
☐ Drawing(s) : paged to paged	
☐ Abstract : paged to paged	
DATE OF REPLACEMENT:	

REPLACEMENT SHEETS	SG
☒ Description : paged ...1... to paged ...11...	
☒ Claim(s) : paged ...2... to paged ...15...	
☒ Drawing(s) : paged ...16... to paged ...25...	
☒ Abstract : paged ...26... to paged ...31...	
DATE OF REPLACEMENT: 3/2/77	

Floor-fired premix burners are used in many steam crackers and reformers, mainly for their ability to produce relatively uniform heat distribution in the tall radiant sections of these furnaces. Flames are non-luminous, permitting tube metal temperatures to be readily monitored. Due to these properties, premix burners are widely used in various steam cracking furnace configurations.

MICHELSON et al., U.S. Patent No. 4,629,413, discloses a low NO_x premix burner and discusses the advantages of premix burners and methods to reduce NO_x emissions; this patent is incorporated herein in its entirety, by reference thereto. The premix burner of MICHELSON et al. lowers NO_x emissions by delaying the mixing of secondary air with the flame and allowing some cooled flue gas to recirculate with the secondary air.

BRAZIER et al., U.S. Patent No. 4,708,638, discloses a fluid fuel burner, in which NO_x emissions are reduced by lowering the flame temperature. A venturi in a combustion air supply passage, upstream of a swirler, induces the flow of flue gas into the combustion air supply passage from ducts opening into the furnace. A swirler is located at the free end of a fuel pipe and mixes the flue gas with the primary combustion air.

FERGUSON, U.S. Patent No. 2,813,578, discloses a heavy liquid fuel burner, which mixes the fuel with steam prior to combustion. The aspirating effect of the fuel and steam draws hot furnace gases into a duct and into the burner block to aid in heating the burner block and the fuel and steam passing through a bore in the block. This arrangement is disclosed as being effective to prevent coke deposits on the burner block and also to prevent any dripping of the oil. Since the flame temperature is raised, this arrangement would not aid

This Sheet Has Been Replaced



This is the replacement sheet

Date: - 3 MAR 1997

in reducing NO_x emissions.

JANSSEN, U.S. Patent No. 4,230,445, discloses a fluid fuel burner, which reduces NO_x emissions by supplying a flue gas/air mixture through several passages. Flue gas is drawn from the combustion chamber by a blower.

ZINK et al., U.S. Patent No. 4,004,875, discloses a low NO_x burner, in which combusted fuel and air is cooled and recirculated back into the combustion zone. The recirculated combusted fuel and air is formed in a zone with a deficiency of air.

OPPENBERG et al., U.S. Patent No. 4,575,332 discloses a burner having both oil and gas burner lances, in which NO_x emissions are reduced by discontinuously mixing combustion air into the oil or gas flame to decelerate combustion and lower the temperature of the flame.

GRIFFIN, U.S. Patent No. 2,918,117, discloses a heavy liquid fuel burner, which includes a venturi to draw products of combustion into the primary air to heat the incoming air stream to therefore completely vaporize the fuel.

In addition to MICHELSON et al., the other patents discussed above are also incorporated herein in their entireties, by reference thereto.

SUMMARY OF THE INVENTION

An object of the present invention is to provide means for retrofitting an existing premix burner to lower NO_x emissions, and thereby decrease air pollution and satisfy government standards. Retrofitting an existing premix burner utilizing the present invention is estimated to cost approximately \$2,000 per burner. In comparison, replacing an existing premix burner with a new low NO_x premix burner would cost approximately \$8,000 to \$10,000 per burner. Because a steam cracking furnace may have 50 burners, for example, retrofitting the furnace utilizing the present invention would

This Sheet Has Been Replaced



This is the replacement sheet

Date: - 3 MAR 1997

therefore present considerable savings over replacing the burners of the furnace.

A premix burner for the combustion of fuel gas and air with reduced NO_x emissions is located adjacent a first opening in a furnace, and includes a burner tube having a downstream end and an upstream end. A burner tip is mounted on the downstream end of the burner tube adjacent the first opening in the furnace, and combustion of the fuel gas and air takes place at the burner tip.

A gas spud is located adjacent the upstream end of the burner tube in a primary air chamber for introducing fuel gas into the burner tube. Air also is introduced into the upstream end of the burner tube. According to the present invention, at least one passageway has one end at a second opening in the furnace and a second end adjacent the upstream end of the burner tube.

Flue gas is drawn from the furnace, through the passageway, in response to fuel gas and air flowing towards the downstream end of the burner tube, whereby the flue gas is mixed with the air at the upstream end of the burner tube prior to the point of combustion of the fuel gas and air, to thereby reduce NO_x emissions.

According to one aspect of the invention the flue gas is drawn from the furnace into the passageway in response to fuel gas flowing through a venturi portion in the burner tube. The passageway includes a duct extending into a second opening in the furnace at one end and into the primary air chamber at the other end. At least one adjustable damper opens into the primary air chamber from the ambient to restrict the amount of ambient air entering into the primary air chamber, thereby providing a vacuum to draw flue gas from the furnace.

According to another aspect of the invention, the passageway includes two ducts. Each duct may be substantially

This Sheet Has Been Replaced



This is the replacement sheet

Date: 3 MAR 1997

L-shaped, and further includes flexible seal means at one or both ends of the duct. The respective seal means are adapted to be connected to a portion of the furnace and to the duct.

The premix burner further includes at least one staged air port opening into the furnace. Ambient air passes into the furnace through the at least one staged air port, and is drawn into the at least one duct to lower the temperature of the gas flowing through the duct.

Another object of the invention is to provide a method of retrofitting an existing premix burner in a furnace to reduce NO_x emissions, wherein the premix burner includes a burner tube having a downstream end and an upstream end, with a burner tip being mounted on the downstream end of the burner tube where combustion of fuel gas and air takes place. Fuel gas is introduced into the upstream end of the burner tube in a primary air chamber, so that air is mixed with the fuel gas in the primary air chamber prior to the point of combustion.

The method includes the following steps:

A passageway is installed between the furnace and the primary air chamber. Flue gas is drawn from the furnace through the passageway in response to fuel gas and air flowing towards the downstream end of the burner tube. Flue gas is mixed with the air in the primary air chamber, prior to the point of combustion, so that NO_x emissions are reduced.

Either one or two pipes may be installed between the furnace and the primary air chamber. Flexible seals are attached to each of the end portions of the pipes, and to a portion of the furnace.

According to another aspect of the invention, the burner tube includes a venturi portion, and flue gas is drawn from the furnace by the aspirating effect of the fuel gas and air passing through the venturi portion. The amount of ambient air drawn into the primary air chamber may be adjustably

This Sheet Has Been Replaced



This is the replacement sheet

Date: - 3 MAR 1997

restricted to provide the vacuum necessary to draw flue gas from the furnace.

According to another aspect of the invention, the pipes are installed by forming openings in the floor of the furnace and in a wall of the primary air chamber, and inserting one end of at least one pipe in the opening in the floor and the other end of the pipe in the opening in the wall. The pipe may then be wrapped with a ceramic fiber blanket.

Another object of the invention is to provide a method for reducing NO_x emissions in a premix burner. The premix burner is located adjacent a first opening in a furnace, and the method includes the steps of: combining fuel gas and air in a primary air chamber; providing combustion of the fuel gas and air at a combustion point downstream of the step of combining the fuel gas and air; and drawing flue gas from the furnace in response to fuel gas and air flowing towards the combustion point, whereby the flue gas mixes with the air in the primary air chamber prior to the point of combustion to thereby reduce NO_x emissions.

The drawing step may include passing the fuel gas and air through a venturi, whereby the aspirating effect of the fuel gas and air flowing through the venturi draws the flue gas from the furnace. Ambient air, which is at a lower temperature than the flue gas, passes into the furnace, and then the lower temperature air, as well as the flue gas, are both drawn to the primary air chamber from the furnace; as a result, the temperature of the drawn flue gas is lowered. The ambient air may be fresh air having an ambient temperature, although the temperature may be in the range between a temperature colder than the ambient temperature and a temperature slightly below the temperature of the flue gas in the furnace.

This Sheet Has Been Replaced



This is the replacement sheet

Date: - 3 MAR 1997

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is further explained in the description which follows with reference to the drawings illustrating, by way of non-limiting examples, various embodiments of the invention wherein:

Fig. 1 illustrates an elevation partly in section of an embodiment of the premix burner of the present invention;

Fig. 1A is a partial elevation of a premix burner similar to Fig. 1, and includes a secondary air port instead of staged air ports.

Fig. 2 is an elevation partly in section taken along line 2-2 of Fig. 1;

Fig. 3 is a plan view taken along line 3-3 of Fig. 1;

Fig. 4 is a plan view taken along line 4-4 of Fig. 1;

Fig. 5 is a second embodiment of the premix burner of the present invention;

Fig. 6 is an elevation partly in section of the recirculation pipe of the present invention;

Fig. 7 is an elevation partly in section of a third embodiment of the premix burner of the present invention;

Fig. 8 is an elevation partly in section taken along line 8-8 of Fig. 7; and

Fig. 9 is a plan view taken along line 9-9 of Fig. 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring particularly to Figs. 1-4, a premix burner 10 includes a freestanding burner tube 12 located in a well in a furnace floor 14. Burner tube 12 includes an upstream end 16, a downstream end 18 and a venturi portion 19. Burner tip 20 is located at downstream end 18 and is surrounded by an annular tile 22. Gas spud 24 is located at upstream end 16 and introduces fuel gas into burner tube 12. Fresh or ambient air is introduced into primary air chamber 26 through adjustable damper 28 to mix with the fuel gas at upstream end

This Sheet Has Been Replaced



This is the replacement sheet

Date: - 3 MAR 1997

16 of burner tube 12. Combustion of the fuel gas and fresh air occurs at burner tip 20.

A plurality of air ports 30 originate in secondary air chamber 32 and pass through furnace floor 14 into the furnace. Fresh air enters secondary air chamber 32 through adjustable dampers 34 and passes through staged air ports 30 or through secondary air port 90 into the furnace to provide secondary or staged combustion and to dilute the oxygen concentration of flue gas, as described in MICHELSON et al.

In order to recirculate flue gas from the furnace to the primary air chamber, ducts or pipes 36, 38 extend from openings 40, 42, respectively, in the floor of the furnace to openings 44, 46, respectively, in burner plenum 48. Flue gas containing, for example, 6-10% O₂, is drawn through pipes 36, 38 by the aspirating effect of fuel gas passing through venturi portion 19 of burner tube 12. In this manner, the primary air and flue gas are mixed in primary air chamber 26, which is prior to the point of combustion. Therefore, the oxygen concentration of the primary air is diluted prior to the point of combustion, thereby slowing down the combustion, and as a result, reducing NO_x emissions. This is in contrast to a liquid fuel burner, such as that of FERGUSON et al., in which the combustion air is mixed with the fuel at the point of combustion, rather than prior to the point of combustion.

Closing damper 28 restricts the amount of fresh air that can be drawn into the primary air chamber and thereby provides the vacuum necessary to draw flue gas from the furnace floor.

Unmixed low temperature ambient air, having entered secondary air chamber 32 through dampers 34, and having passed through air ports 30 into the furnace, is also drawn through pipes 36, 38 into the primary air chamber by the aspirating effect of the fuel gas passing through venturi portion 19. The ambient air may be fresh air as discussed above. The mixing

This Sheet Has Been Replaced



This is the replacement sheet

Date: - 3 MAR 1997



of the ambient air with the flue gas lowers the temperature of the hot flue gas flowing through pipes 36, 38 and thereby substantially increases the life of the pipes and allows use of this type burner to reduce NO_x emission in high temperature cracking furnaces having flue gas temperature above 1900°F in the radiant section of the furnace.

Advantageously, a mixture of approximately 50% flue gas and approximately 50% ambient air should be drawn through pipes 36, 38. The desired proportions of flue gas and ambient air may be achieved by proper placement and/or design of pipes 36, 38 in relation to air ports 30. That is, the geometry of the air ports, including but not limited to their distance from the burner tube, the number of air ports, and the size of the air ports, may be varied to obtain the desired percentages of flue gas and ambient air.

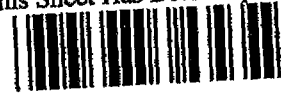
A sight and lighting port 50 is provided in the burner plenum 48, both to allow inspection of the interior of the burner assembly, and to provide access for lighting of the burner. The burner plenum may be covered with mineral wool soundproofing 52 and wire mesh screening 54 to provide insulation therefor.

An alternate embodiment of premix burner 10 is shown in Fig. 5, wherein like reference numbers indicate like parts. The main difference between the embodiment of Figs. 1-4, and that of Fig. 5, is that the latter employs only one recirculation pipe 56. For example, one 6 inch diameter pipe may be used instead of two 4 inch pipes.

The recycle pipe 56 of Fig. 5, or the recycle pipes 36, 38 of Figs. 1-4, may be retrofitted into an existing premix burner. Referring to Fig. 6, an opening 58 is formed in furnace floor 14, and an opening 60 is formed in a wall of burner plenum 48. Pipe 56 is then inserted, so that its respective ends extend into openings 58 and 60. Pipe 56 may

This is the replacement sheet

Date: - 3 MAR 1997



be covered by insulation portions 62, 64, which may be ceramic fiber blankets.

Flange 66 is attached to furnace floor casing plate 68, and flange 70 is attached to burner plenum 48. Seal bag 72 is attached at one end to flange 66, and at the other end to insulation portion 62. Seal bag 74 is attached to flange 70 at one end, and to insulation portion 62 at the other end. The seal bags 72, 74 may be flexible and be made of any suitable heat-resistant material. Alternately, one or both seal bags may be eliminated and the recycle pipe may be seal welded to floor casing plate 68 or burner plenum 48.

The flue gas recycling system of the present invention may also be applied to a new low NO_x burner such as illustrated in Figs. 7, 8 and 9, wherein like reference numbers indicate like parts. A flue gas recirculation passageway 76 is formed in furnace floor 14 and extends to primary air chamber 78, so that flue gas is mixed with fresh air drawn into the primary air chamber from opening 80. The external surface of passageway 76 may be wrapped with insulation 82, which may be a ceramic fiber blanket. Sight and lighting port 84 provides access to the interior of burner plenum 86 for pilot lighting element 88. It is noted that a similar pilot lighting element may also be used in the embodiments of Figs. 1 and 5.

Premix burners, according to the present invention may be used under a wide range of operating conditions. An example is described below with reference to Fig. 5.

Fuel gas at 190 lbs./hr. is introduced into burner tube 12 from gas spud 24. Fresh air at 620 lbs./hr. and 60°F. flows through damper 28 into primary air chamber 26. Air at 2760 lbs./hr. and 60°F. flows through damper 34 into secondary air chamber 32 and passes through air ports 30 at 2,400 lbs./hr. and 60°F. As a result, fuel and flue gas are

This is the replacement sheet

Date: - 3 MAR 1997

provided at 1,550 lbs./hr. and 2,100°F. at burner tip 20. The air ports 30 and pipe 56 are arranged such that flue gas at 380 lbs./hr. and 1,840°F. and air from air ports 30 at 360 lbs./hr. are drawn into pipe 56, to result in a flue gas and air mixture at 740 lbs./hr. which contains 9.4% O_2 and is at 1,025°F. in pipe 56.

As discussed above, the cooling of the flue gas by the fresh air increases the service life of the recycling pipe 56. The recycled flue gas dilutes the concentration of O_2 in the combustion air, which lowers the flame temperature, and thereby reduces NO_x emissions.

Although the premix burners of this invention have been described in connection with floor-fired hydrocarbon cracking furnaces, they may also be used on the side walls of such furnaces or in furnaces for carrying out other reactions or functions.

Thus, it can be seen that, by use of this invention, NO_x emissions may be reduced in a premix burner without the use of fans or special burners. The flue gas recirculation system of the invention can also easily be retrofitted to existing premix burners.

Although the invention has been described with reference to particular means, materials and embodiments, it is to be understood that the invention is not limited to the particulars disclosed and extends to all equivalents within the scope of the claims.

This Sheet Has Been Replaced



This is the replacement sheet

Date: - 3 MAR 1997

CLAIMS:

1. A premix burner for obtaining reduced NO_x emissions in the combustion of fuel gas, said premix burner being located adjacent a first opening in a furnace, said premix burner comprising:

(a) a burner tube having a downstream end, and having an upstream end for receiving air and fuel gas, a burner tip being mounted on the downstream end of said burner tube adjacent the first opening in the furnace, so that combustion of the fuel gas takes place at said burner tip;

(b) a gas spud located adjacent the upstream end of said burner tube, for introducing fuel gas into said burner tube;

(c) at least one passageway having a first end at a second opening in the furnace and a second end adjacent the upstream end of said burner tube; and

(d) means for drawing flue gas from said furnace, through said passageway, in response to fuel gas and air flowing through said burner tube from its upstream end towards its downstream end, whereby the flue gas is mixed with air at said upstream end of said burner tube prior to the point of combustion of the fuel gas and air.

2. The premix burner according to claim 1, wherein said means for drawing flue gas from said furnace comprises a venturi portion in said burner tube.

3. The premix burner according to claim 1, comprising a primary air chamber, wherein said at least one passageway comprises a duct having a first end and a second end, said first end extending into a second opening in the furnace, and said second end extending into said primary air chamber.

4. The premix burner according to claim 2, comprising a primary air chamber, comprising at least one adjustable damper opening into said primary air chamber to restrict the



This is the replacement sheet

Date: - 3 MAR 1997



amount of ambient air entering into said primary air chamber, and thereby to provide a vacuum to draw flue gas from the furnace.

5. The premix burner according to claim 3, wherein said at least one passageway comprises two of said ducts.

6. The premix burner according to claim 3, wherein said duct is substantially L-shaped.

7. The premix burner according to claim 3, further including flexible seal means at at least one of said first end and said second end of said duct.

8. The premix burner according to claim 7, wherein said seal means at said first end of said duct is for connection to a portion of the furnace and said duct, and wherein said seal means at said second end of said duct is connected to said duct and said primary air chamber.

9. The premix burner according to claim 1, further comprising at least one air opening into the furnace, for allowing air to be passed therethrough into said furnace, and thereafter to be drawn into said at least one passageway.

10. A method of retrofitting an existing premix burner in a furnace to reduce NO_x emissions, said premix burner including a burner tube, having a downstream end and an upstream end, a burner tip being mounted on the downstream end of said burner tube where combustion of fuel gas takes place, means for introducing fuel gas into the upstream end of said burner tube in a primary air chamber, so that air is mixed with the fuel gas in the primary air chamber prior to the point of combustion; said method comprising the step of installing a passageway between the furnace and the primary air chamber for drawing flue gas from the furnace through the passageway in response to fuel gas and air flowing towards the downstream end of said burner tube.

11. The method of retrofitting an existing premix burner



This is the replacement sheet

Date: - 3 MAR 1997



according to claim 10, wherein said step of installing said at least one passageway comprises installing at least one pipe between the furnace and the primary air chamber.

12. The method of retrofitting an existing premix burner according to claim 10, wherein said step of installing said at least one passageway comprises installing two pipes between the furnace and the primary air chamber.

13. The method of retrofitting an existing premix burner according to claim 11, further comprising attaching flexible sealing means to each end portion of said at least one pipe, and also attaching said sealing means to a portion of the furnace.

14. The method of retrofitting an existing premix burner according to claim 10, wherein said burner tube includes a venturi portion, wherein the drawing of flue gas from the furnace is caused by the aspirating effect of the fuel gas and air passing through said venturi portion.

15. The method of retrofitting an existing premix burner according to claim 14, in which said premix burner comprises means for adjustably restricting the amount of ambient air drawn into the primary air chamber to provide the vacuum necessary to draw flue gas from the furnace.

16. The method of retrofitting an existing premix burner according to claim 11, comprising forming openings in the floor of the furnace and in a wall of the primary air chamber, and inserting one end of said at least one pipe in the opening in said floor and the other end of said pipe in said wall.

17. The method of retrofitting an existing burner according to claim 11, comprising wrapping said at least one pipe with a ceramic fiber blanket.

18. A method for reducing NO_x emissions in a premix burner, said premix burner being located adjacent a first opening in a furnace, said method comprising the steps of:



This is the replacement sheet

Date: - 3 MAR 1997



(a) combining fuel gas and air at a predetermined location;

(b) combusting said fuel gas at a combustion point downstream of said predetermined location; and

(c) drawing flue gas from the furnace in response to fuel gas and air flowing towards said combustion point, said flue gas mixing with said air at said predetermined location upstream of said point of combustion.

19. The method for reducing NO_x emissions according to claim 18, wherein said drawing step includes passing the fuel gas and air through a venturi, whereby the aspirating effect of the fuel gas and air flowing through said venturi draws the flue gas from the furnace.

20. The method for reducing NO_x emissions according to claim 18, further comprising passing into the furnace, air having a temperature lower than the temperature of the flue gas, and then drawing said lower temperature air, along with said flue gas, to said predetermined location, to thereby lower the temperature of the drawn flue gas.



This is the replacement sheet

Date: - 3 MAR 1997

FLUE GAS RECIRCULATION FOR NO_x REDUCTION IN
PREMIX BURNERS

ABSTRACT

A method and apparatus for reducing NO_x emission from premix burners by recirculating flue gas. Flue gas is drawn from the furnace through a pipe or pipes (36, 38, 56, 76) by the aspirating effect of fuel gas and combustion air passing through a venturi portion (19) of a burner tube (12). The flue gas mixes with combustion air in a primary air chamber (26, 78) prior to combustion to dilute the concentration of O₂ in the combustion air, which lowers flame temperature and thereby reduces NO_x emissions. The flue gas recirculating system may be retrofitted into existing premix burners or may be incorporated in new low NO_x burners.

FIGURE 2.

This is the replacement sheet

Date:

- 3 MAR 1997

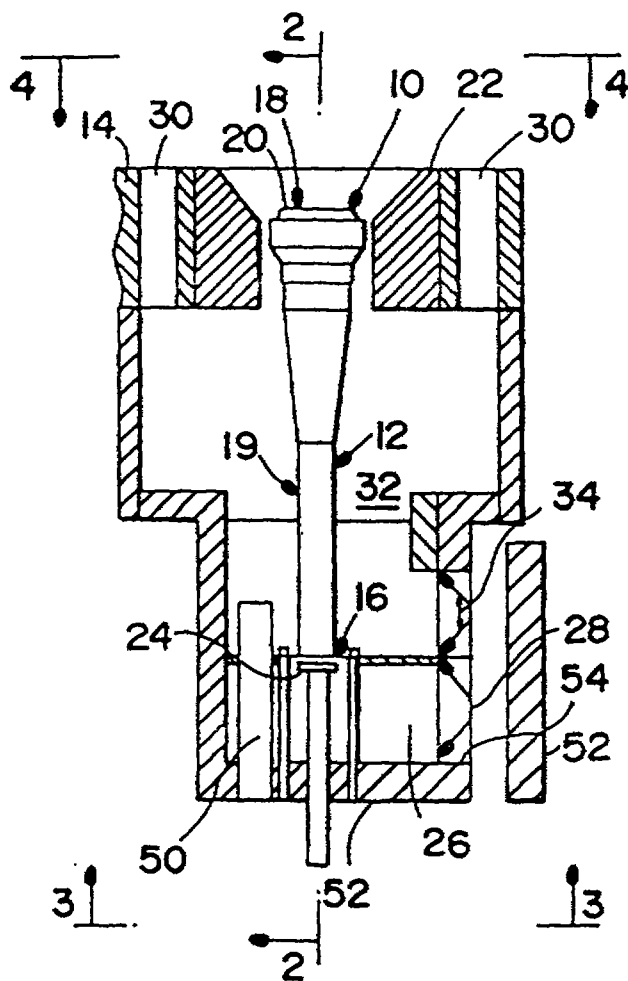


FIG- 1

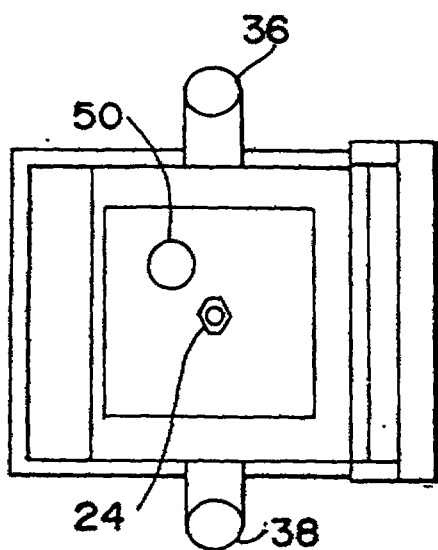
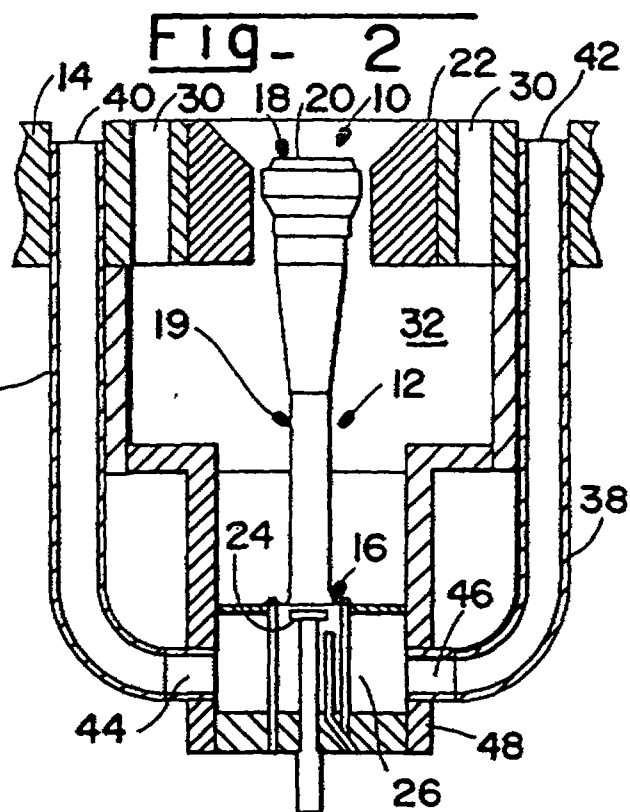


FIG- 3

This is the replacement sheet

- 3 MAR 1997

Date:

2.

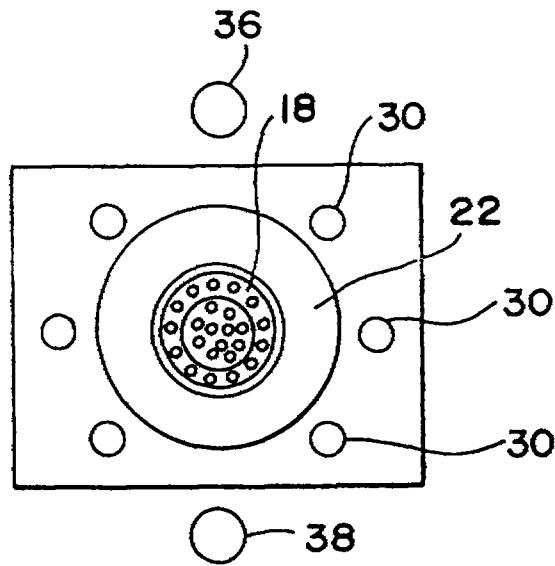


FIG- 4

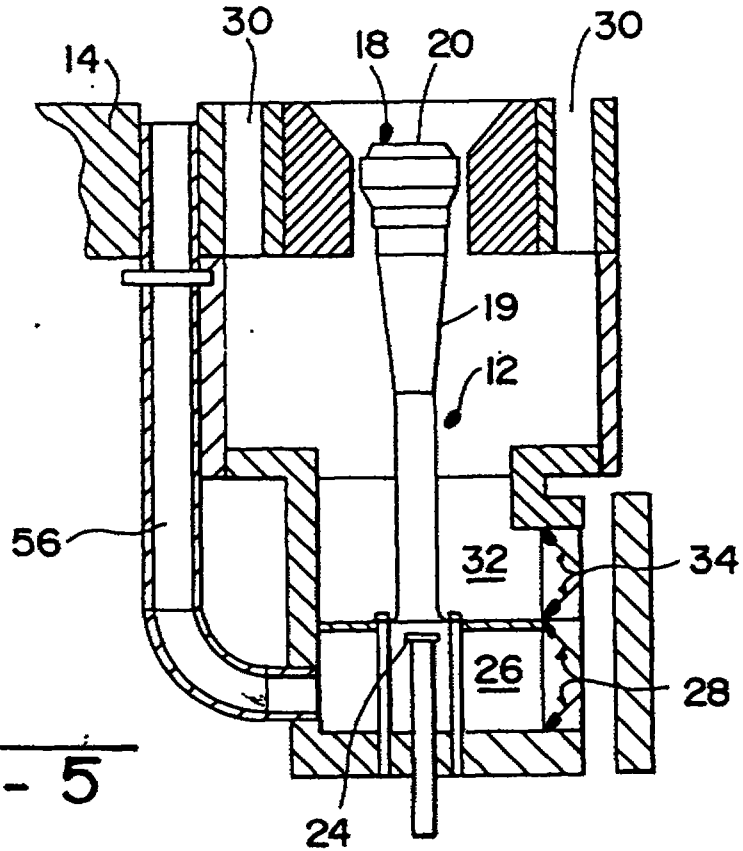


FIG- 5

This is the replacement sheet

Date: - 3 MAR 1997

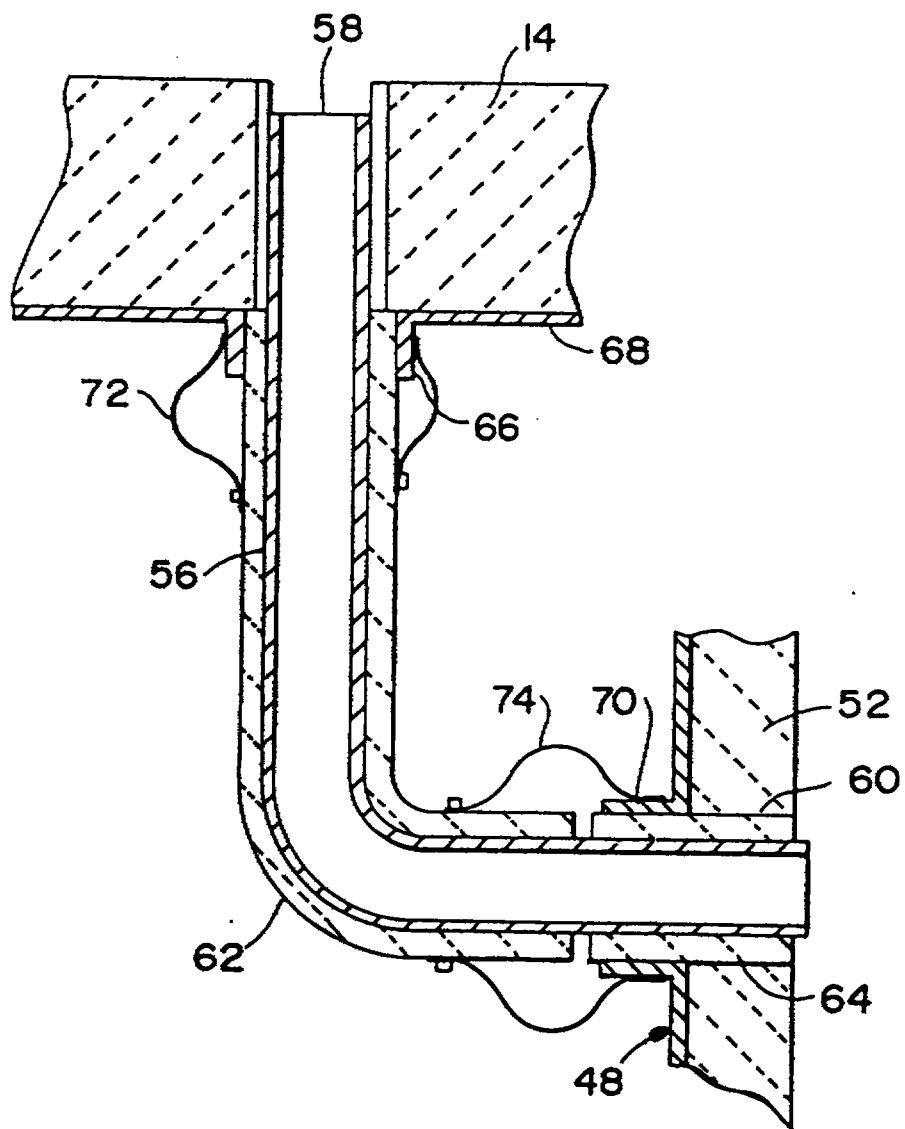
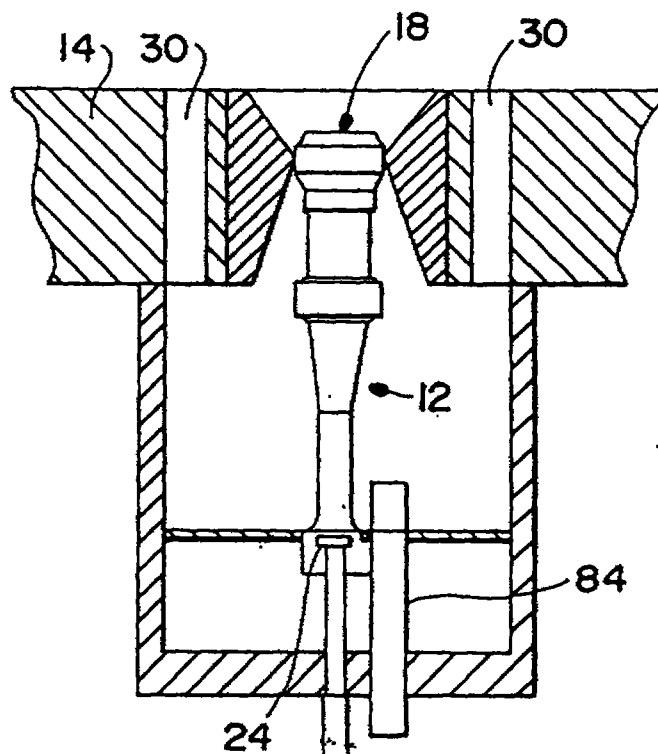
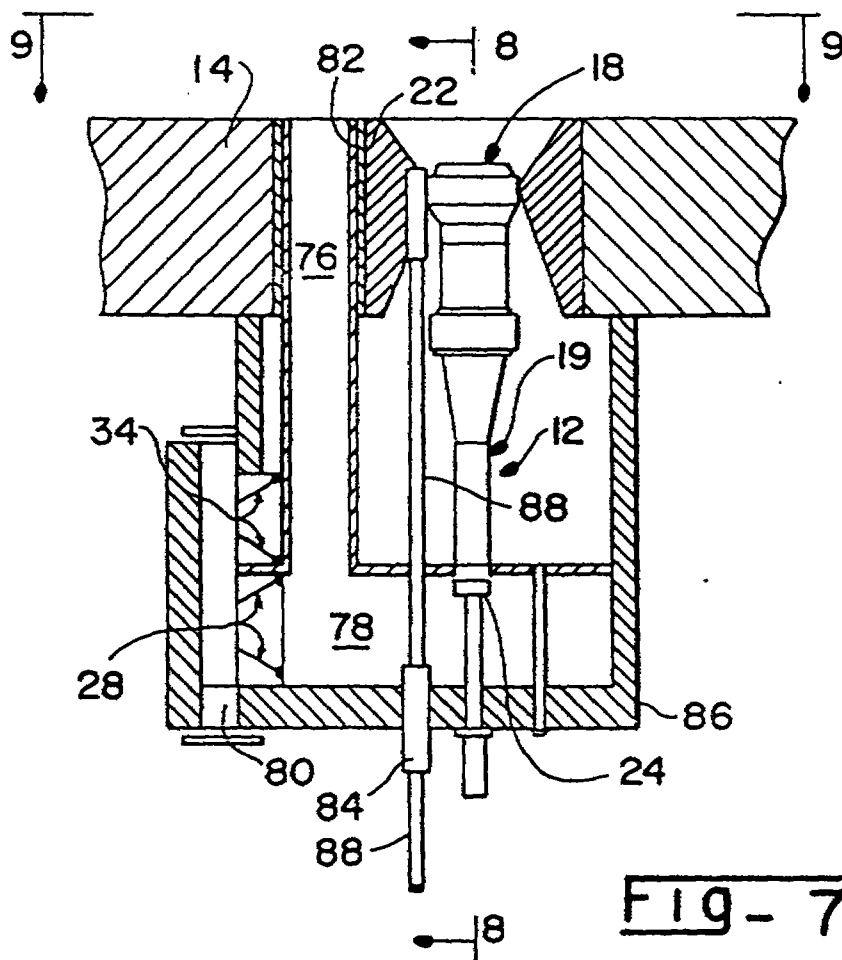


Fig. 6

This is the replacement sheet

Date: - 3 MAR 1997



This is the replacement sheet

Date: 3 MAR 1997

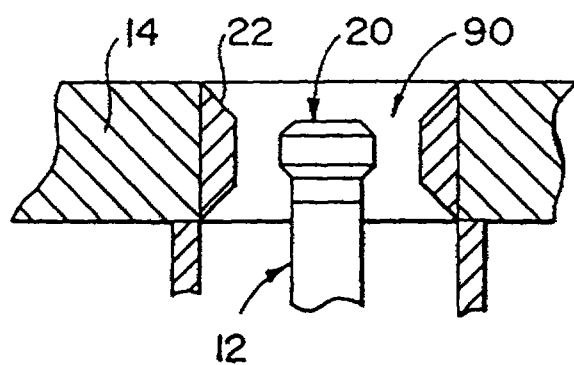


Fig- 1A

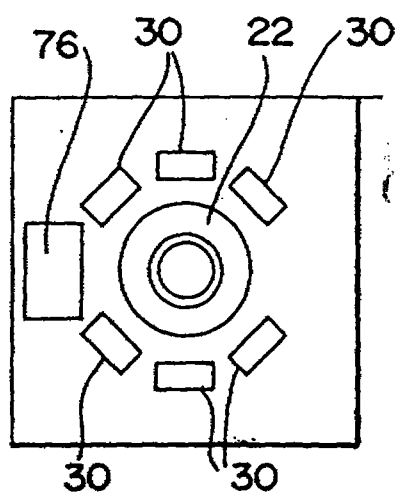


Fig- 9

This is the replacement sheet

Date: - 3 MAR 1997

FLUE GAS RECIRCULATION FOR NO_x-REDUCTION IN PREMIX BURNERS**Description****BACKGROUND OF THE INVENTION****1. Field Of The Invention**

This invention is related to an apparatus and method for reducing NO_x emissions from premix burners, without altering critical heat distribution from the burners. This invention may be employed in high temperature furnaces, for example, for steam cracking hydrocarbons.

2. Description Of Background And Relevant Information

Various nitrogen oxides, i.e., NO_x compounds, are formed in air at high temperatures; these include, but are not limited to, nitric oxide and nitrogen dioxide. Reduction of NO_x emissions is a desired goal in order to decrease air pollution and meet government regulations.

Burners may use either liquid fuel or gas. Liquid fuel burners may mix the fuel with steam prior to combustion to atomize the fuel to enable more complete combustion, and combustion air is mixed with the fuel at the point of combustion.

Gas fired burners are classified as either raw gas or premix, depending on the method used to combine the combustion air and fuel. These burners differ in configuration, and in the type of burner tip used.

Raw gas burners inject fuel directly into the combustion air stream, and the mixing of fuel and air occurs simultaneously with combustion.

Premix burners mix the fuel with some or all of the combustion air prior to combustion. Premixing is accomplished by using the energy of the fuel stream so that air flow is generally proportional to fuel flow. Therefore, frequent adjustment is not required and the achievement of desired flame characteristics is facilitated.

REVISIONS	SG
✓ Description page 11 to page 12..	
✓ Description page 12 to page 13..	
✓ Description page 13 to page 14..	
✓ Description page 14 to page 15..	
✓ Description page 15 to page 16..	
✓ Description page 16 to page 17..	
✓ Description page 17 to page 18..	
✓ Description page 18 to page 19..	
✓ Description page 19 to page 20..	
✓ Description page 20 to page 21..	
✓ Description page 21 to page 22..	
✓ Description page 22 to page 23..	
✓ Description page 23 to page 24..	
✓ Description page 24 to page 25..	
✓ Description page 25 to page 26..	
✓ Description page 26 to page 27..	
✓ Description page 27 to page 28..	
✓ Description page 28 to page 29..	
✓ Description page 29 to page 30..	
✓ Description page 30 to page 31..	
✓ Description page 31 to page 32..	
✓ Description page 32 to page 33..	
✓ Description page 33 to page 34..	
✓ Description page 34 to page 35..	
✓ Description page 35 to page 36..	
✓ Description page 36 to page 37..	
✓ Description page 37 to page 38..	
✓ Description page 38 to page 39..	
✓ Description page 39 to page 40..	
✓ Description page 40 to page 41..	
✓ Description page 41 to page 42..	
✓ Description page 42 to page 43..	
✓ Description page 43 to page 44..	
✓ Description page 44 to page 45..	
✓ Description page 45 to page 46..	
✓ Description page 46 to page 47..	
✓ Description page 47 to page 48..	
✓ Description page 48 to page 49..	
✓ Description page 49 to page 50..	
✓ Description page 50 to page 51..	
✓ Description page 51 to page 52..	
✓ Description page 52 to page 53..	
✓ Description page 53 to page 54..	
✓ Description page 54 to page 55..	
✓ Description page 55 to page 56..	
✓ Description page 56 to page 57..	
✓ Description page 57 to page 58..	
✓ Description page 58 to page 59..	
✓ Description page 59 to page 60..	
✓ Description page 60 to page 61..	
✓ Description page 61 to page 62..	
✓ Description page 62 to page 63..	
✓ Description page 63 to page 64..	
✓ Description page 64 to page 65..	
✓ Description page 65 to page 66..	
✓ Description page 66 to page 67..	
✓ Description page 67 to page 68..	
✓ Description page 68 to page 69..	
✓ Description page 69 to page 70..	
✓ Description page 70 to page 71..	
✓ Description page 71 to page 72..	
✓ Description page 72 to page 73..	
✓ Description page 73 to page 74..	
✓ Description page 74 to page 75..	
✓ Description page 75 to page 76..	
✓ Description page 76 to page 77..	
✓ Description page 77 to page 78..	
✓ Description page 78 to page 79..	
✓ Description page 79 to page 80..	
✓ Description page 80 to page 81..	
✓ Description page 81 to page 82..	
✓ Description page 82 to page 83..	
✓ Description page 83 to page 84..	
✓ Description page 84 to page 85..	
✓ Description page 85 to page 86..	
✓ Description page 86 to page 87..	
✓ Description page 87 to page 88..	
✓ Description page 88 to page 89..	
✓ Description page 89 to page 90..	
✓ Description page 90 to page 91..	
✓ Description page 91 to page 92..	
✓ Description page 92 to page 93..	
✓ Description page 93 to page 94..	
✓ Description page 94 to page 95..	
✓ Description page 95 to page 96..	
✓ Description page 96 to page 97..	
✓ Description page 97 to page 98..	
✓ Description page 98 to page 99..	
✓ Description page 99 to page 100..	

This is the replacement sheet

Date: 5 AUG 1999

Floor-fired premix burners are used in many steam crackers and reformers, mainly for their ability to produce relatively uniform heat distribution in the tall radiant sections of these furnaces. Flames are non-luminous, permitting tube metal temperatures to be readily monitored. Due to these properties, premix burners are widely used in various steam cracking furnace configurations.

MICHELSON et al., U.S. Patent No. 4,639,413, discloses a low NO_x premix burner and discusses the advantages of premix burners and methods to reduce NO_x emissions. The premix burner of MICHELSON et al. lowers NO_x emissions by delaying the mixing of secondary air with the flame and allowing some cooled flue gas to recirculate with the secondary air.

BRAZIER et al., U.S. Patent No. 4,708,638, discloses a fluid fuel burner, in which NO_x emissions are reduced by lowering the flame temperature. A venturi in a combustion air supply passage, upstream of a swirler, induces the flow of flue gas into the combustion air supply passage from ducts opening into the furnace. A swirler is located at the free end of a fuel pipe and mixes the flue gas with the primary combustion air.

FERGUSON, U.S. Patent No. 2,813,578, discloses a heavy liquid fuel burner, which mixes the fuel with steam prior to combustion. The aspirating effect of the fuel and steam draws hot furnace gases into a duct and into the burner block to aid in heating the burner block and the fuel and steam passing through a bore in the block. This arrangement is disclosed as being effective to prevent coke deposits on the burner block and also to prevent any dripping of the oil. Since the flame temperature is raised, this arrangement would not aid in reducing NO_x emissions.

JANSSEN, U.S. Patent No. 4,230,445, discloses a fluid fuel burner, which reduces NO_x emissions by supplying a flue gas/air mixture through several passages. Flue gas is drawn from the combustion chamber by a blower.

ZINK et al., U.S. Patent No. 4,004,875, discloses a low NO_x burner, in which combusted fuel and air is cooled and recirculated back into the combustion zone.

This is the replacement sheet

Date: - 5 AUG 1989

The recirculated combusted fuel and air is formed in a zone with a deficiency of air.

OPPENBERG et al., U.S. Patent No. 4,575,332, discloses a burner having both oil and gas burner lanes, in which NO_x emissions are reduced by discontinuously mixing combustion air into the oil or gas flame to decelerate combustion and lower the temperature of the flame.

GRIFFIN, U.S. Patent No. 2,918,117, discloses a heavy liquid fuel burner, which includes a venturi to draw products of combustion into the primary air to heat the incoming air stream to therefore completely vaporize the fuel.

EP-A-0,374,423, DE-U-9,003,576 and EP-A-0,284,011 each disclose a furnace with flue gas recirculation including a premix burner for reducing NO_x emissions when combusting fuel gas, the premix burner being located adjacent a first opening in the furnace. The premix burner comprises a burner tip mounted on a downstream end of a burner tube and an upstream end for receiving air and fuel gas to be combusted at the burner tip. The fuel gas is introduced into the burner tube via a gas spud located adjacent the upstream end of the burner tube. A passageway having a first end at a second opening in the furnace and a second end adjacent the upstream end of the burner tube enables flue gas to be drawn from the furnace and mixed with air at the upstream end of the burner tube prior to combustion of the fuel gas and air.

US-A-4,130,388 discloses a fuel burner for producing a stable, non-contaminating fuel flame over a broad operating range where the fuel is a liquid hydrocarbon to which may be added a gaseous hydrocarbon. The problem addressed in US-A-4,130,388 is to provide adequate atomisation of the liquid fuel to achieve efficient operation over a wide operating range, i.e. a wide liquid-flow turn-down range. Feeding combustion air directly into the combustion zone overcomes problems of objectionable contaminants being formed when the burner is turned down. To solve the problem of incomplete combustion, the combustion air is led directly into the combustion zone and a portion of the hot combustion gas

This is the replacement sheet

- 5 AUG 1999

Date:

produced in the combustion zone is recirculated to pre-vaporize the atomised liquid fuel being fed to the combustion zone.

SUMMARY OF THE INVENTION

An object of the present invention is to provide means for retrofitting an existing premix burner to lower NO_x emissions, and thereby decrease air pollution and satisfy government standards. Retrofitting an existing premix burner utilizing the present invention is estimated to cost approximately \$2,000 per burner. In comparison, replacing an existing premix burner with a new low NO_x premix burner would cost approximately \$8,000 to \$10,000 per burner. Because a steam cracking furnace may have 50 burners, for example, retrofitting the furnace utilizing the present invention would therefore present considerable savings over replacing the burners of the furnace.

According to the invention there is provided a premix burner for obtaining reduced NO_x emissions in the combustion of fuel gas, which burner, when in combination with a furnace, is located adjacent a first opening in the furnace, and comprises:

(a) a burner tube having an upstream end and receiving air and fuel gas, a downstream end and a burner tip mounted on the downstream end so as to be adjacent the first opening in the furnace when in combination with the furnace, so that in the use of the burner, combustion of the fuel gas takes place at the burner tip;

(b) a gas spud located adjacent the upstream end of the burner tube, for introducing fuel gas into said burner tube;

(c) at least one flue passageway having a first end adapted so as to locate with a second opening in the furnace and a second end adjacent the upstream end of said burner tube;

This is the replacement sheet

Date: - 5 AUG 1999

(d) means for drawing flue gas from said furnace, when in combination with said furnace, through the flue passageway, in response to the aspiring effect of uncombusted fuel gas flowing through the burner tube from its upstream end towards its downstream end, whereby the flue gas is mixed with air at said upstream end of the burner tube prior to the point of combustion of the fuel gas and air characterised in that the premix burner is provided.

with (e) at least one air opening spaced from the flue passageway and being located so as to open into the furnace, when in combination with said furnace and arranged to allow uncombusted air, which is cooler than the flue gas, to be passed there through into the furnace, and thereafter to be drawn into the flue passageway along with flue gas, to thereby lower the temperature of the drawn flue gas.

There is also provided a method of retrofitting an existing premix burner/furnace combination to reduce NO_x emissions comprising replacing an existing premix burner with a premix burner according to any preceding claim, the new premix burner being connected to the furnace by at least one passageway having a first end located with the second opening in the furnace and a second end adjacent the upstream end of burner tubes.

According to one aspect of the invention the flue gas is drawn from the furnace into the passageway in response to fuel gas flowing through a venturi portion in the burner tube. The passageway includes a duct extending into a second opening in the furnace at one end and into the primary air chamber at the other end. At least one adjustable damper opens into the primary air chamber from the ambient to restrict the amount of ambient air entering into the primary air chamber, thereby providing a vacuum to draw flue gas from the furnace.

According to another aspect of the invention, the passageway includes two ducts. Each duct may be substantially L-shaped, and further includes flexible seal means at one or both ends of the duct. The respective seal means are adapted to be connected to a portion of

the furnace and to the duct.

The premix burner further includes at least one staged air port opening into the furnace. Ambient air passes into the furnace through the at least one staged air port, and is drawn into the at least one duct to lower the temperature of the gas flowing through the duct.

Another object of the invention is to provide a method of retrofitting an existing premix burner in a furnace to reduce NO_x emissions, wherein the premix burner includes a burner tube having a downstream end and an upstream end, with a burner tip being mounted on the downstream end of the burner tube where combustion of fuel gas and air takes place. Fuel gas is introduced into the upstream end of the burner tube in a primary air chamber, so that air is mixed with the fuel gas in the primary air chamber prior to the point of combustion.

The method includes the following steps:

A passageway is installed between the furnace and the primary air chamber. Flue gas is drawn from the furnace through the passageway in response to fuel gas and air flowing towards the downstream end of the burner tube. Flue gas is mixed with the air in the primary air chamber, prior to the point of combustion, so that NO_x emissions are reduced.

Either one or two pipes may be installed between the furnace and the primary air chamber. Flexible seals are attached to each of the end portions of the pipes, and to a portion of the furnace.

According to another aspect of the invention, the burner tube includes a venturi portion, and flue gas is drawn from the furnace by the aspirating effect of the fuel gas and air passing through the venturi portion. The amount of ambient air drawn into the primary air chamber may be adjustably restricted to provide the vacuum necessary to draw flue gas from the furnace.

According to another aspect of the invention, the pipes are installed by forming openings in the floor of the furnace and in a wall of the primary air chamber, and inserting one end of at least one pipe in the opening in the floor and the other end of the pipe in the opening in the wall. The pipe may then be wrapped with a ceramic fiber blanket.

This is the replacement sheet

Date: - 5 AUG 1999

Another object of the invention is to provide a method for reducing NO_x emissions in a premix burner. The premix burner is located adjacent a first opening in a furnace, and the method includes the steps of: combining fuel gas and air in a primary air chamber; providing combustion of the fuel gas and air at a combustion point downstream of the step of combining the fuel gas and air; and drawing flue gas from the furnace in response to fuel gas and air flowing towards the combustion point, whereby the flue gas mixes with the air in the primary air chamber prior to the point of combustion to thereby reduce NO_x emissions.

The drawing step may include passing the fuel gas and air through a venturi, whereby the aspirating effect of the fuel gas and air flowing through the venturi draws the flue gas from the furnace. Ambient air, which is at a lower temperature than the flue gas, passes into the furnace, and then the lower temperature air, as well as the flue gas, are both drawn to the primary air chamber from the furnace; as a result, the temperature of the drawn flue gas is lowered. The ambient air may be fresh air having an ambient temperature, although the temperature may be in the range between a temperature colder than the ambient temperature and a temperature slightly below the temperature of the flue gas in the furnace.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is further explained in the description which follows with reference to the drawings illustrating, by way of non-limiting examples, various embodiments of the invention wherein:

Fig. 1 illustrates an elevation partly in section of an embodiment of the premix burner of the present invention;

Fig. 1A is a partial elevation of a premix burner similar to Fig. 1, and includes a secondary air port instead of staged air ports.

Fig. 2 is an elevation partly in section taken along line 2-2 of Fig. 1;

This is the replacement sheet

Date: - 5 AUG 1999

Fig. 3 is a plan view taken along line 3-3 of Fig. 1;
Fig. 4 is a plan view taken along line 4-4 of Fig. 1;
Fig. 5 is a second embodiment of the premix burner of the present invention;
Fig. 6 is an elevation partly in section of the recirculation pipe of the present invention;
Fig. 7 is an elevation partly in section of a third embodiment of the premix burner of the present invention;
Fig. 8 is an elevation partly in section taken along line 8-8 of Fig. 7; and
Fig. 9 is a plan view taken along line 9-9 of Fig. 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring particularly to Figs. 1-4, a premix burner 10 includes a freestanding burner tube 12 located in a well in a furnace floor 14. Burner tube 12 includes an upstream end 16, a downstream end 18 and a venturi portion 19. Burner tip 20 is located at downstream end 18 and is surrounded by an annular tile 22. Gas spud 24 is located at upstream end 16 and introduces fuel gas into burner tube 12. Fresh or ambient air is introduced into primary air chamber 26 through adjustable damper 28 to mix with the fuel gas at upstream end 16 of burner tube 12. Combustion of the fuel gas and fresh air occurs at burner tip 20.

A plurality of air ports 30 originate in secondary air chamber 32 and pass through furnace floor 14 into the furnace. Fresh air enters secondary air chamber 32 through adjustable dampers 34 and passes through staged air ports 30 or through secondary air port 90 into the furnace to provide secondary or staged combustion and to dilute the oxygen concentration of flue gas, as described in MICHELSON et al.

In order to recirculate flue gas from the furnace to the primary air chamber, ducts or pipes 36, 38 extend from openings 40, 42, respectively, in the floor of the furnace to openings 44, 46, respectively, in burner plenum 48. Flue gas containing, for example, 6-10% O₂ is drawn through pipes 36, 38 by the aspirating effect of

This is the replacement sheet

Date: - 5 AUG 1999

fuel gas passing through venturi portion 19 of burner tube 12. In this manner, the primary air and flue gas are mixed in primary air chamber 26, which is prior to the point of combustion. Therefore, the oxygen concentration of the primary air is diluted prior to the point of combustion, thereby slowing down the combustion, and as a result, reducing NO_x emissions. This is in contrast to a liquid fuel burner, such as that of FERGUSON et al., in which the combustion air is mixed with the fuel at the point of combustion, rather than prior to the point of combustion.

Closing damper 28 restricts the amount of fresh air that can be drawn into the primary air chamber and thereby provides the vacuum necessary to draw flue gas from the furnace floor.

Unmixed low temperature ambient air, having entered secondary air chamber 32 through dampers 34, and having passed through air ports 30 into the furnace is also drawn through pipes 36, 38 into the primary air chamber by the aspirating effect of the fuel gas passing through venturi portion 19. The ambient air may be fresh air as discussed above. The mixing of the ambient air with the flue gas lowers the temperature of the hot flue gas flowing through pipes 36, 38 and thereby substantially increases the life of the pipes and allows use of this type burner to reduce NO_x emission in high temperature cracking furnaces having flue gas temperature above 1900°F in the radiant section of the furnace.

Advantageously, a mixture of approximately 50% flue gas and approximately 50% ambient air should be drawn through pipes 36, 38. The desired proportions of flue gas and ambient air may be achieved by proper placement and/or design of pipes 36, 38 in relation to air ports 30. That is, the geometry of the air ports, including but not limited to their distance from the burner tube, the number of air ports, and the size of the air ports, may be varied to obtain the desired percentages of flue gas and ambient air.

A sight and lighting port 50 is provided in the burner plenum 48, both to allow inspection of the interior of the burner assembly, and to provide access for lighting of the burner. The burner plenum may be covered with

This is the replacement sheet

Date: - 5 AUG 1999

mineral wool soundproofing 52 and wire mesh screening 54 to provide insulation therefor.

An alternate embodiment of premix burner 10 is shown in Fig. 5, wherein like reference numbers indicate like parts. The main difference between the embodiment of Figs. 1-4, and that of Fig. 5, is that the latter employs only one recirculation pipe 56. For example, one 6 inch diameter pipe may be used instead of two 4 inch pipes.

The recycle pipe 56 of Fig. 5, or the recycle pipes 36, 38 of Figs. 1-4, may be retrofitted into an existing premix burner. Referring to Fig. 6, an opening 58 is formed in furnace floor 14, and an opening 60 is formed in a wall of burner plenum 48. Pipe 56 is then inserted, so that its respective ends extend into openings 58 and 60. Pipe 56 may be covered by insulation portions 62, 64, which may be ceramic fiber blankets.

Flange 66 is attached to furnace floor casing plate 68, and flange 70 is attached to burner plenum 48. Seal bag 72 is attached at one end to flange 66, and at the other end to insulation portion 62. Seal bag 74 is attached to flange 70 at one end, and to insulation portion 62 at the other end. The seal bags 72, 74 may be flexible and be made of any suitable heat-resistant material. Alternately, one or both seal bags may be eliminated and the recycle pipe may be seal welded to floor casing plate 68 or burner plenum 48.

The flue gas recycling system of the present invention may also be applied to a new low NO_x burner such as illustrated in Figs. 7, 8 and 9, wherein like reference numbers indicate like parts. A flue gas recirculation passageway 76 is formed in furnace floor 14 and extends to primary air chamber 78, so that flue gas is mixed with fresh air drawn into the primary air chamber from opening 80. The external surface of passageway 76 may be wrapped with insulation 82, which may be a ceramic fiber blanket. Sight and lighting port 84 provides access to the interior of burner plenum 86 for pilot lighting element 88. It is noted that a similar pilot lighting element may also be used in the embodiments of Figs. 1 and 5.

This is the replacement sheet

Date: - 5 AUG 1999

Premix burners, according to the present invention may be used under a wide range of operating conditions. An example is described below with reference to Fig. 5.

Fuel gas at 190 lbs./hr. is introduced into burner tube 12 from gas spud 24. Fresh air at 620 lbs./hr. and 60°F. flows through damper 28 into primary air chamber 26. Air at 2760 lbs./hr. and 60°F. flows through damper 34 into secondary air chamber 32 and passes through air ports 30 at 2,400 lbs./hr. and 60°F. As a result, fuel and flue gas are provided at 1,550 lbs./hr. and 2,100°F at burner tip 20. The air ports 30 and pipe 56 are arranged such that flue gas at 380 lbs./hr. and 1,840°F. and air from air ports 30 at 360°F result in an air mixture at 740 lbs./hr. which contains 9.4% O₂ and is at 1,025°F. in pipe 56.

As discussed above, the cooling of the flue gas by the fresh air increases the service life of the recycling pipe 56. The recycled flue gas dilute the concentration of O₂ in the combustion air, which lowers the flame temperature, and thereby reduces NO_x emissions.

Although the premix burners of this invention have been described in connection with floor-fired hydrocarbon cracking furnaces, they may also be used on the side walls of such furnaces or in furnaces for carrying out other reactions or functions.

Thus, it can be seen that, by use of this invention, NO_x emissions may be reduced in a premix burner without the use of fans or special burners. The flue gas recirculation system of the invention can also easily be retrofitted to existing premix burners.

Claims

1. A premix burner (10) for obtaining reduced NO_x emissions in the combustion of fuel gas, which burner, when in combination with a furnace, is located adjacent a first opening in the furnace, and comprises:
 - (a) a burner tube (12) having an upstream end (16) and receiving air and fuel-gas, a downstream end (18), and a burner tip (20) mounted on the downstream end so as to be adjacent the first opening in the furnace when in combination with the furnace, so that in the use of the burner, combustion of the fuel gas takes place at the burner tip;
 - (b) a gas spud (24) located adjacent the upstream end (16) of the burner tube (12), for introducing fuel gas into said burner tube;
 - (c) at least one flue passageway (36,38) having a first end adapted so as to locate with a second opening in the furnace and a second end adjacent the upstream end (16) of said burner tube (12);
 - (d) means for drawing flue gas from said furnace, when in combination with said furnace, through the flue passageway, in response to the aspirating effect of uncombusted fuel gas flowing through the burner tube (12) from its upstream end (16) towards its downstream end (18), whereby the flue gas is mixed with air at said upstream end of the burner tube prior to the point of combustion of the fuel gas and air characterised in that the premix burner is provided with (e) at least one air opening (30) spaced from the flue passageway (36,38) and being located so as to open into the furnace, when in combination with said furnace and arranged to allow uncombusted air, which is cooler than the

This is the replacement sheet



Date: - 5 AUG 1999

flue gas, to be passed therethrough into the furnace, and thereafter to be drawn into the flue passageway (36,38) along with flue gas, to thereby lower the temperature of the drawn flue gas.

2. The premix burner according to claim 1, wherein the means for drawing flue gas from the furnace comprises a venturi portion (19) in the burner tube (12).
3. The premix burner according to claim 1 or 2, comprising a primary air chamber (26) for introducing air into the upstream end (16) of the burner tube (12), and comprising at least one adjustable damper opening (28) into the primary air chamber to restrict the amount of ambient air entering into the primary air chamber, and thereby to provide a vacuum to draw flue gas from the furnace.
4. The premix burner according to claim 1, 2, or 3, wherein the flue passageway is substantially L-shaped and comprises a duct, (36,38), having a first end adapted to extend into the furnace, and a second end extending into the primary air chamber (26).
5. The premix burner according to claim 1, comprising two flue passageways (36,38).
6. The premix burner according to claim 4 or 5, further including flexible seal means (72,74) at the first end and/or the second end of the or one of the duct(s).
7. The premix burner according to claim 6, wherein said seal means (72) at the first end is for connection to a portion of the furnace and the duct, and said seal means (74) at the second end is connected to the duct and the primary air chamber.
8. The premix burner according to any preceding claim wherein all of the combustion air is mixed with the fuel gas prior to combustion. —

This is the replacement sheet



Date: - 5 AUG 1999

9. A method of retrofitting an existing premix burner/furnace combination to reduce NO_x emissions, in which combination the premix burner (10) includes a gas spud (24), a burner tube (12) having a downstream end (18) where in use combustion of fuel gas takes place, and means for introducing fuel gas into the upstream end in a primary air chamber, so that air is mixed with the fuel gas in the primary air chamber (26) prior to the point of combustion; which method comprises the step of installing at least one passageway (36,38) between the furnace and the primary air chamber (26) to form the premix burner (10) according to any precoding claim, wherein, in use, the combination provides for drawing flue gas from the furnace through the passageway in response to the aspiring effect of uncombusted fuel gas flowing through the burner tube from its upstream end towards its downstream end and passing into the furnace air having a temperature lower than the temperature of the flue gas, to said primary air chamber, to thereby lower the temperature of the drawn flue gas;
10. The method of claim 9, wherein the step comprises installing at least one, preferably two, pipes (56) between the furnace and the primary air chamber, and optionally wrapping at least one pipe with a ceramic fiber blanket (62,64).
11. The method of claim 10, comprising forming an opening (58) in the floor (14) of the furnace and an opening (60) in a wall of the primary air chamber, and inserting one end of said at least one pipe in the opening (58) in the floor and the other end of said pipe in the opening (60) in the wall.
12. The method of claim 10 or 11, further comprising attaching flexible sealing means (72, 74) to each end portion of the or one of the pipes, and also attaching the sealing means to a portion of the furnace.

This is the replacement sheet



Date:

- 5 AUG 1999

13. A method of operating a premix burner (10) according to any of claims 1 to 8 when in combination with a furnace, or of operating a premix burner/furnace combination retrofitted according to the method of any of claims 9 to 12, with reduced NO_x emissions, which method comprises the steps of:

(a) combining fuel gas and air at a predetermined location (16);

(b) combusting said fuel gas at a combustion point (20) downstream of said predetermined location;

(c) drawing flue gas from the furnace in response to the aspiring effect of uncombusted fuel gas exiting the gas spud (24) and flowing towards the combustion point, the flue gas mixing with the air at the predetermined location (16) upstream of the point of combustion; and

(d) passing into the furnace, air having a temperature lower than the temperature of the flue gas, and then drawing the lower temperature air, along with the flue gas, to the predetermined location, to thereby lower temperature of the drawn flue gas.



This is the replacement sheet

Date:

- 5 AUG 1999