FILED

MAR 3 2000

Phil Lombardi, Clerk
U.S. DISTRICT COURT

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF OKLAHOMA

JOHN ZINK COMPANY, LLC

Plaintiff,

vs.

ZEECO, INC.,

Defendant.

No. 00CV0199C (E)

COMPLAINT AND DEMAND FOR JURY TRIAL
INJUNCTIVE RELIEF REQUESTED

Plaintiff JOHN ZINK COMPANY, LLC, for its complaint against Defendant ZEECO, INC., alleges as follows:

1. Plaintiff is a Delaware Limited Liability Company having a place of business at 11920 East Apache, Tulsa, Oklahoma.

2. Defendant is a corporation duly organized and existing under the laws of the State of Oklahoma, with a place of business at 22151 East 91st Street, Broken Arrow, Oklahoma.

3. This is an action for patent infringement brought under the patent laws of the United States, including 35 U.S.C. §§ 271 and 281-285. Subject matter jurisdiction is provided under 28 U.S.C. §1338(a). Venue is proper under 28 U.S.C. §§ 1391(b), 1391(c) and/or 1400(b).

4. On March 19, 1985, United States Letters Patent No. 4,505,666 was granted to Richard R. Martin and Kurt S. Jaeger for an invention entitled "Staged Fuel and Air for Low NO_x Burner" (the "'666 patent-in-suit"). A copy of the '666 patent-in-suit is attached as Exhibit 1.

5. On October 27, 1987, United States Letters Patent No. 4,702,691 was granted to Richard Ogden for an invention entitled "Even Flow Radial Burner Tip" (the "'691 patent-in-suit"). A copy of the '691 patent-in-suit is attached as Exhibit 2.

6. On March 24, 1992, United States Letters Patent No. 5,098,282 was granted to Robert E. Schwartz, Richard T. Waibel, Paul M. Rodden and Samuel O. Napier for an invention entitled "Methods and Apparatus for Burning Fuel with Low NO_x Formation" (the "'282 patent-in-suit"). A copy of the '282 patent-in-suit is attached as Exhibit 3.

7. On October 13, 1992, United States Letters Patent No. 5,154,596 was granted to Robert E. Schwartz, Richard T. Waibel, Paul M. Rodden and Samuel O. Napier for an invention entitled "Methods and Apparatus for Burning Fuel with Low NO_x Formation" (the "'596 patent-in-suit"). A copy of the '596 patent-in-suit is attached as Exhibit 4.

8. On December 14, 1993, United States Letters Patent No. 5,269,678 was granted to Robert E. Schwartz, Richard T. Waibel, Paul M. Rodden and Samuel O. Napier for an invention entitled "Methods and Apparatus for Burning Fuel with Low NO_x Formation" (the "'678 patent-in-suit"). A copy of the '678 patent-in-suit is attached as Exhibit 5.

9. On September 6, 1994, United States Letters Patent No. 5,344,307 was granted to Robert E. Schwartz, Richard T. Waibel, Paul M. Rodden and Samuel O. Napier for an invention entitled "Methods and Apparatus for Burning Fuel with Low NO_x Formation" (hereinafter the "'307 patent-in-suit"). A true copy of the '307 patent-in-suit is attached as Exhibit 6.

10. Plaintiff is the owner of all right and title to the '666, '691, '282, '596, '678 and '307 patents-in-suit by virtue of respective assignments recorded in the records of the United States Patent and Trademark Office.

11. On information and belief, Defendant has infringed and is infringing each of the '666, '691, '282, '596, '678 and '307 patents-in-suit by making, using, selling and/or offering to sell, in the Northern District of Oklahoma, and elsewhere, burner devices which infringe each of the '666, '691, '282, '596, '678 and '307 patents-in-suit, and Defendant will continue to do so unless enjoined by this Court.

12. Defendant infringement of the '666, '691, '282, '596, '678 and '307 patents-in-suit is willful and deliberate and in flagrant disregard of Plaintiff's rights.

WHEREFORE, Plaintiff prays for judgment as follows:

(A) that the '666, '691, '282, '596, '678 and '307 patents-in-suit are valid and enforceable;

(B) that Defendant ZEECO, INC. has infringed the '666, '691, '282, '596, '678 and '307 patents-in-suit;

(C) that Defendant ZEECO, INC. and all parties contemplated by Rule 65(d) F.R.Civ.P., be preliminarily and permanently enjoined from further infringement of the '666, '691, '282, '596, '678 and '307 patents-in-suit;

(D) that Defendant ZEECO, INC. be ordered to account for and pay to Plaintiff JOHN ZINK COMPANY, LLC the damages, including lost profits and reasonable royalties, to which Plaintiff JOHN ZINK COMPANY, LLC is entitled as a consequence of Defendant ZEECO, INC.'s infringement, and that in view of Defendant ZEECO, INC.'s acts of willful, deliberate, and intentional infringement, such damages should be trebled;

(E) that Plaintiff JOHN ZINK COMPANY, LLC be awarded its costs, interest on the damages awarded, and reasonable attorney fees; and

(F) such other and further relief as the Court deems just and equitable.

Respectfully submitted,

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United States Patent [19]
Martin et al.

[11] **Patent Number:** **4,505,666**
[45] **Date of Patent:** **Mar. 19, 1985**

[54] **STAGED FUEL AND AIR FOR LOW NO_x BURNER**

[75] Inventors: Richard R. Martin; Kurt S. Jaeger, both of Tulsa, Okla.

[73] Assignee: John Zink Company, Tulsa, Okla.

[21] Appl. No.: 542,098

[22] Filed: Sep. 28, 1983

Related U.S. Application Data

[63] Continuation of Ser. No. 306,412, Sep. 28, 1981, abandoned.

[51] Int. Cl.[3] F23C 5/28
[52] U.S. Cl. 431/175; 431/10; 431/285
[58] Field of Search 431/10, 12, 174, 175, 431/181, 187, 188, 278, 284, 285, 351, 352; 60/732, 733

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,263,170	11/1941	Haedike	431/278
2,395,276	2/1946	Jordan	431/174
2,851,093	9/1958	Zink et al.	431/174
3,033,273	5/1962	Zink et al.	431/174
3,376,098	4/1968	Pryor	431/12
3,873,671	3/1975	Reed et al.	423/235
3,911,083	10/1975	Reed et al.	423/235
3,925,002	12/1975	Verdouw	431/10
4,004,875	1/1977	Zink et al.	431/9
4,033,725	7/1977	Reed et al.	431/5
4,089,639	5/1978	Reed	431/211
4,095,929	6/1978	McCartney	431/284
4,157,890	6/1979	Reed	431/187
4,162,140	7/1979	Reed	431/284
4,244,325	1/1981	Hart et al.	122/4
4,245,980	1/1981	Reed et al.	431/182
4,257,763	3/1981	Reed	431/188
4,395,223	7/1983	Okigami et al.	431/10

FOREIGN PATENT DOCUMENTS

74929 6/1977 Japan .

OTHER PUBLICATIONS

Low NO_x Burner Two Stage Fuel Supply System, Hitachi, Zosen, Jul. 1978, No. D-14B, 6 pages, 345 Park Ave., New York, N.Y. 10022, U.S.A., Jul. 1978.

Primary Examiner—Carroll B. Dority, Jr.
Attorney, Agent, or Firm—Head, Johnson & Stevenson

[57] **ABSTRACT**

A low NO_x burner for a furnace and a method of operating the burner involving a primary and secondary combustion zone wherein staged fuel and air to both combustion zones is provided. By injection of from about 40 to 60% of the liquid or gaseous hydrocarbon fuel along with about 90% of the total air required to a first reaction zone and injection of the remaining fuel with the remaining 10% of the air to a secondary reaction zone the formation of NO_x is significantly suppressed. Such a burner is useful in minimizing NO_x emissions for a variety of furnace types including both natural draft and forced draft furnaces.

4 Claims, 10 Drawing Figures

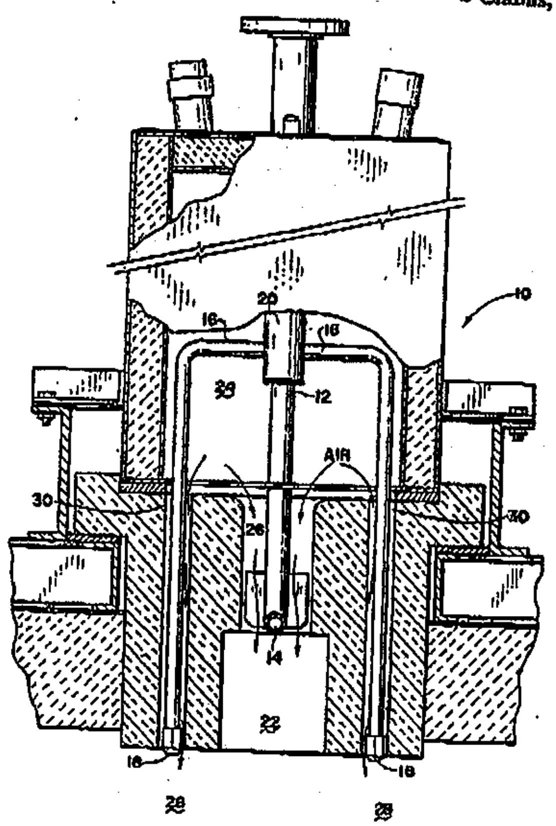


Exhibit 1

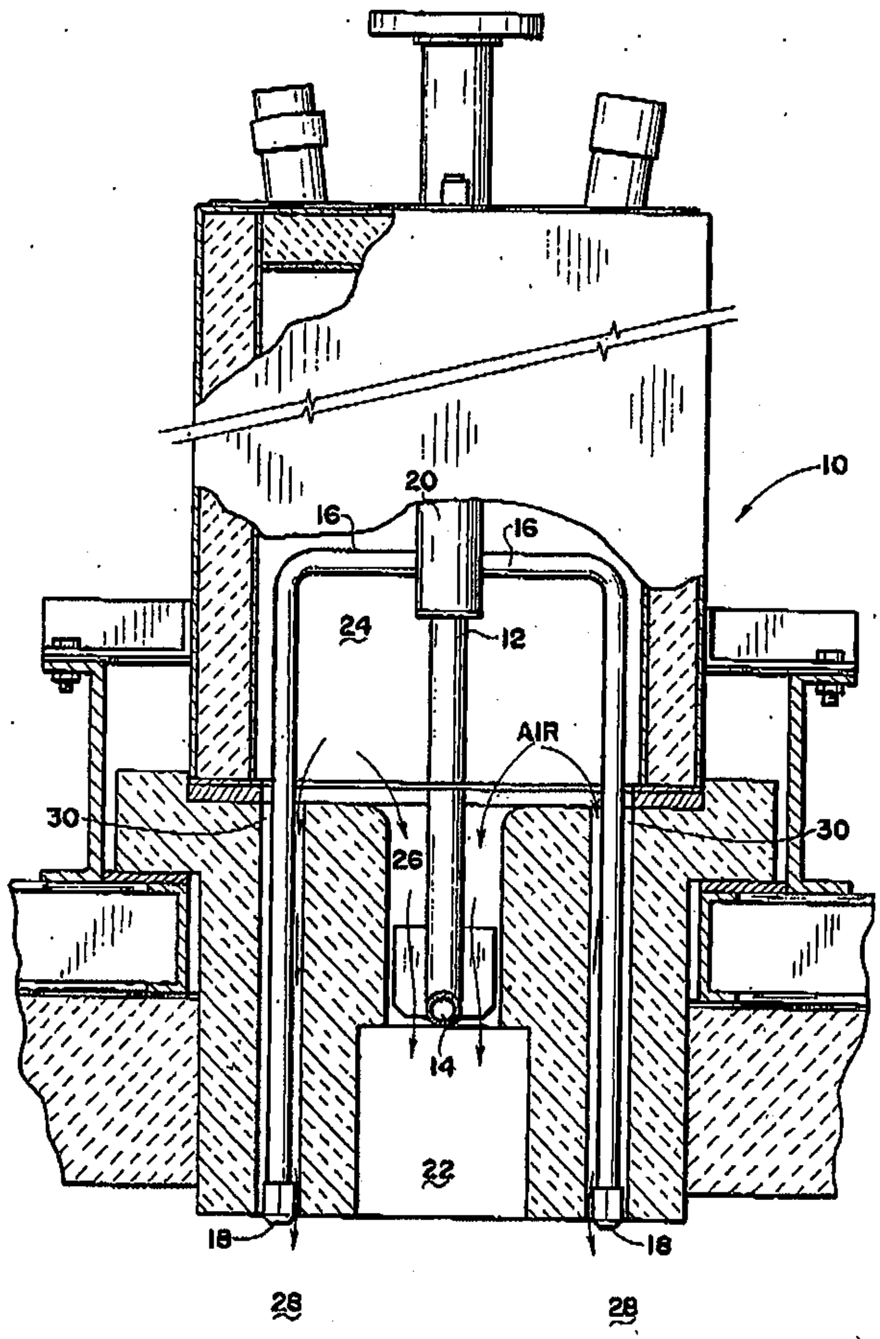


Fig. 1

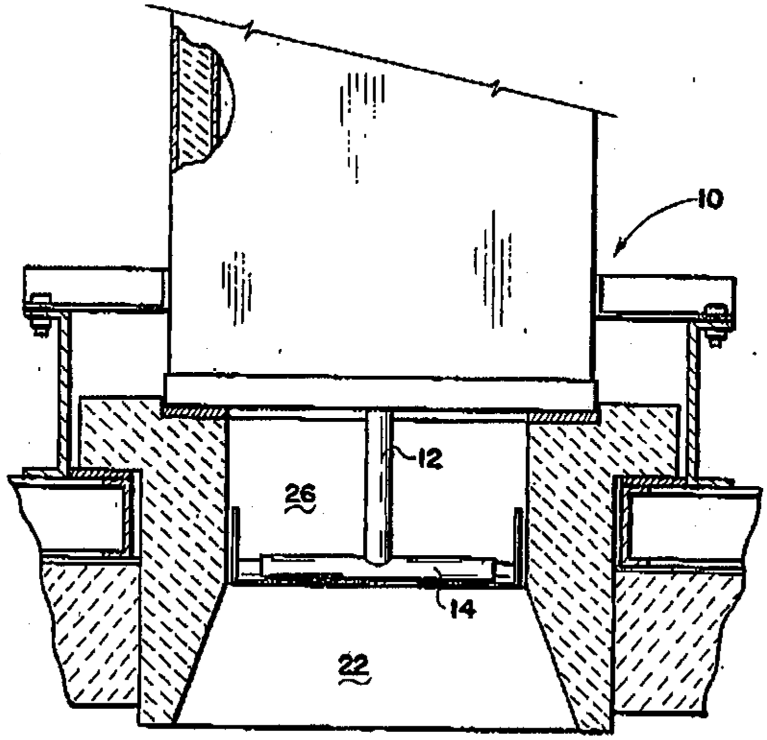


Fig. 2

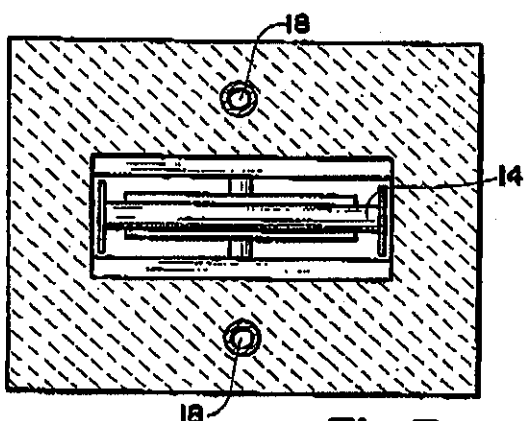


Fig. 3

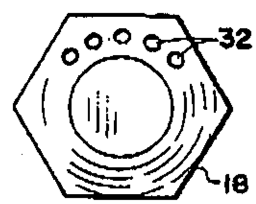


Fig. 4

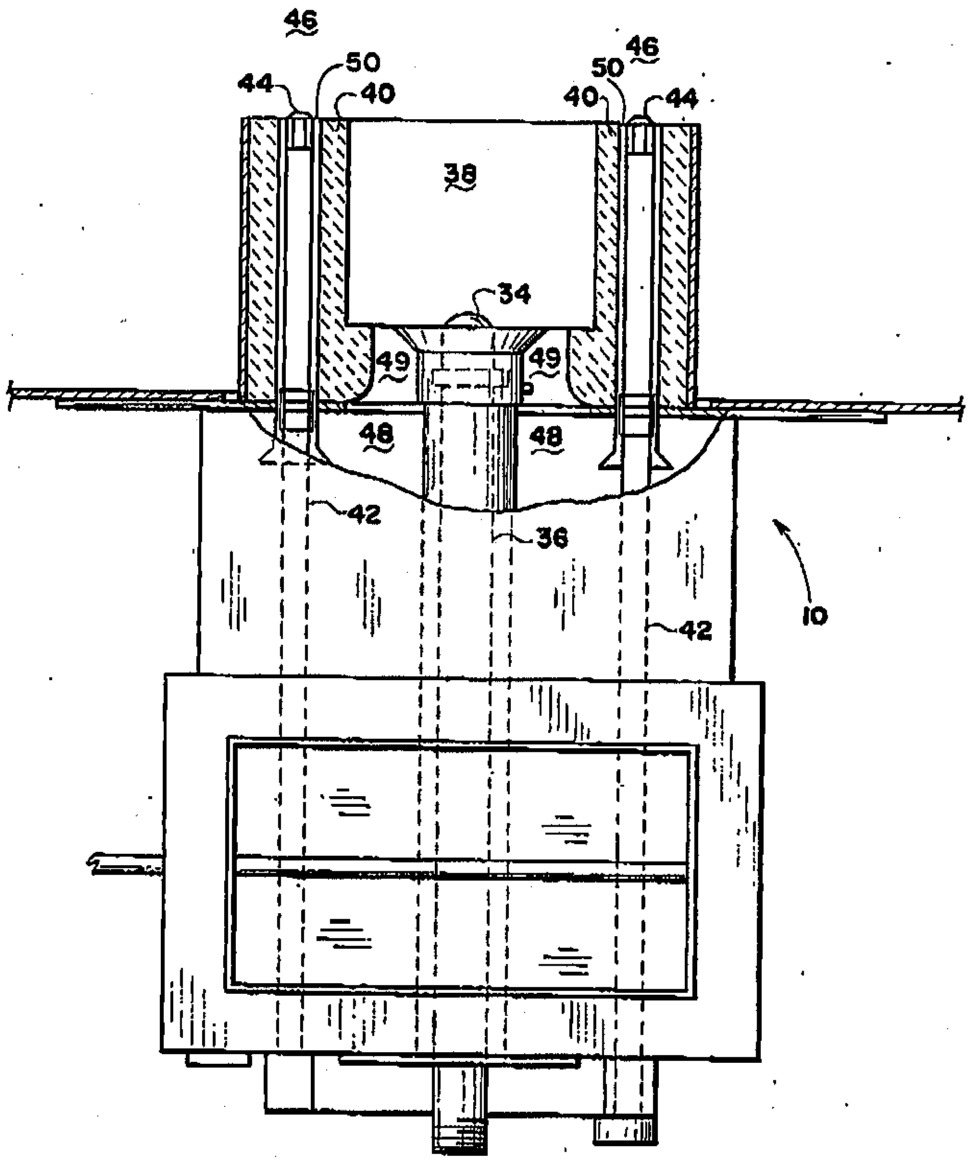


Fig. 5

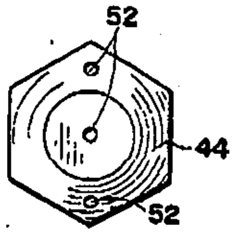


Fig. 6

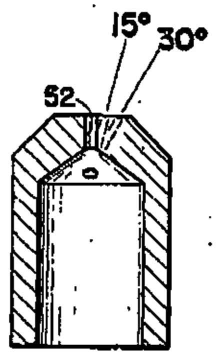


Fig. 7

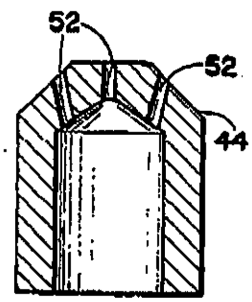


Fig. 8

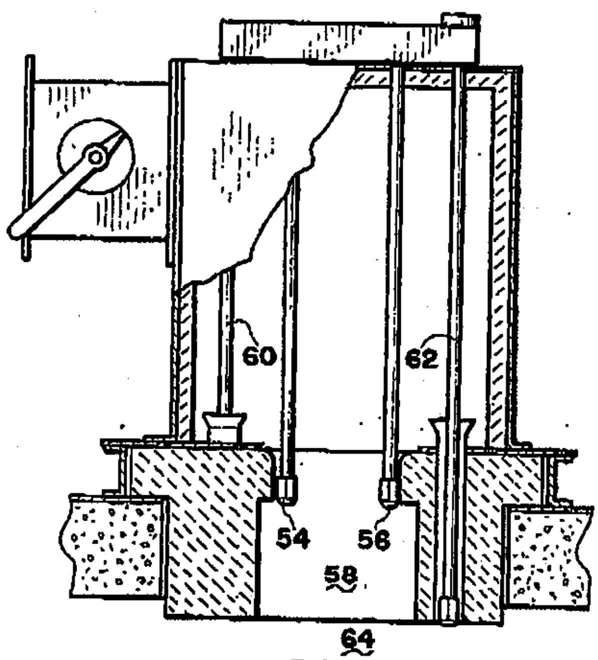
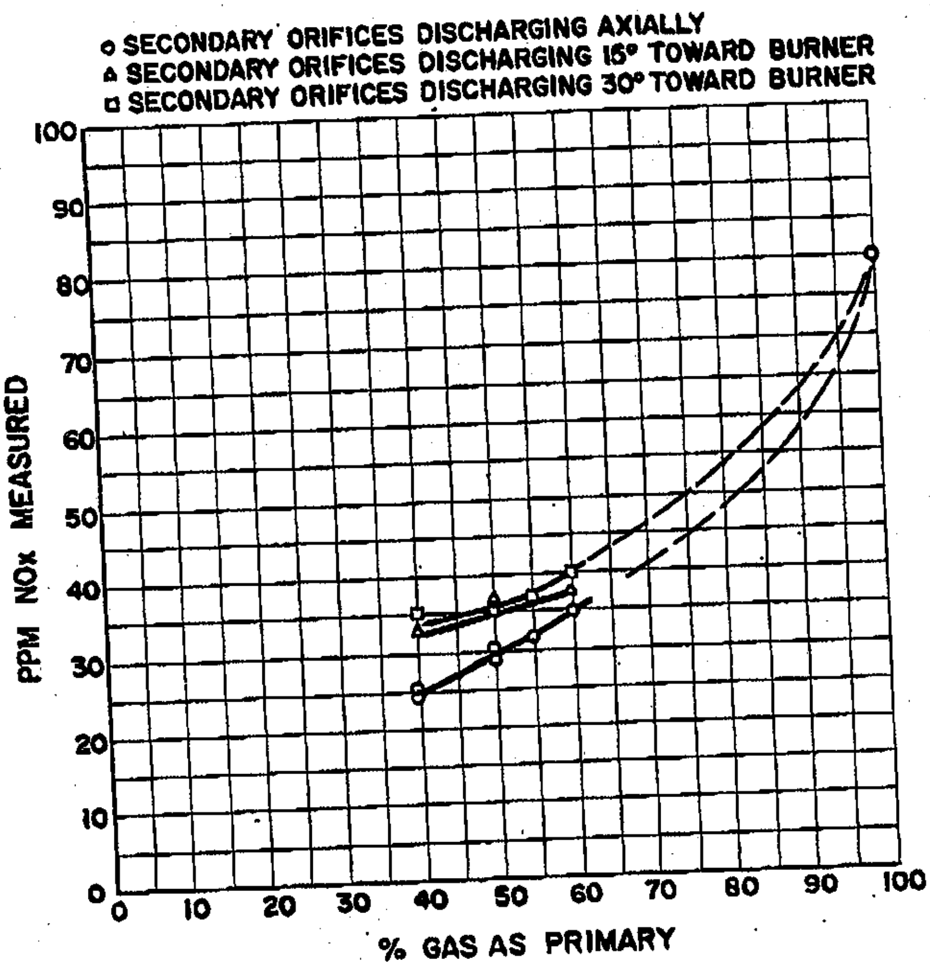


Fig. 9



o SECONDARY ORIFICES DISCHARGING AXIALLY
Δ SECONDARY ORIFICES DISCHARGING 15° TOWARD BURNER
□ SECONDARY ORIFICES DISCHARGING 30° TOWARD BURNER
PPM NOx MEASURED
0
10
20
30
40
50
60
70
80
90
100
% GAS AS PRIMARY

Fig. 10

STAGED FUEL AND AIR FOR LOW NO_x BURNER

This is a continuation application of Ser. No. 306,412, filed Sep. 28, 1981, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method and apparatus for burning fuel resulting in low NO_x formation. More specifically, this invention relates to a staged fuel and air injection burner.

2. Description of the Prior Art

With the advent of contemporary environmental emission standards being imposed by various governmental authorities and agencies involving ever stricter regulations, methods and apparatus to suppress the formation of oxides of nitrogen during combustion with air are becoming increasingly numerous. Various techniques have been suggested and employed in the design and operation of burners and furnaces to meet those regulations. Thus it is known that to burn a hydrocarbon fuel in less than a stoichiometric concentration of oxygen intentionally produces a reducing environment of CO and H_2. This concept is utilized in a staged air type low NO_x burner wherein the fuel is first burned in a deficiency of air in one zone producing a reduced environment that suppresses NO_x formation and then the remaining portion of the air is added in a subsequent zone. Staged fuel has also been suggested wherein all of the air and some of the fuel is burned in the first zone and then the remaining fuel is added in the second zone. The presence of an over abundance of air in the first reaction zone acts as a diluent thus lowering the temperature and suppressing formation of NO_x. It has also been proposed to recirculate fule gas to accomplish the lowering of the flame temperature.

However, each of the prior art processes have certain inherent deficiencies and associated problems which have led to limited commercial acceptance. For example, when burning fuel in a substoichiometric oxygen environment the tendency for soot formation is increased. The presence of even small amounts of soot will alter the heat transfer properties of the furnace and heat exchanger surfaces downstream from the burner. Also, flame stability can become a critical factor when operating a burner at significantly sub-stoichiometric conditions.

SUMMARY OF THE INVENTION

In view of the problems associated with previously proposed low NO_x burners, we have discovered a method for burning a gaseous or liquid hydrocarbon fuel in air resulting in low NO_x formation comprising the steps of:

(a) burning a portion of the fuel with a major portion of the air in a primary reaction zone such as to reduce the formation of NO_x;

(b) directing the effluent from the primary reaction zone into a second reaction zone; and

(c) burning the remaining portion of the fuel with the remaining minor portion of the air in the second reaction zone.

Thus, the low NO_x forming burner of the present invention comprises;

(a) a primary reaction zone;

(b) a secondary reaction zone sequentially following the primary reaction zone;

(c) a means for proportioning the fuel between the primary and secondary reaction zones; and

(d) a means for supplying a major portion of the air for burning the fuel to the primary reaction zone and supplying the remaining minor portion of the air to the secondary reaction zone.

The present invention further provides for the fuel to be proportioned from about 40 to 60% to the primary reaction zone and then from about 60 to 40% to the second reaction zone while the air is proportioned from about 80 to 95% to the primary zone (preferably 90%) and from about 20 to 5% to the secondary zone (preferably 10%).

The invention further provides for the primary reaction zone to involve at least one injection nozzle within a centrally located chamber and a secondary reaction zone to involve at least one nozzle and preferably a plurality of nozzles surrounding the outlet of the primary reaction zone. Accordingly, the fuel is supplied to the injection nozzles from a single source with the orifices of the nozzles being sized to proportion the fuel between the primary and secondary reaction zones.

It is an object of the present invention to provide a method and apparatus for burning a hydrocarbon fuel resulting in reduced emission of nitrogen oxides generated by the combustion. It is a further object that a two stage fuel and air system be employed in a manner that maintains furnace efficiency without significant soot formation. And, it is an additional object that the method and apparatus be consistent with a variety of burner designs including, for example, flat flame design, round or conical flame burners, high intensity burners and the like. Fulfillment of these objects and the presence and fulfillment of other objects will be apparent upon complete reading of the specification and claims taken in conjunction with the attached drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a cross-sectional view of one embodiment of the invention illustrating a T-bar primary nozzle and a pair of secondary nozzles.

FIG. 2 is a cross-sectional side view of the T-bar primary nozzle of FIG. 1.

FIG. 3 is an end view of the burner of FIG. 1.

FIG. 4 illustrates the orifice configuration of the secondary nozzles for the burner illustrated in FIG. 1.

FIG. 5 is a cross-sectional view of an alternate embodiment of this invention illustrating a domed nozzle.

FIGS. 6, 7 and 8 illustrate an alternate secondary nozzle and orifice configuration for burner of FIG. 5.

FIG. 9 is another embodiment illustrating a pair of flat flame design primary nozzles.

FIG. 10 is a graphic illustration of NO_x levels achieved for a variety of secondary tips and various fuel split ratios.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawing and, in particular, to FIGS. 1, 2 and 3 there is shown one embodiment of the present invention wherein the burner is indicated generally by the numeral 10. This particular embodiment involves a primary burner tube 12 leading to a T-bar primary nozzle 14 along with a pair of secondary burner tubes 16 and secondary burner nozzles 18 all being supplied hydrocarbon fuel from a common source through tube 20. The fuel exiting primary nozzle 14 enters the primary combustion zone 22 wherein it is burned in the presence of a significant stoichiometric excess of air flowing through the interior 24 of the burner and entering the primary reaction zone 22 through an annular space 26 surrounding the primary nozzle 14, as indicated by the presence of arrows.

The effluent from the primary reaction zone 22 enters a larger secondary reaction zone 28. Simultaneously, the fuel exiting the secondary nozzle 18 is mixed with air from the interior 24 of the burner 10 passing through annular conduits 30 surrounding burner tubes 16 and is then burned in the secondary reaction zone 28 in the presence of the effluent from the first reaction zone 22.

The orifices of the respective T-bar nozzle 14 and secondary nozzles 18 are sized such that the fuel is proportioned between the primary reaction zone and the secondary reaction zone. Preferably from about 40 to about 60% of the fuel is directed through the primary nozzle 14 and the remaining fuel is directed to the secondary nozzles 18. Similarly, the cross-sectional area of the annular space 26 and the annular conduits 30 for conducting air to primary and secondary reaction zones are selected such as to deliver about 80 to 95% of the total air to the primary reaction zone 22 and the remaining 20 to 5% of the total air to the secondary reaction zone 28.

FIG. 4 illustrates the directional characteristics of the orifices of each secondary nozzle 18. As illustrated, the five fuel ports 32 will issue a fan like sheet of fuel directed towards the effluent of the primary combustion zone.

In FIG. 5 an alternate forced draft burner 10 is illustrated involving a single gas nozzle 34 that directs the fuel delivered through conduit 36 into the primary combustion zone 38 defined by the refractory walls 40 of the burner. Riser pipes 42 fitted with orifice tips 44 extend through this refractory wall 40 such as to deliver the secondary fuel to the secondary combustion zone 46. Similar to FIG. 1, combustion air flows through the interior 48 of burner 10 into the primary zone 38 by way of annular conduit 49 and into secondary combustion zone 46 through annular openings 50. FIGS. 6, 7 and 8 illustrate the basic orifice or port configuration 52 of the secondary nozzles 44 including alternate angles of inclination (see FIG. 7) towards the axial direction of the flow in the primary reaction zone 38.

FIG. 9 illustrates another alternate embodiment of a staged fuel and air burner 10 of the present invention wherein the particular burner is a flat flame design involving a pair of primary nozzles 54 and 56 each essentially adjacent to the refractory walls forming the primary reaction zone 58. Similar to the previous embodiments, secondary fuel conduits 60 and 62 pass through the refractory material such as to deliver fuel to the secondary reaction zone 64.

EXAMPLE

In order to evaluate the principle of separating the gaseous fuel into two essentially equal but sequential burning stages wherein a significant stoichiometric excess or major portion of the air is employed in the first stage with the remaining minor portion of the air in the second stage, a series of tests were conducted using a burner configuration as illustrated in FIG. 5. The burner was of a forced draft design using natural gas. A center mounted gas gun was mounted to fire inside a refractory chamber. Four riser pipes fitted with orifice tips were installed through the refractory wall of the combustion chamber parallel to the center line of the burner. Three sets of tips were tested, each having orifices discharging at different angles to the tip centerline. The burner was tested by firing vertically upward into a furnace.

Three series of tests were conducted; one series for each set of secondary riser tip drillings. The tip drillings included three orifices, and were oriented in the first series discharging vertically upward (parallel to the centerline of the burner), in the second series discharging at a small angle, e.g. 15° off vertical (towards the burner centerline) and in the third series discharging 30° off vertical (towards the burner centerline). Each test series of each set of tips included variations of primary/secondary fuel ratio and turned down tests.

FIG. 10 illustrates the NO_x levels achieved for each set of tips at various fuel split ratios. The burner was also fired on center gas only to establish the base point for non-staged operation of 80 ppm NO_x. The lowest NO_x levels were obtained with secondary orifices discharging parallel to the burner axis, but this set of tips also produces the highest level of combustibles. Turn down on 30° tips was about 3:1 on a fifty/fifty fuel split, and turn down on 15° tips was about 2:1 on a forty/sixty split. Flame appearance was generally good on all arrangements.

From the data and test results it is readily apparent that the basic concept of staged air and fuel combustion is capable of producing NO_x levels significantly lower than conventional combustion. The test results have also established that these low NO_x levels are achieved in the absence of significant soot formation or flame instability. Additional advantages of the present invention include the fact that the NO_x levels achieved are lower than those associated with staged air combustion and the fact that the basic concept of staged air and fuel is compatible with a wide variety of types of burners.

Having thus described the invention with a certain degree of particularity, it is manifest that many changes can be made in the details of construction and arrangement of components without departing from the spirit and scope of this disclosure. Therefore, it is to be understood that the invention is not limited to the embodiment set forth here for purposes of exemplification, but is to be limited only by the scope of the attached claims, including a full range of equivalents to which each element thereof is entitled.

We claim:

1. A low NO_x emission fuel-air burner for a furnace chamber comprising:

an air-fuel mixing and injection burner attached to the wall of said furnace such that the downstream face of said burner terminates substantially adjacent an inner wall of said furnace chamber;

means to supply to said burner, at a given instant of burning, a given total amount of fuel under pressure and a given total amount of air, said total amount of air being at least substantially stoichiometrically sufficient to burn said total amount of fuel supplied to said burner;

means to create a primary reaction burning zone that begins in an enclosed space upstream of said inner wall and extends downstream of said inner wall into said furnace chamber and means to supply to said burning zone a first portion of said total fuel and a portion of said total air which exceeds the stoichiometric requirements for burning said first portion of fuel thereto;

a plurality of conduits in said burner located adjacent said enclosed space, said conduits providing communication between said total air supply and said furnace chamber;

fuel injection nozzle means positioned within each of said conduits such that there is passage of said air thereabout, said nozzle means terminating adjacent said downstream face of said burner;

means to supply the remaining portion of said total fuel to said nozzle means, and means to supply the remaining portion of said total air through said conduits surrounding said nozzle means, said remaining portion of said total air being less than the stoichiometric requirements to burn said remaining portion of said total fuel;

said nozzle means directing said remaining portion of said total fuel as a fan shaped sheet which along with said remaining portion of said total air contributes to the formation of an unconfined secondary reaction burning zone substantially surrounding and reacting with a substantial portion of the unconfined effluent of said primary reaction zone within said furnace chamber, and to cause the inspiration of products of combustion that substantially surround said secondary reaction zone into said secondary reaction zone.

2. A burner of claim 1 including means to supply within the range of about 40 to about 60% of said total fuel to said primary reaction zone and about 60 to about 40% of said fuel being supplied to said secondary reaction zone.

3. A burner of claim 2 including means to supply in the range from about 80 to about 95% of the said total air to said primary reaction zone.

4. A burner of claim 1 including means to supply in the range from about 80 to about 95% of the said total air to said primary reaction zone.

* * * * *

United States Patent [19]

Ogden

[11] **Patent Number: 4,702,691**

[45] **Date of Patent: Oct. 27, 1987**

[54] **EVEN FLOW RADIAL BURNER TIP**

[75] Inventor: Richard Ogden, Bristow, Okla.

[73] Assignee: John Zink Company, Tulsa, Okla.

[21] Appl. No.: 894,703

[22] Filed: Aug. 7, 1986

Related U.S. Application Data

[63] Continuation of Ser. No. 592,013, Mar. 19, 1984, abandoned.

[51] Int. Cl.[4] F23C 7/00

[52] U.S. Cl. 431/187; 431/346; 431/354; 239/552; 239/553

[58] Field of Search .... 431/348, 202, 354, 171, 431/114, 108, 353, 127, 346; 239/553.3, 553, 552; 126/39 E

[56] **References Cited**

U.S. PATENT DOCUMENTS

563,630	7/1896	Webster	239/552
794,225	7/1905	Humphrey	239/552
1,923,393	8/1933	Pickup	239/552 X
2,224,450	12/1940	Scofield	239/553 X
2,537,542	1/1951	Norman	239/552 X
2,669,300	2/1954	Blaha	431/348
2,671,507	3/1954	Morck	431/348
3,000,435	9/1961	Bloom et al.	431/348
3,076,498	2/1963	Williams et al.	431/348
3,182,712	5/1965	Zink et al.	431/348 X
3,311,155	3/1967	Hershey et al.	431/114
3,684,424	8/1972	Zink et al.	431/353 X
3,773,075	11/1973	Thompson et al.	431/354 X
3,940,234	2/1976	Reed et al.	431/348

FOREIGN PATENT DOCUMENTS

78156	1/1894	Fed. Rep. of Germany	239/558
448052	7/1927	Fed. Rep. of Germany	239/552
2035563	1/1972	Fed. Rep. of Germany	431/354
188684	11/1922	United Kingdom	239/552
691818	5/1953	United Kingdom	431/348
828502	2/1960	United Kingdom	431/348
933591	8/1963	United Kingdom	431/348
1257053	12/1971	United Kingdom	239/552

Primary Examiner—Randall L. Green
Attorney, Agent, or Firm—Head & Johnson

[57] **ABSTRACT**

A gas burner assembly supported in an opening in a furnace wall has injected gas and/or air flowing through an inner burner tube then outwardly through a plurality of openings for burning along the surface of a wall thus providing a near uniform radiant heat energy to the furnace. A flow divider positioned opposite the openings divides the flowing gas and/or air to improve distribution, and retard flashback in the event of variations in fuel-air mixture and/or flow.

4 Claims, 7 Drawing Figures

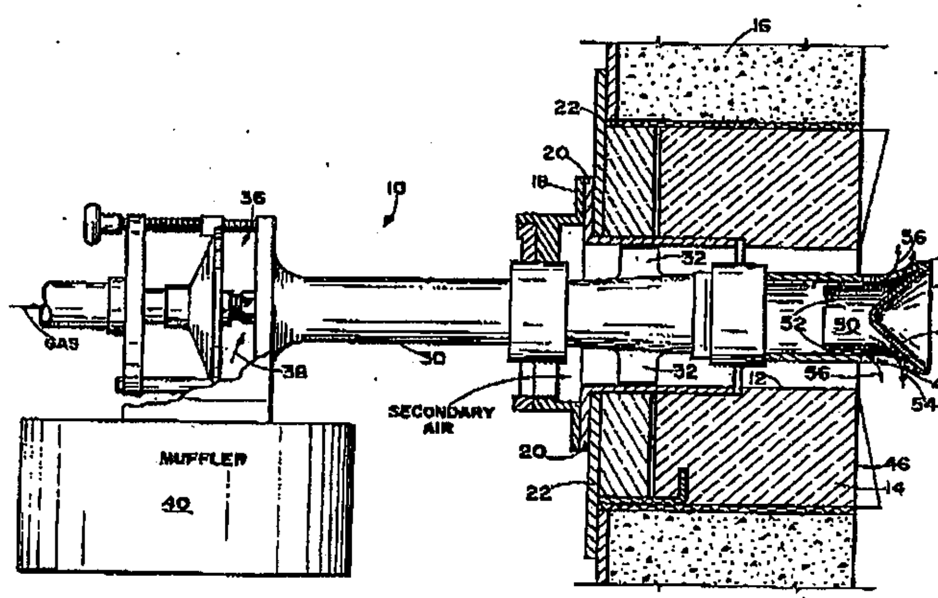


Exhibit 2

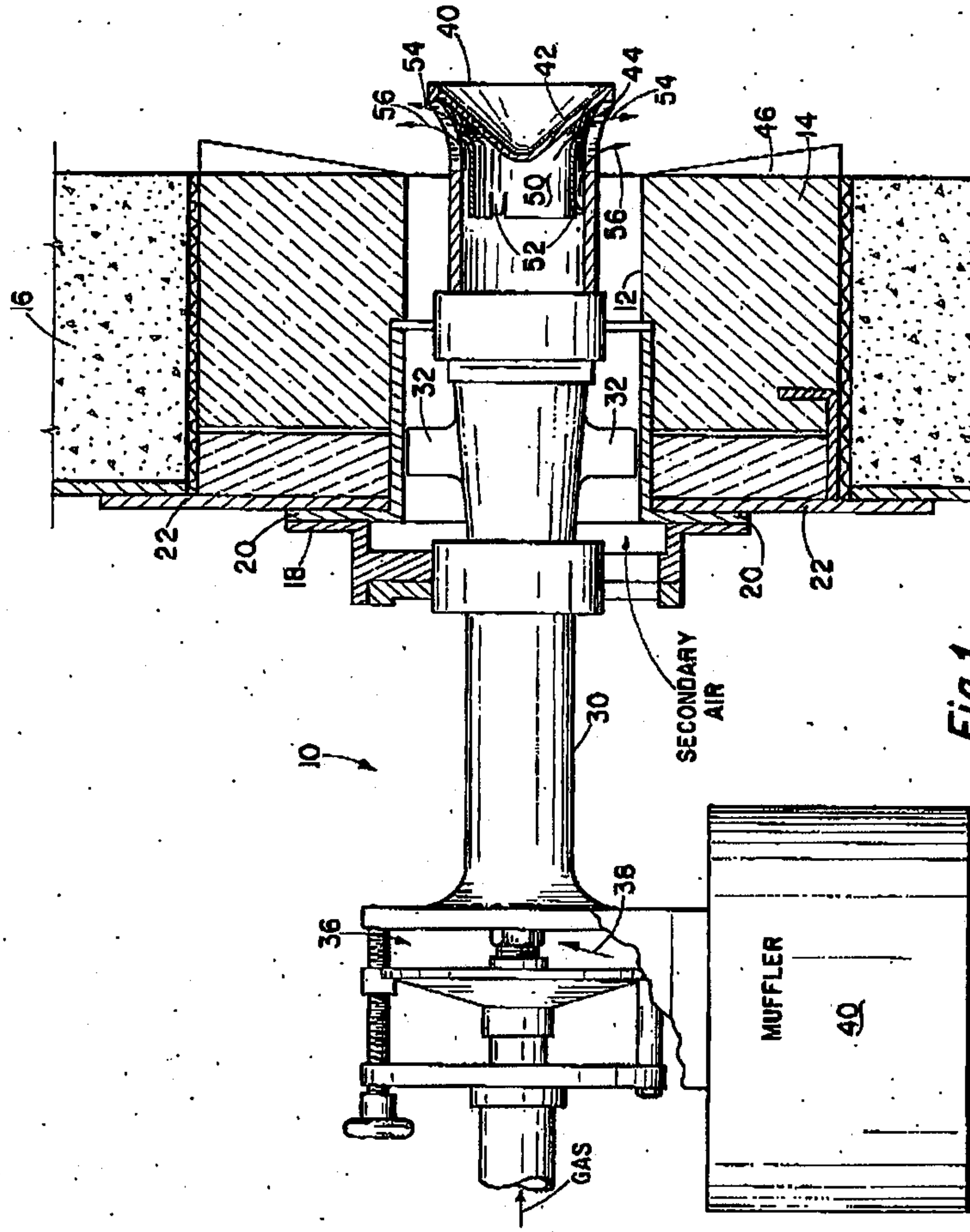


Fig. 1

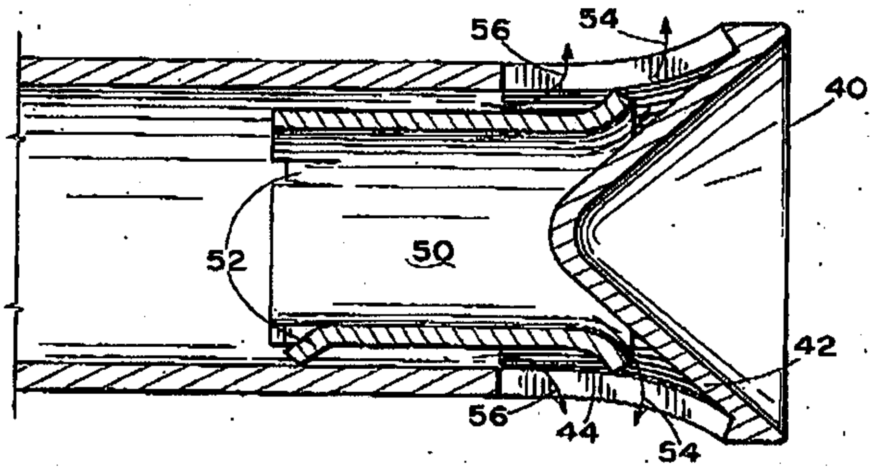


Fig. 2

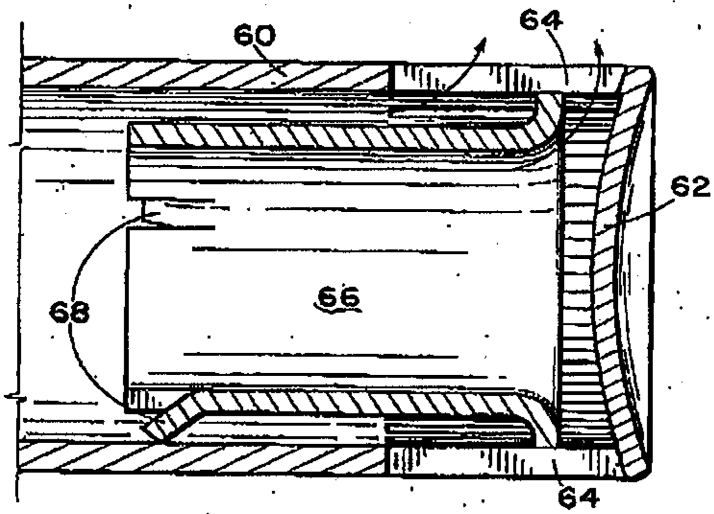


Fig. 3

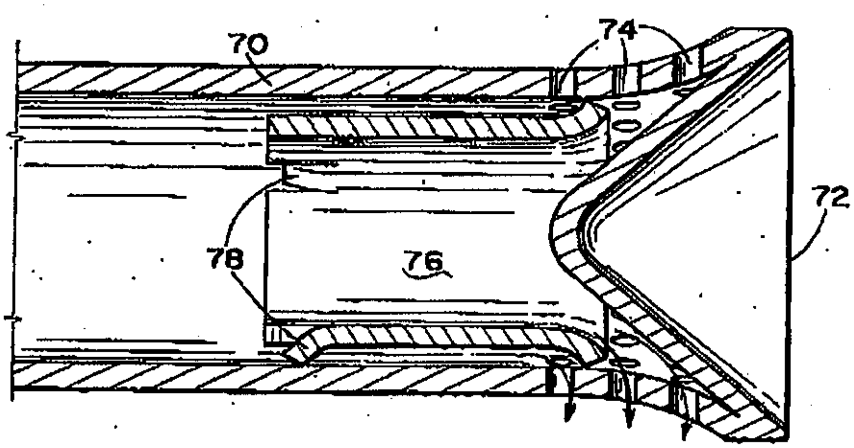


Fig. 4

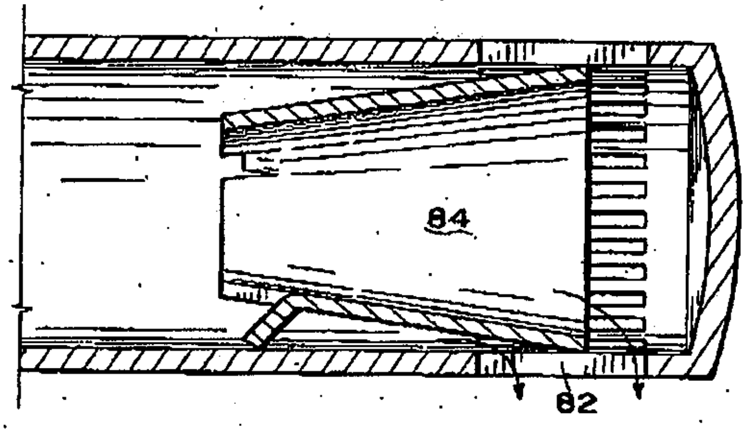


Fig. 5

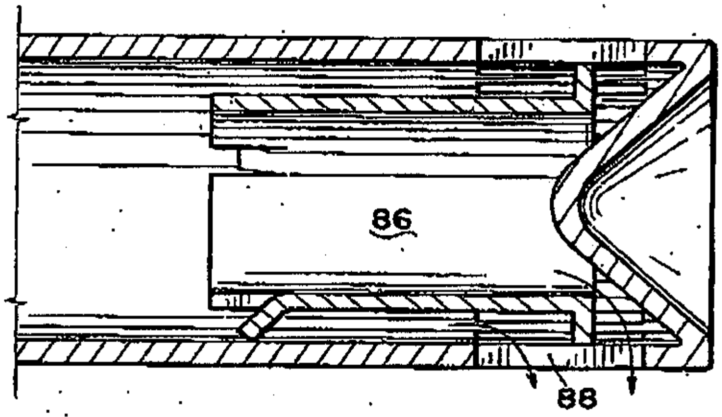


Fig. 6

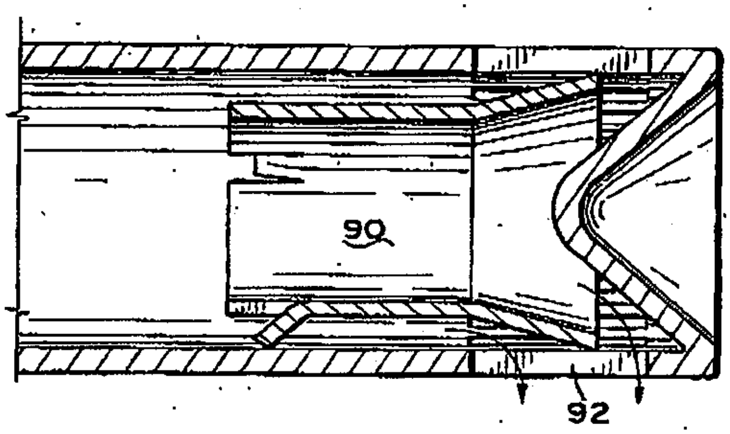


Fig. 7

EVEN FLOW RADIAL BURNER TIP

This is a continuation of copending application Ser. No. 592,013, filed on Mar. 19, 1984, abandoned.

BACKGROUND OF THE INVENTION

This invention is an improvement upon radiant wall burning apparatus such as that which has been heretofore developed and patented and typically shown in the following U.S. Pat. Nos.:

3,416,735
3,684,424
4,257,762

The invention is directed to a burner which inspirates or educts air with gas to burn beyond openings at the end of a burner tube. In addition, the invention is applicable to a burner that uses forced air or forced air and gas for burning outside openings at the end of a burner tube. The outlet slots or openings must allow maximum emission of the gas-air mixture at sufficient velocity to prevent flashback into the burner tube.

SUMMARY OF THE INVENTION

It is an object of this invention to maintain efficient burning of radiant wall burner apparatus despite changes in velocity of the combustible gases and/or changes in types of fuel.

It is another object of this invention to provide, at the outlet of a radiant furnace wall burner tube, apparatus to make the outward flowing velocity substantially uniform through the openings at the tip. A further object is to provide improved distribution of air or gas-air mixtures through the openings or slots provided at the end of the burner tube adjacent a furnace wall.

It is to be understood that the invention is for use with a variety of gas-air, or air-gas mixing burners. For example, the invention includes burners using forced air pre-mixed with gas or alone such as found in U.S. Pat. No. 4,257,762, the invention being directed to the division of fluid flow at the downstream tip.

A particular description of the invention provides a gas burner assembly for furnaces in which a stream of high velocity fuel gas issues from an orifice to inspirate combustion supporting air into and mix with the air in a mixing section of a burner pipe. The burner pipe is inserted into an oversized opening through the wall of the furnace terminating at a downstream end adjacent and beyond the inner wall of the furnace. The inner wall of the furnace surrounding the furnace opening typically includes a radiant wall surface. The downstream end of the burner pipe is closed. A plurality of openings such as slots or holes are provided in the burner pipe adjacent the downstream end to project gas-air mixtures issuing therefrom, outwardly along the radiant furnace wall surface for burning. A flow divider comprised of an undersized cylindrical member is centrally located permanently or temporarily inside the burner tube adjacent the downstream end. The downstream end of the flow divider is oriented in close proximity to the inside periphery of the burner tube at said openings to effectively divide the openings into what is defined herein as a downstream flowing portion and an upstream flowing portion. The cylindrical flow-divider causes that portion of the fuel-air mixture which passes through the inside of the flow divider to be directed through the downstream portion of the openings. The remaining portion of the fuel-air mixture which passes

through the annular space located between the flow divider and the burner tube flows through the upstream portion of the openings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a partial sectional view describing the apparatus of this invention as it can be located in a furnace wall.

FIG. 2 is an enlarged sectional view of the tip of FIG. 1.

FIGS. 3 and 4 depict other embodiments of the invention.

FIGS. 5, 6 and 7 depict other forms of flow divider baffles within the scope of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Before explaining the present invention in detail, it is to be understood that the invention is not limited in its application to the details of the construction and arrangement of parts illustrated in the accompany drawings. The invention is capable of other embodiments and of being practiced or carried out in a variety of ways. It is to be understood that the phraseology and terminology employed herein is for the purpose of description and not of limitation.

The burner assembly of FIGS. 1 and 2 is generally designated by the numeral 10 is inserted through an opening 12 formed as a part of a burner block 14 located through furnace wall 16. The basic gas-air mixing burner assembly shown here is merely typical, as the invention is not to be limited to that type shown. The burner assembly is supported by a mounting plate 18 as by welding or bolting to plates 20 and/or 22. The mounting plate centrally supports the burner tube 30 and includes openings which may be regulated for the flow of secondary air as shown. Centering lugs 32 may be provided in the annular space between the burner tube and the mounting thimble or plate 20. By supplying gas into the aspirator section 36, primary air, from a muffler 40, is caused to be inspirated at 38 into the burner tube 30 where it is mixed with the gas and thence caused to issue from the downstream end 40.

As stated, this invention is directed to improvements in the flow of the gas-air mixture from the downstream end. A conical shaped plug 42 typically closes the downstream end. A plurality of spaced openings or slots 44 are provided around the circumference of the downstream end of the burner tube 30. These openings 44 project gas and air essentially outwardly for burning along the furnace wall and tile surface 46 which is capable of providing additional radiant heat energy to the interior of the furnace as is known in the art. The invention is particularly directed to a flow divider 50 which is provided in the interior of the burner tube, adjacent the downstream end. The flow divider is comprised of a cylinder which includes outwardly projecting lugs or feet 52 which centralize the flow divider in the position as shown. Other forms of centralizer means such as protrusions from the body of the cylinder and the like are inclusive of the invention. The flow divider can be permanently installed as by welding in a centralized position. The downstream end of the flow divider is caused to be oriented in close proximity to the inside periphery of the burner tube at said openings, thus dividing the openings into a downstream flow 54 and an upstream flow 56.

FIGS. 3 and 4 are directed towards other embodiments which are inclusive of the invention. In FIG. 3 a straight burner tube 60 is depicted having an end closure 62 and a plurality of slots 64 disposed inside the tip. In this embodiment the flow divider 66 disposed about the tip. In this embodiment the flow divider 66 with its' centralizing members 68 is shown. Likewise, in FIG. 4 the primary distinction is the use of a burner tube 70, which may be straight or curved as shown, having an end closure 72 and a plurality of holes 74 surrounding the tip. The flow divider 76 with its' centralizing members 78 is shown positioned with respect to that embodiment.

FIGS. 5, 6 and 7 depict different forms of flow dividers, such as an angularly inclined member 84 dividing slots 82 of FIG. 5, a right angle divider 86 dividing slots 88 of FIG. 7 and a beveled flow divider 90 dividing slots 92.

What is claimed is:

1. A gas burner assembly for furnaces in which a fluid stream of pre-mixed fuel and aspirated combustion supporting air flows through a burner pipe, said burner pipe inserted into an oversized opening through the wall of said furnace forming an annulus for the passage of secondary air therethrough, a downstream end of said burner pipe closed, a plurality of circumferentially spaced openings in said burner pipe adjacent said downstream end to project said fluid stream issuing therefrom outwardly to intersect and said secondary air for burning along a radiant furnace wall surface surrounding said burner pipe; a flow divider means centrally positioned inside of said burner pipe at the said downstream end, said flow divider means comprising a thin walled metallic cylindrical member of length substantially less than the length of said burner tube, the upstream end of said flow divider means being of lesser diameter than said burner pipe forming a substantially undivided annular flow space between said cylindrical member and the inside diameter of said burner pipe and an undivided inside central space, the cross-sectional area of said annular flow space being less than the cross-sectional area of said inside central space, the downstream end of said flow divider flaring outwardly so as to be contiguous with the inner periphery of said burner pipe opposite said openings to divide said openings into downstream openings and upstream openings, said flow divider diving said fluid stream into an undivided downstream portion which passes through said inside central space of said flow divider thence outwardly through said downstream openings and a substantially undivided upstream portion of said fluid stream which passes through said annular flow space thence through said upstream openings.

2. The burner of claim 1 wherein the downstream flaring outward portion of said flow divider contiguous with said openings has a curved surface.

3. The burner of claim 1 wherein the downstream flaring outward portion of said flow divider contiguous with said openings has a tapered or beveled surface.

4. The burner of claim 1 wherein the downstream flaring outward portion of said flow divider contiguous with said openings is approximately perpendicular to said openings.

* * * * *

US005098282A

United States Patent [19]

Schwartz et al.

[11] Patent Number: **5,098,282**

[45] Date of Patent: **Mar. 24, 1992**

[54] **METHODS AND APPARATUS FOR BURNING FUEL WITH LOW NO_x FORMATION**

[75] Inventors: Robert E. Schwartz, Tulsa; Richard T. Waibel, Broken Arrow; Paul M. Rodden, Sand Springs; Samuel O. Napier, Sapulpa, all of Okla.

[73] Assignee: John Zink Company, Tulsa, Okla.

[21] Appl. No.: 578,953

[22] Filed: Sep. 7, 1990

[51] Int. Cl.[5] F23M 3/00; F23C 5/00

[52] U.S. Cl. 431/9; 431/174; 431/181; 431/187; 431/116

[58] Field of Search 431/9, 278, 181, 187, 431/188, 115, 116, 8, 10, 174

[56] References Cited

U.S. PATENT DOCUMENTS

3,174,526	3/1965	Von Linde	158/4
3,658,482	4/1972	Evans et al.	23/277 C
3,716,001	2/1973	Potasek et al.	110/8 A
3,794,459	2/1974	Meenan	431/5
4,004,875	1/1977	Zink et al.	431/9
4,130,388	12/1978	Flanagan	431/116
4,257,763	3/1981	Reed	431/174 X
4,277,942	7/1981	Egnell et al.	60/517
4,481,889	11/1984	Sikander et al.	110/212
4,505,666	3/1985	Martin et al.	431/175
4,575,332	3/1986	Oppenberg et al.	431/9
4,645,449	2/1987	Schwartz et al.	431/8
4,699,071	10/1987	Vier et al.	110/345
4,708,638	11/1987	Brazier et al.	431/116
4,907,962	3/1990	Azuhata et al.	431/174
5,044,932	9/1991	Martin et al.	431/116

FOREIGN PATENT DOCUMENTS

89119591.9 10/1989 European Pat. Off. .

Primary Examiner—Larry Jones
Attorney, Agent, or Firm—Laney, Dougherty, Hessin & Beavers

[57] ABSTRACT

Improved methods and burner apparatus are provided for discharging mixtures of fuel and air into furnace spaces wherein said mixtures are burned and flue gases having low NO_x content are formed therefrom. The methods basically comprise discharging a first fuel mixture containing a portion of the fuel and flue gases from the furnace space into the furnace space whereby the mixture is burned in a primary reaction zone therein and flue gases having low NO_x content are formed therefrom, and then discharging the remaining portion of the fuel into a secondary reaction zone wherein the remaining portion of fuel mixes with air and flue gases to form a second fuel mixture which is burned in the secondary reaction zone and additional flue gases having low NO_x content are formed therefrom.

29 Claims, 3 Drawing Sheets

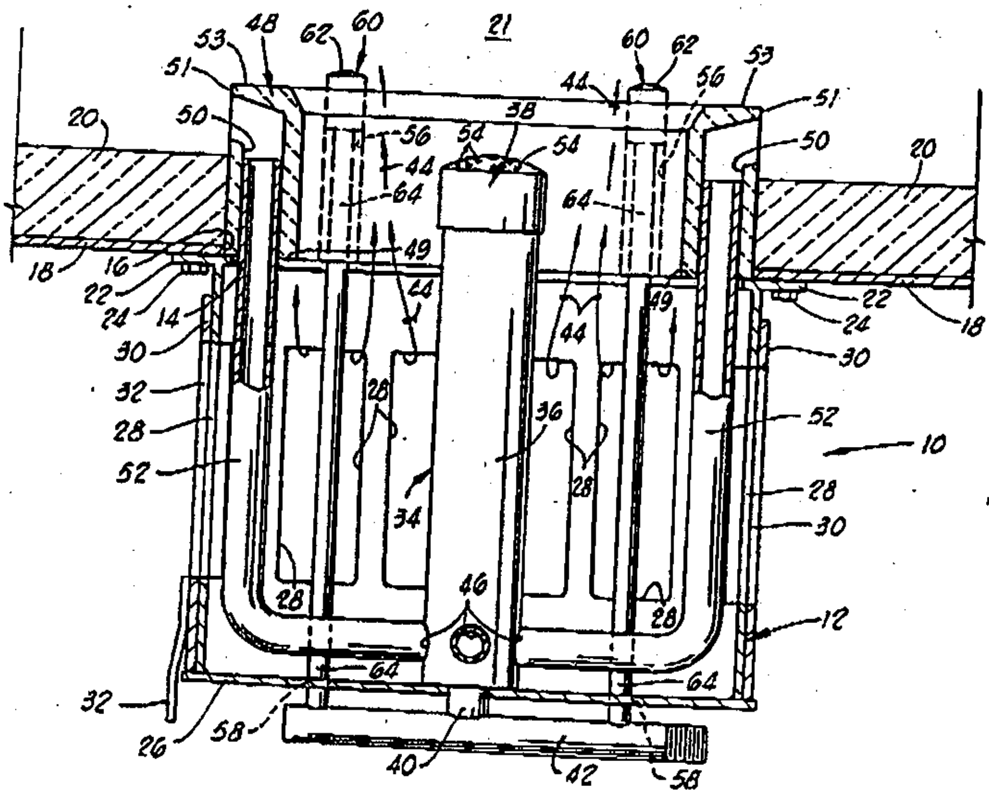


Exhibit 3

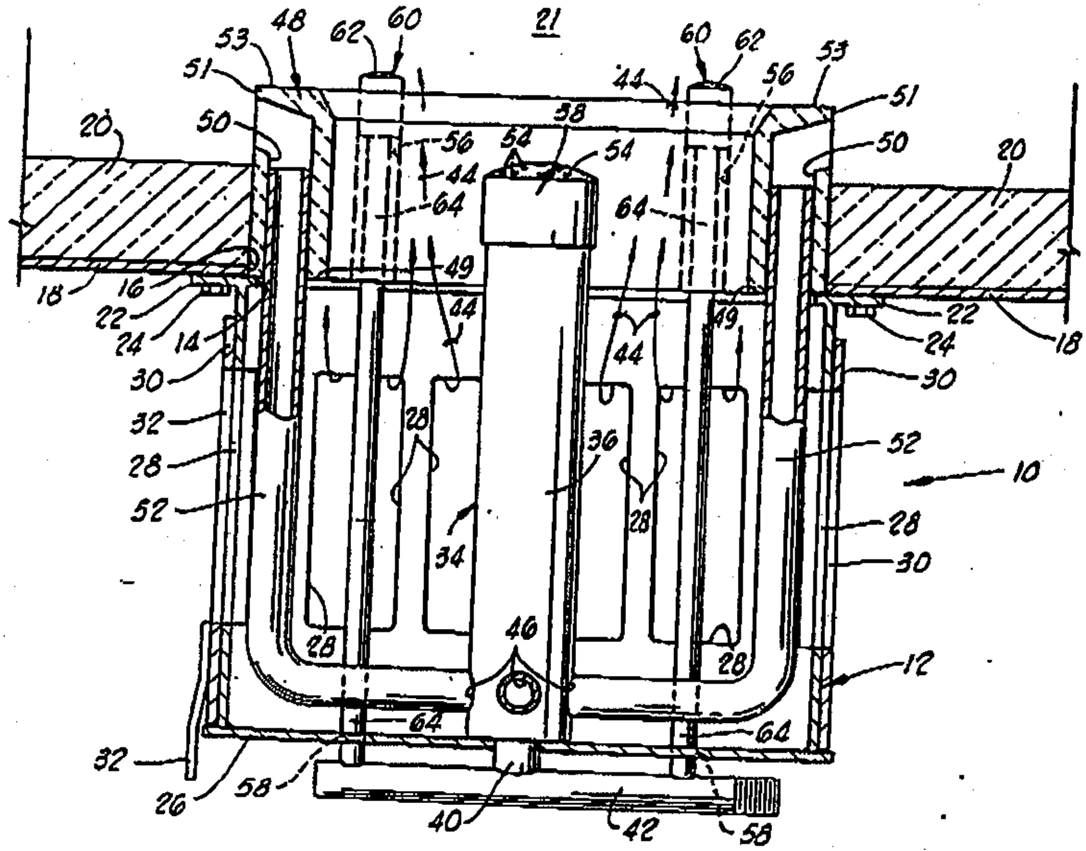


FIG. 1

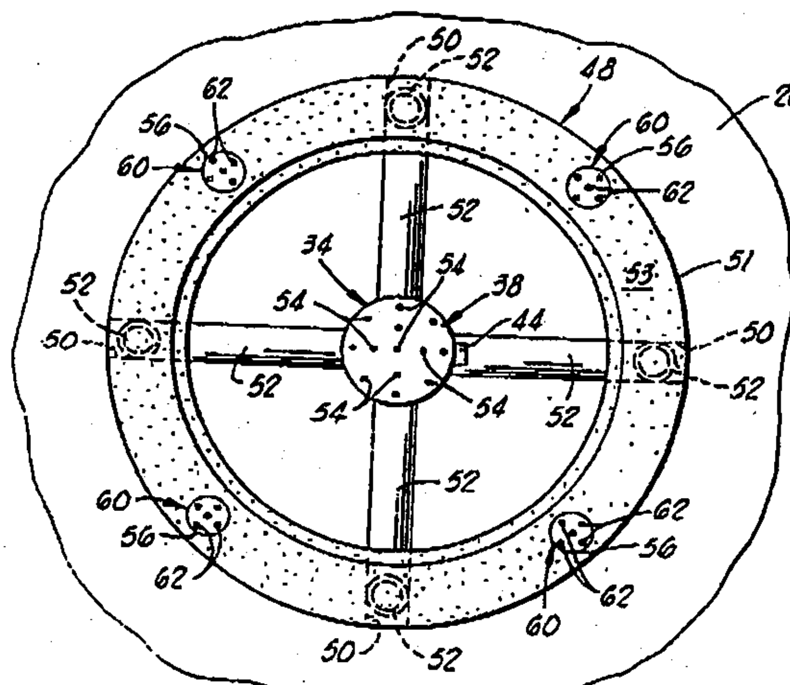


FIG. 2

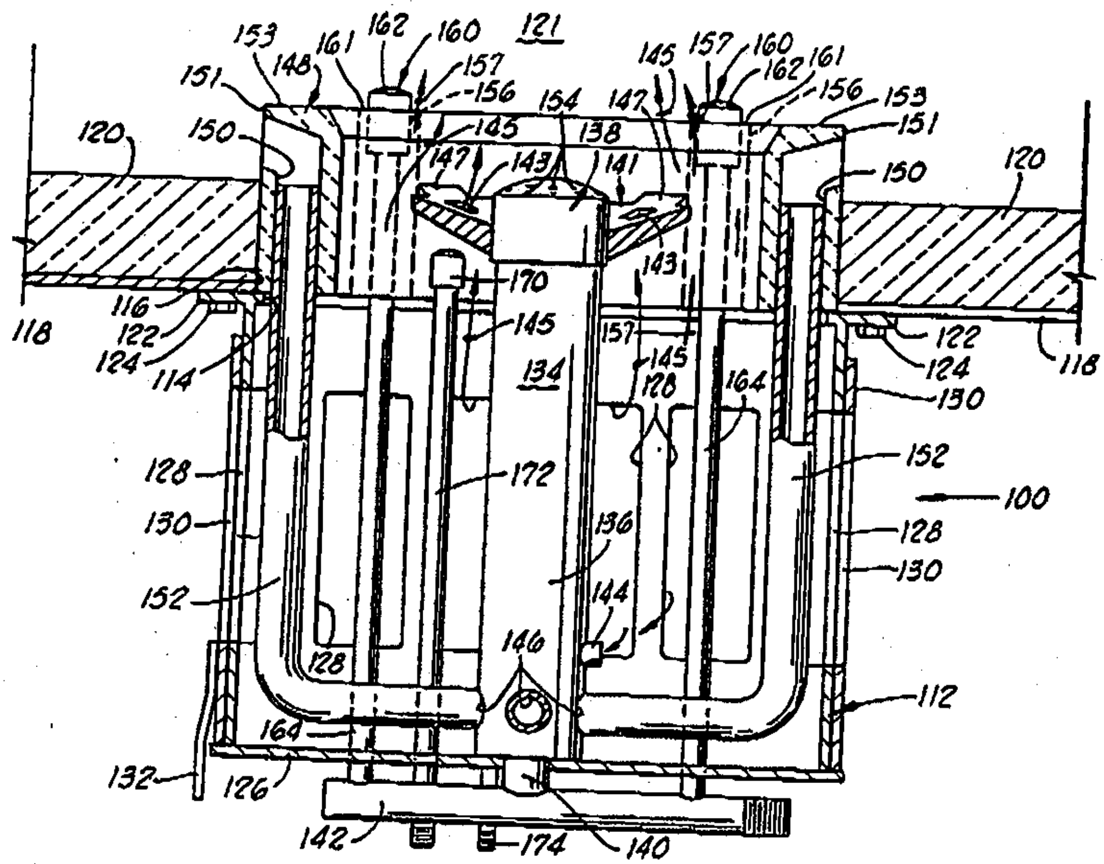
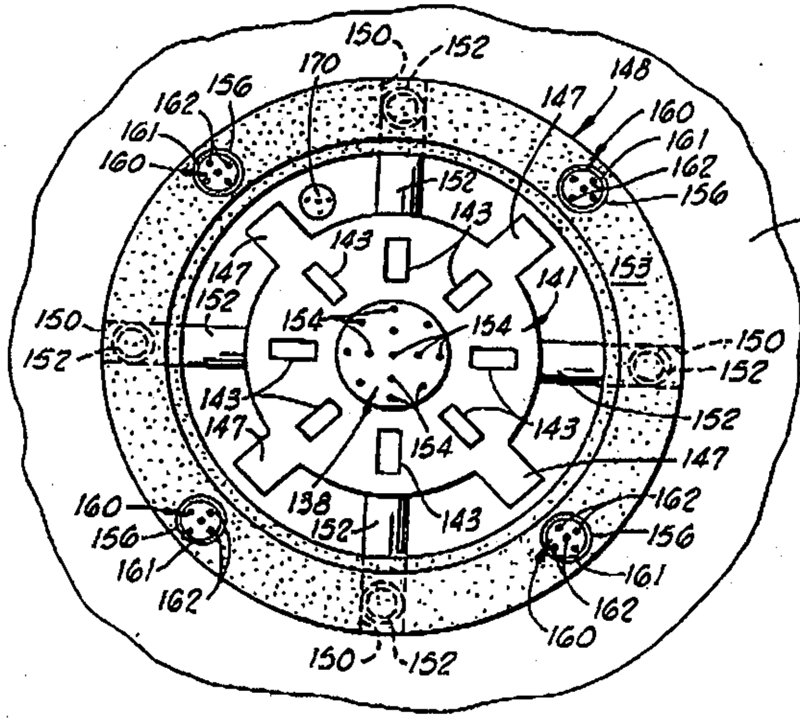


FIG. 3



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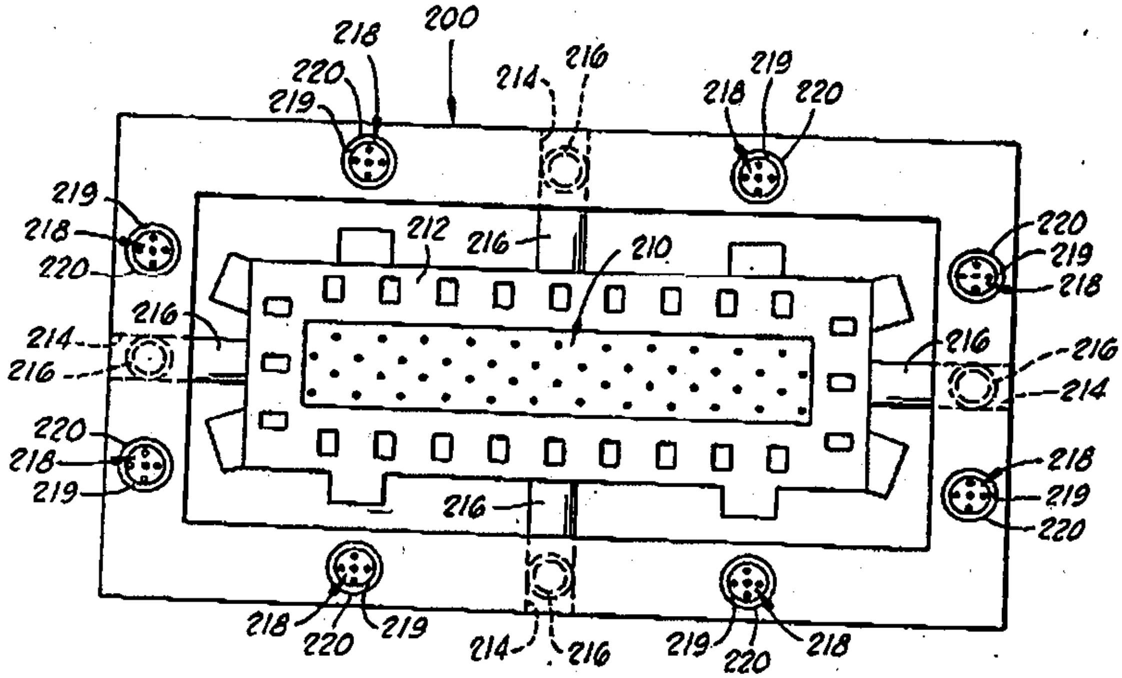
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FIG. 5

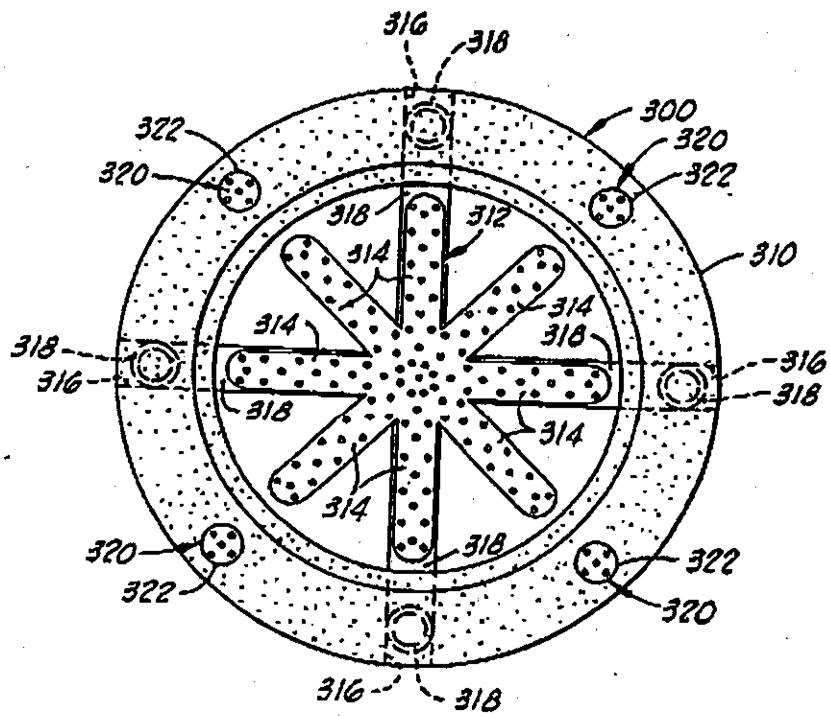
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FIG. 6

METHODS AND APPARATUS FOR BURNING FUEL WITH LOW NO_x FORMATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to methods and apparatus for burning fuel-air mixtures whereby flue gases having low NO_x content are produced.

2. Description of the Prior Art

As a result of the adoption of stringent environmental emission standards by government authorities and agencies, methods and apparatus to suppress the formation of oxides of nitrogen (NO_x) in flue gases produced by the combustion of fuel-air mixtures have been developed and used heretofore. For example, methods and apparatus wherein fuel is burned in less than a stoichiometric concentration of oxygen to intentionally produce a reducing environment to CO and H_2 have been proposed. This concept has been utilized in staged air burner apparatus wherein the fuel is burned in a deficiency of air in a first zone producing a reducing environment that suppresses NO_x formation, and then the remaining portion of air is introduced into a second zone. Methods and apparatus have also developed wherein all of the air and some of the fuel is burned in a first zone with the remaining fuel being introduced into a second zone. In this staged fuel approach, an excess of air in the first zone acts as a dilutent which lowers the temperature of the burning gases and thereby reduces the formation of NO_x. Other methods and apparatus have been developed wherein flue gases are combined with fuel-air mixtures to dilute the mixtures and thereby lower their combustion temperatures and formation of NO_x.

While the prior art methods and burner apparatus for producing flue gases having low NO_x content have achieved varying degrees of success, there still remains a need for improvement in such methods and burner apparatus whereby low NO_x content flue gases are produced and simple economical burner apparatus is utilized.

SUMMARY OF THE INVENTION

By the present invention, the above mentioned needs for improved methods of burning fuel-air mixtures and improved burner apparatus for carrying out the methods are met. That is, the present invention provides improved methods and burner apparatus for discharging mixtures of fuel and air into furnace spaces wherein the mixtures are burned and flue gases having low NO_x content are formed therefrom. The methods each basically comprise the steps of mixing a portion of the total fuel needed for the required heat release in the furnace space and flue gases from the furnace space to form a first fuel mixture. The first fuel mixture is discharged into the furnace space whereby it combines with a portion of the total air required for forming an at least substantially stoichiometric total fuel-total air mixture, and the resultant fuel-flue gases-air mixture is burned in a primary reaction zone therein. Because the fuel and air in the mixture are diluted with flue gases and, as a result, burn at a relatively low temperature, low NO_x content flue gases are formed therefrom. The remaining portion of fuel is discharged into a secondary reaction zone in the furnace space wherein it mixes with cooled flue gases contained in the furnace space and air remaining therein to form a second fuel mixture. The second fuel mixture also burns at a relatively low temperature and flue gases having low NO_x content contain a portion of the air mixed simultaneously with the fuel and flue gases, and a portion of the air can optionally be separately conducted to and discharged into the secondary reaction zone with the remaining portion of the fuel.

The improved burner apparatus of the present invention which is relatively simple and economical utilizes a primary fuel jet mixer-nozzle assembly for mixing a portion of the fuel and inspirated flue gases drawn from the furnace space and discharging the resultant first fuel mixture into a primary reaction zone in the furnace space. A portion of the air can optionally be inspirated into the primary mixer-nozzle assembly and simultaneously mixed with the first fuel mixture.

The remaining portion of the fuel is discharged into the furnace space by way of one or more secondary fuel nozzles positioned adjacent to the primary nozzle whereby the fuel enters a secondary reaction zone sequentially following the primary reaction zone. A portion of the air flows into the primary reaction zone wherein it combines with the first fuel mixture discharged from the primary mixer-nozzle assembly, and optionally, a portion of the air can be separately conducted to the location of each secondary fuel nozzle utilized whereby air is discharged along with the fuel into the secondary reaction zone.

It is, therefore, a general object of the present invention to provide an improved method and burner apparatus for discharging a mixture of fuel and air into a furnace space wherein the mixture of fuel and air into a furnace space wherein the mixture is burned and flue gases having a low NO_x content are formed therefrom.

A further object of the present invention is the provision of an improved low NO_x burner apparatus which is of simple and economical construction.

Other and further objects, features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the description of preferred embodiments which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side cross-sectional view of a burner apparatus of the present invention attached to a furnace wall.

FIG. 2 is a top plan view of the burner and furnace wall of FIG. 1.

FIG. 3 is a side cross-sectional view of an alternate embodiment of the burner apparatus of the present invention attached to a furnace wall.

FIG. 4 is a top plan view of the burner and furnace wall of FIG. 3.

FIG. 5 is a top plan view of another alternate embodiment of the burner of the present invention.

FIG. 6 is a top plan view of yet another alternate embodiment of the burner of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawings, a presently preferred embodiment of burner apparatus of the present invention is illustrated and generally designated by the numeral 10. The burner 10 includes a cylindrical housing 12 which is connected at an open end 14 thereof over a complimentary opening 16 in a furnace wall 18. As will be understood by those skilled in the art, the furnace wall 18 generally includes an internal layer of insulation material 20, and the wall 18 and insulation material 20 together with a portion of the interior of a burner tile 48 which will be described further hereinbelow define a furnace space 21 within which fuel and air are burned to form hot flue gases.

As illustrated in FIG. 1, the burner housing 12 includes an annular flange 22 at the open end 14 thereof. The flange 22 is bolted to the furnace wall 18 by a plurality of bolts 24. The opposite end of the housing 12 is closed by an end wall 26, and a plurality of air inlet openings 28 are disposed in spaced relationship around the cylindrical side of the housing 12. A cylindrical damper 30 is rotatably positioned over the cylindrical side of the housing 12 having a handle 32 attached thereto. The damper 30 includes air openings 32 which are complimentary to the air openings 28 whereby the damper 30 can be rotated, using the handle 32, between a closed position whereby the openings 28 are covered by solid portions of the damper 30, a partially open position and a fully open position whereby the openings 28 are in registration with the openings 32 as shown in FIG. 1.

Positioned co-axially within the housing 12 is a primary fuel jet mixer-discharge nozzle assembly designated by the numeral 34. The assembly 34 is comprised of an elongated fuel jet mixer 36 connected to a discharge nozzle 38. The mixer 36 attached to the end plate 26 of the housing 12 includes a pressurized fuel inlet connection (not shown) to which a conduit 40 (via an opening in the end plate 26) is connected. The conduit 40 is in turn connected to a header or conduit 42 which conducts pressurized fuel from a source thereof to the burner 10. The mixer 36 also includes four flue gases inlet connections 46 which are positioned in equally spaced relationship around the base thereof.

At the open end 14 of the housing 12 is an annular burner tile 48 formed of flame and heat resistant material. As shown in FIGS. 1 and 2, the burner tile 48 includes four passageways 50 which extend from the end 49 thereof adjacent the open end 14 of the housing 12 to the exterior side 51 thereof within the furnace 21. Connected to each of the flue gases inlet connections 46 of the mixer 36 are the ends of four conduits which are disposed within the housing 12, the other ends of which extend into the passageways 50 formed in the burner tile 48. Thus, the four conduits 52 connect the four flue gases inlet connections 46 of the primary mixer-nozzle assembly 34 to the passageways 50 in the burner tile 48. As best shown in FIG. 2, the passageways 50 with the conduits 52 extending therein are positioned in equally spaced relationship around the primary mixer-nozzle assembly 34. As will be understood, more or less than four conduits 52 and inlet connections 46 may be utilized in the burner apparatus 10 depending upon various design considerations known to those skilled in the art.

The nozzle 38 of the primary mixer-nozzle assembly 34 includes one or more orifices 54 formed therein through which, as will be described further hereinbelow, a mixture of fuel and flue gases is discharged into a primary reaction zone in the furnace space 21.

Four additional passageways 56 are disposed in the burner tile 48 extending from the end 49 thereof to the other end 53 thereof. As best shown in FIG. 2, the opening 56 are positioned in spaced relationship around the burner tile 48 between the passageways 50 therein. Disposed within the passageways 56 are four secondary fuel discharge nozzles 60. The discharge nozzles 60 each include one or more discharge orifices 62 in the external ends thereof, and are each snugly fitted within

a passageway 56. The internal ends of the nozzles 60 are connected to conduits 64 which extend through the passageways 56 of the burner tile 48, through the interior of the housing 12 and through complimentary openings 58 in the end wall 26 of the housing 12. The conduits 64 are connected to a pressurized fuel source by way of the conduit 42. As will be described further hereinbelow, the fuel nozzles 60 discharge fuel into the furnace space 21 wherein the fuel mixes with cool flue gases contained in the furnace space 21 and air remaining therein. The resulting mixture is burned is a secondary reaction zone in the furnace space 21 adjacent to and downstream from the primary reaction zone. More or less than four fuel nozzles 60 can also be utilized in the apparatus 10 based on known design considerations.

In the operation of the furnace of which the burner apparatus 10 is a part, fuel and air are discharged into the furnace space 21 and burned therein to form hot flue gases. The hot flue gases are cooled as they circulate through the furnace space 21 and lose heat prior to being vented to the atmosphere. In order to meet environmental emission standards, the flue gases must have low NO_x content.

The required flue gases low NO_x content is accomplished in accordance with the present invention by: (a) discharging into the furnace space 21 the air required for producing at least a substantially stoichiometric mixture of fuel and air therein by way of the opening 14 in the housing 12; (b) mixing, within the primary mixer-nozzle assembly 34, a portion of the total fuel needed for the required heat release within the furnace space 21 and flue gases from the furnace space 21 to thereby form a first fuel mixture, i.e., fuel diluted with flue gases; (c) discharging the first fuel mixture into the furnace space 21 by way of the orifices 54 of the nozzle 38 whereby the mixture combines with air discharged into the furnace space 21, the resulting fuel-flue gases-air mixture is burned in a primary reaction zone therein and flue gases having low NO_x content are formed therefrom; and (d) discharging the remaining portion of the fuel by way of the nozzles 60 into a secondary reaction zone which sequentially follows the primary reaction zone in the furnace space 21 whereby the fuel combines with cooled flue gases from the furnace space 21, with the products of combustion from the primary reaction zone and with air in the furnace space 21 to form a second fuel mixture which is burned in the secondary reaction zone and additional flue gases having low NO_x content are formed therefrom.

Referring to FIGS. 1 and 2, atmospheric air is introduced into the housing 12 of the burner apparatus 10 by way of the openings 28 therein and is discharged, in accordance with step (a) described above, through the open end 14 of the housing 12, through the open interior of the burner tile 48 and into the furnace space 21. As is well understood, the damper 30 is utilized to control the rate of total air introduced into the housing 12 at a level whereby at least a substantially stoichiometric mixture of total air and total fuel results in the furnace space 21.

In accordance with step (b), pressurized fuel flows by way of the conduit 40 into the primary mixer-nozzle assembly 34. The pressurized fuel, which can be fuel gas or vaporized liquid fuel, is formed into a high velocity jet as it enters the mixer 36 which causes a suction to be created at the flue gases inlet connections 46, the conduits 52 and the passageways 50. This in turn causes flue gases contained within the furnace space 21 to be drawn into the passageways 50 from the furnace space 21 and to flow by way of the conduits 52 to the mixer 36 wherein the flue gases are inspirated into and mixed with the fuel to form a first fuel mixture.

In accordance with step (c) described above, the first fuel mixture is discharged through the orifices 54 of the discharge nozzle 38 of the primary mixer-nozzle assembly 34 into a primary reaction zone adjacent thereto. Upon being discharged from the nozzle 38, the first fuel mixture combines with air flowing into the furnace space 21 by way of the open end 14 of the housing 12 and the interior of the burner tile 48 (as shown by the arrows 44), and the resultant flue gases-fuel-air mixture is burned in the primary reaction zone. Because the burning of the mixture takes place at a relatively low temperature due, at least in part, to the presence of the flue gases therein, the flue gases formed have a low NO_x content. The term "relatively low temperature" is used herein to mean a temperature that is lower than the temperature at which the same fuel-air mixture, but undiluted with fuel gases, would burn.

Generally, the portion of fuel introduced into the primary mixer-nozzle assembly 34 and contained in the first fuel mixture discharged into the primary reaction zone is an amount in the range of from about 10% to about 50% by volume of the total fuel required. The flue gases which are drawn into and mixed with the fuel in the primary mixer-nozzle assembly 34 are preferably present in an amount in the range of from about 30% to about 400% by volume of the fuel depending on the composition of the fuel and other factors. As will be understood, the fuel utilized in a burner or furnace apparatus is normally expressed as a rate, i.e., a volume of fuel per unit time. The term "% by volume" as used herein means the stated % of the rate of fuel referred to. While the rate of the air discharged into the furnace space 21 can be varied, the rate of air utilized preferably results in at least substantially stoichiometric fuel-air mixture. The term "stoichiometric fuel-air mixture" is used herein to mean a mixture in which the relative portions of fuel and air are such that when the mixture is burned to completion, no excess oxygen or fuel remains.

In accordance with step (d), the remaining portion of the fuel flows to the secondary nozzles 60 by way of the conduits 64 connected thereto and to the conduit 42. The fuel is discharged by way of the orifices 62 in the secondary nozzles 60 into the furnace space 21. That is, the portion of the fuel discharged by the secondary fuel nozzles 60 into the furnace space 21 mixes with air therein, with cooled flue gases contained within the furnace space 21 and with products of combustion, i.e., flue gases, from the primary reaction zone to form a second fuel mixture. Like the first fuel mixture, the second fuel mixture, at least in part as a result of the dilution thereof with flue gases, is burned in the secondary reaction zone at a relatively low temperature whereby the flue gases formed have a low NO_x content.

Because the secondary fuel nozzles 60 are located adjacent to and downstream from the nozzle 38 of the primary mixer-nozzle assembly 34, the secondary reaction zone in which the second fuel mixture is burned sequentially follows the primary reaction zone in which the first fuel mixture is burned. Stated another way, the primary reaction zone extends from the primary nozzle 38 into the furnace space 21 and the secondary reaction zone substantially surrounds and extends outwardly from the primary reaction zone.

Referring now to FIGS. 3 and 4, an alternate embodiment of the burner apparatus of the present invention is shown and generally designated by the numeral 100. The burner 100 includes a cylindrical housing 112 which is connected at an open end 114 over a complimentary opening 116 in a furnace wall 118. An internal layer of insulation material 120 is provided adjacent the wall 118; and the wall 118, the insulation material 120 and a portion of the interior of a burner tile 148 define a furnace space 121 within which fuel and air are burned to form hot flue gases. The burner housing 112 includes an annular flange 122 at the open end 114 thereof which is bolted to the furnace wall 118 by a plurality of bolts 124. The opposite end of the housing 112 is closed by an end wall 126, nd a plurality of air inlet openings 128 are disposed in spaced relationship around a cylindrical side of the housing 112. Like the burner apparatus 10, the apparatus 100 includes a cylindrical damper 130 rotatably positioned over the cylindrical side of the housing 112 having a handle 132 attached thereto.

A primary fuel jet mixer-discharge nozzle assembly generally designated by the numeral 134 is positioned co-axially within the housing 112. The assembly 134 is comprised of an elongated fuel jet mixture 136 connected to a discharge nozzle 138. The mixer 136 includes a pressurized fuel inlet connection to which a conduit 140 is connected. The conduit 140 is in turn connected to a source of pressurized fuel by a conduit 142. The primary mixer-nozzle assembly 134 also includes an air inlet 144, and four flue gases inlet connections 146 which are positioned in equally spaced relationship around the mixer 136.

In the embodiment illustrated in FIGS. 3 and 4, a conical shield 141 is attached to the nozzle 138 to enhance flame stability thereto. The shielding cone 141 is dish-shaped and includes a plurality of openings 143 formed therein for allowing the passage of a limited amount of air therethrough. The shielding cone 141 functions to create a protected area adjacent the nozzle 138 whereby air flowing in the direction indicated by the arrows 145 is deflected and instability of flame adjacent the nozzle 138 is reduced. The shielding cone 141 further includes tabs 147 extending therefrom towards and adjacent the secondary fuel nozzles 160 to be described further hereinbelow. The shielding tabs 147 function to enhance flame stability to the secondary fuel nozzles 160 by deflecting the flow of air in areas adjacent thereto.

An annular burner tile 148 is connected at the open end 114 of the housing 112. Like the burner tile 148 of the apparatus 10, the burner tile 148 includes four passageways 150 which extend from the inner end 149 thereof to the exterior side 151 within the furnace space 121. Connected to each of the flue gases inlet connections 146 of the mixer 136 are the ends of four conduits 152, the other ends of which extend into the passageways 150 formed in the burner tile 148. The four conduits 52 connect the four flue gases inlet connections 146 of the mixer 136 to the passageways 150 in the burner tile 148. The passageways 150 with the conduits 152 extending therein are positioned in equally spaced relationship around the primary mixer-nozzle assembly 134. The nozzle 138 of the primary mixer-nozzle assembly 134 includes one or more orifices 154 formed therein through which a fuel-air mixture diluted with flue gases is discharged into a primary reaction zone in the furnace space 121.

Four enlarged passageways 156 are disposed in the burner tile 148 extending from the inner end 149 thereof to the exterior end 153 thereof. The passageways 156 are positioned in spaced relationship around the burner tile 148 between the passageways 150 therein. Disposed within the passageways 156 are four secondary fuel discharge nozzles 160, each including one or more discharge orifices 162 in the external ends thereof. The nozzles 160 are connected by conduits 164 to the pressurized fuel conducting conduit 142. The diameters of the passageways 156 are sized with respect to the external sizes of the secondary fuel nozzles 160 such that annular air conducting conduits 161 are provided between the external surfaces of the nozzles 160 and the interiors of the passageways 156. Thus, as indicated by the arrows 157 in FIG. 3, air from within the housing 12 flows by way of the annular conduits 161 provided between the passageways 156 and the nozzles 160 into the secondary reaction zone above and adjacent to the secondary fuel nozzles 160. The particular rate of air which flows through the annular conduits 161 is controlled by the sizes of the annular conduits 161.

The fuel nozzles 160 discharge fuel into the furnace space 121 wherein the fuel mixes with the air entering the furnace space 121 by way of the annular conduits 161. As described above in connection with the burner apparatus 10, the fuel-air mixture combines with cool flue gases contained in the furnace space 121, products of combustion from the primary reaction zone and with any air remaining in the furnace space 121, and the resulting mixture is burned in a secondary reaction zone within the furnace space 121.

In order to further lower the production of NO_x within the furnace space 121, a steam injection nozzle 170 connected to a steam conduit 172 is disposed within the housing 112. Alternatively the steam can be introduced into the primary mixer nozzle assembly 134 by way of a conduit 174 connected thereto. The steam injection contributes to low NO_x production as is well known by those skilled in the art.

The operation of the apparatus 100 is similar to the operation of the apparatus 10 described above, except that a portion of the air which flows into the housing 112 by way of the openings 128 is drawn into the primary mixer-nozzle assembly 134, mixed with the fuel and flue gases therein and the resulting flue gases-fuel-air mixture is discharged into the furnace space 121 by way of the nozzle 138. In addition, a portion of the air within the housing 112 flows by way of the annular conduits 161 directly into the secondary reaction zone in the furnace space 121. More specifically, a portion of the total fuel needed for the required heat release is mixed within the primary mixer-nozzle assembly 134 with a portion of the total air required for at least the substantial stoichiometric combustion of the total fuel and with flue gases from the furnace space 21 to thereby form a first fuel-air mixture diluted with flue gases.

Generally, the portion of the total fuel which is introduced into the primary mixer-nozzle 134 and contained in the first fuel-air mixture diluted with flue gases discharged into the primary reaction zone is as amount in the range of from about 10% to about 50% by volume of the total fuel. The flue gases which dilute the first fuel-air mixture are preferably present therein in an amount in the range of from about 30% to about 400% by volume of the fuel in the fuel-air mixture depending on the composition of the fuel and other factors. The portion of the total air which is drawn into the mixer 136 by way of the air inlet 144 and which is contained in the first fuel-air mixture diluted with flue gases discharged into the furnace space 121 is an amount in the range of from about 50% to about 500% by volume of the fuel in the first fuel-air mixture depending on the composition of the fuel and other factors. As will be understood, the amounts of flue gases and air drawn into the mixer 136 are substantially set when the design of the burner apparatus 100 is finalized and the number and sizes of the various inlets, passageways, conduits, etc. are selected. However, some adjustments are normally possible.

The first fuel-air mixture diluted with flue gases is discharged into the furnace space 121 by way of the orifices 154 of the nozzle 138 whereby the mixture combines with a further portion of the total air which is discharged from the housing 112 into the furnace space 121 by way of the open end 114 of the housing 112 as illustrated by the arrows 145. The flow of air is deflected and slowed down adjacent the nozzle 138 by the shielding cone 141 to insure stability of the flame adjacent the burner 138 in the primary reaction zone. The resulting fuel-air mixture diluted with flue gases is burned in the primary reaction zone and flue are formed therein having low NO_x content as a result at least in part of the presence of the diluting flue gases causing the burning to take place at a relatively low temperature.

The remaining portion of the fuel is discharged by way of the fuel nozzles 160 into a secondary reaction zone which sequentially follows the primary reaction zone. The discharged fuel combines with the air which is separately conducted to the secondary reaction zone by way of the annular conduits 161 formed within the passageways 156 around the nozzles 160. The air mixes with the fuel, with the products of combustion from the primary reaction zone and with cooled flue gases and any air contained in the furnace space to form a second fuel-air mixture diluted with flue gases. The second diluted fuel-air mixture is burned in the secondary reaction zone at a relatively low temperature thereby forming additional flue gases having a low NO_x content.

Generally, the portion of the air which flows by way of the annular conduits 161 directly to the secondary reaction zone is an amount of air in the range of from about 10% to about 100% by volume of the fuel which is discharged into the secondary reaction zone by way of the nozzles 160.

Referring now to FIGS. 5 and 6, alternate forms of burner apparatus of the present invention are illustrated. Referring to FIG. 5, a rectangular shaped burner apparatus 200, often referred to as a flat flame burner, is illustrated. The burner apparatus 200 is generally the same design as the burner apparatus 100 described above except that it includes an elongated rectangular primary nozzle 210 with a rectangular shield 212 for providing flame stability attached thereto. Flue gases passageways 214 and conduits 216 are provided for drawing flue gases into the primary mixer-nozzle assembly, and a plurality of secondary fuel nozzles 218 are disposed in passageways 220. Air is discharged around the nozzles 218 by way of annular conduits 219 formed between the passageways 220 and nozzle 218. The passageways 214 and 220 are disposed in a rectangular burner tile 222 attached to the burner housing (not shown).

FIG. 6 illustrates another alternate form of burner apparatus of the present invention generally designated by the numeral 300. The apparatus 300 is similar to the apparatus 10 and includes a cylindrical burner tile 310 attached to a cylindrical burner housing (not shown). Instead of a circular burner nozzle with or without a flame stability shield the apparatus 300 includes a primary mixer-nozzle assembly wherein the nozzle 312 thereof includes a plurality of radially extending fingers 314. The configuration of the nozzle 312 is commonly referred to as a "spider" configuration. The apparatus 300 includes a plurality of flue gas intake passageways 316 and conduits 318 as well as a plurality of secondary fuel nozzles 320 disposed in passageways 322.

The burner apparatus 200 and 300 can include the structure and can be operated as described above in connection with the burner apparatus 10, or the burners 200 and 300 can include the structure and be operated as described above in connection with the burner 100, or various combinations of the structure and operation steps can be utilized depending upon the particular applications in which the burners are used. That is, for a particular application, a burner apparatus of the present invention may be rectangular, cylindrical or other shape, may or may not include a nozzle flame stabilizing shield, may or may not inspirate air into the primary mixer-nozzle assembly, may or may not separately conduct air directly to the secondary reaction zone or may or may not inject steam. Also, the apparatus may utilize natural air draft or forced air draft. The term "air" is used herein to mean atmospheric air, oxygen enriched atmospheric air or air which otherwise includes more or less oxygen therein than atmospheric air. The selection of a particular embodiment of the burner apparatus of this invention and its operation depends on the particular application in which the burner apparatus is used and various design considerations relating to that application which are well known to those skilled in the art.

In order to facilitate a clear understanding of the methods and apparatus of the present invention, the following examples are given.

EXAMPLE I

A burner apparatus 10 designed for a heat release of 10,000,000 BTU/hour by burning natural gas having a caloric value of 1,000 BTU/SCF is fired into the furnace space 21.

Pressurized fuel gas is supplied to the burner 10 at a pressure of about 30 PSIG and at a rate of 10,000 SCF/hour. A 30% by volume portion of the fuel (3,000 SCF/hour) flows into and through the primary mixer-nozzle assembly 34 wherein it is mixed with about 7,500 SCF/hour of flue gases (about 250% by volume of the fuel gas present in the mixture). The remaining portion of the fuel gas i.e., 7,000 SCF/hour flows from the conduit 42 to the four secondary fuel nozzles 60 from where the fuel gas is discharged into the furnace space 21. The rate of air introduced into the housing 12 is controlled by means of the damper 30 such that the total rate of air introduced into the furnace space 21 is an amount which results in at least a substantially stoichiometric total fuel-total air mixture therein.

The air flows through the open end 14 of the housing 12 into the furnace space 21 by way of the interior of the burner tile 48.

The fuel discharged from the secondary fuel nozzles 60 mixes with the remaining air, products of combustion (flue gases) from the primary reaction zone and relatively cool flue gases in the furnace space 21 to form a second combustion products and flue gases diluted fuel-air mixture which is burned in a secondary reaction zone adjacent to and surrounding the primary reaction zone in the furnace space 21.

Because of the dilution of the first and second fuel mixtures with flue gases, such mixtures burn at a relatively low temperature whereby the additional flue gases formed have a low NO_x content. That is, the mixture of flue gases withdrawn from the furnace space 21 has a NO_x content of less than about 25 ppm.

EXAMPLE II

A burner apparatus 100 designed for a heat release of 10,000,000 BTU/hour by burning natural gas having a caloric value of 1,000 BTU/SCF is fired into the furnace space 121.

Pressurized fuel-gas is supplied to the burner 100 at a pressure of about 30 PSIG and at a rate of 10,000 SCF/hour. A 30% by volume portion of the fuel (3,000 SCF/hour) flows into and through the primary mixer-nozzle assembly 34 wherein it mixes with 3,000 SCF/hour of air and about 7,500 SCF/hour of flue gases. The portion of the total air mixed with the fuel gas in the primary mixer-nozzle assembly and discharged therefrom results in a sub-stoichiometric fuel-air mixture.

The first flue gases diluted fuel-air mixture discharged from the nozzle 138 mixes with additional air flowing into the furnace space 121 by way of the open end 114 of the housing 112. The resulting mixture is burned in the primary reaction zone, and because, at least in part of the presence of flue gases, the additional flue gases produced have a low NO_x content.

The remaining portion of fuel, i.e., 7,000 SCF/hour, flows to the nozzles 160 from where the fuel gas is discharged into a secondary reaction zone within the furnace space 121. A 1,000 SCF/hour amount of air is conducted directly to the secondary reaction zone by way of the annular conduits 161. The air flows from the annular conduits 161, mixes with the fuel discharged from the nozzles 160, mixes with products of combustion (flue gases) from the primary reaction zone and mixes with relatively cool flue gas and any air contained in the furnace space 121 to form a second products of combustion and flue gases diluted fuel-air mixture which is burned in the secondary reaction zone at a relatively low temperature.

The mixture of flue gases formed in the furnace space 121 and withdrawn therefrom has a NO_x content of less than about 25 ppm.

Thus, the present invention is well adapted to carry out the objects and attain the advantages mentioned as well as those inherent therein. While presently preferred embodiments of the invention have been described for purposes of this disclosure, numerous changes in construction and in the arrangement of parts and steps will suggest themselves to those skilled in the art which are encompassed within the spirit of this invention as defined by the appended claims.

What is claimed is:

1. An improved burner apparatus for discharging a mixture of fuel and air into a furnace space wherein said mixture is burned and flue gases having low NO_x content are formed therefrom comprising:

a housing having an open end attached to said furnace space;

means for introducing a controlled quantity of air into said housing and into said furnace space attached to said housing;

primary mixer-nozzle means for mixing fuel with flue gases from said furnace space and discharging the resulting mixture into said furnace space disposed within said housing, said primary mixer-nozzle means including a pressurized fuel inlet for connection to a source of pressurized fuel and at least one flue gases inlet connection;

flue gases conduit means connected at one end to said flue gases inlet connection of said primary mixer-nozzle means, the other end extending into said furnace space whereby flue gases from within said furnace space are drawn into said conduit and conducted to said primary mixer-nozzle means thereby; and

at least one secondary fuel nozzle means attached to said housing having a pressurized fuel inlet for connection to a source of pressurized fuel for introducing additional fuel into said furnace space which mixes with flue gases and air therein, said secondary fuel nozzle means being positioned adjacent to said primary mixer-nozzle means.

2. The apparatus of claim 1 wherein said primary mixer-nozzle means is further characterized to include an air inlet connection whereby air from within said housing is mixed with said fuel and flue gases in said mixer-nozzle means and the resulting fuel-flue gases and air mixture is discharged therefrom into said furnace space.

3. The apparatus of claim 1 which is further characterized to include at least one air conduit means connected to said housing for separately conducting air from within said housing to a location adjacent said secondary fuel nozzle means.

4. The apparatus of claim 1 wherein said primary mixer-nozzle means includes a plurality of flue gases inlet connections spaced therearound and said flue gases conduit means are comprised of a plurality of flue gases conduits connected at the ends thereof to said flue gases inlet connections and positioned whereby the other ends thereof are located in spaced relationship around said primary mixer-nozzle means and connect to said furnace space.

5. The apparatus of claim 1 wherein a plurality of secondary fuel nozzle means for introducing additional fuel into said furnace space are attached to said housing and positioned in spaced relationship around said primary mixer-nozzle means.

6. The apparatus of claim 5 which is further characterized to include a plurality of air conduits attached to said housing for conducting air from within said housing to locations adjacent each of said secondary fuel nozzle means.

7. The apparatus of claim 6 wherein said primary mixer-nozzle means is positioned centrally within said burner housing and said secondary fuel nozzle means, said flue gases conduits and said air conduits are positioned around the periphery of said housing.

8. An improved burner apparatus for discharging a mixture of fuel and air into a furnace space wherein said mixture is burned and flue gases having low NO_x content are formed therefrom comprising:

a housing having an open end attached to said furnace space;

means for introducing a controlled quantity of air into said housing and into said furnace space attached to said housing;

primary mixer-nozzle means for mixing a mixture of fuel, air and flue gases and discharging said mixture into said furnace space attached centrally within said housing, said primary mixer-nozzle means including a pressurized fuel inlet for connection to a source of pressurized fuel, at least one air inlet and a plurality of flue gases inlet connections;

a plurality of flue gases conduits connected at the ends thereof to said flue gases inlet connections and being positioned whereby the other ends thereof are located in spaced relationship around said primary mixer-nozzle means and connect to said furnace space whereby flue gases from within said furnace space are drawn into said flue gases conduits and are conducted to said primary mixer-nozzle means thereby; and

a plurality of secondary fuel nozzle means attached to said housing and having pressurized fuel inlets for connection to a source of pressurized fuel for introducing additional fuel into said furnace space positioned in spaced relationship around the periphery of said housing whereby fuel introduced into said furnace space thereby mixes with air and flue gases contained within said furnace space.

9. The apparatus of claim 8 wherein said housing is cylindrical and includes a burner tile attached to the open end thereof and extending into said furnace space.

10. The apparatus of claim 8 wherein said flue gases conduits extend into said furnace space by way of passageways disposed in said burner tile.

11. The apparatus of claim 8 wherein secondary fuel nozzle means extend into said furnace space by way of passageways disposed in said burner tile.

12. The apparatus of claim 11 wherein said passageways disposed in said burner tile through which said secondary fuel nozzles extend are enlarged with respect to said nozzles thereby providing annular conduits for conducting controlled amounts of air from within said housing to locations adjacent each of said secondary fuel nozzles.

13. A method of discharging an at least substantially stoichiometric mixture of fuel and air into a furnace space wherein said mixture is burned and flue gases having low NO_x content are formed therefrom comprising the steps of:

discharging said air into said furnace space;

mixing a portion of said fuel with flue gases from said furnace space to form a first fuel mixture;

discharging said first fuel mixture into said furnace space whereby said mixture combines with air and is burned in a primary reaction zone therein and flue gases having low NO_x content are formed therefrom; and

discharging the remaining portion of said fuel into a secondary reaction zone in said furnace space whereby said fuel mixes with flue gases and air contained in said furnace space to form a second fuel mixture which is burned in said secondary reaction zone and additional flue gases having low NO_x content are formed therefrom.

14. The method of claim 13 wherein a portion of said air is mixed with said first fuel mixture prior to discharging said first fuel mixture into said furnace space.

15. The method of claim 13 wherein said secondary reaction zone sequentially follows said primary reaction zone in said furnace space.

16. The method of claim 13 wherein a portion of said air is separately conducted to said secondary reaction zone.

17. The method of claim 13 wherein said first fuel mixture is formed in a fuel jet mixer and discharged into said primary reaction zone through a primary nozzle attached to said mixer.

18. The method of claim 17 wherein said remaining portion of fuel is discharged into said secondary combustion zone by way of at least one secondary fuel nozzle positioned adjacent to said primary nozzle.

19. The method of claim 17 wherein said remaining portion of fuel is discharged into said secondary combustion zone by way of a plurality of secondary fuel nozzles positioned in spaced relationship around said primary nozzle.

20. The method of claim 13 wherein said portion of said fuel contained in said first fuel mixture is an amount in the range of from about 10% to about 50% by volume of the total fuel discharged into said furnace space, and said flue gases in said first fuel mixture are present therein in the range of about 30% to about 400% by volume of said fuel in said mixture.

21. A method of discharging an at least substantially stoichiometric mixture of fuel and air into a furnace space wherein said mixture is burned and flue gases having low NO_x content are formed therefrom comprising the steps of:

mixing a portion of said fuel with a portion of said air and flue gases from said furnace space to form a first fuel-air mixture diluted with flue gases;

discharging the remaining portion of said air into said furnace space;

discharging said diluted first fuel-air mixture into said furnace space whereby said mixture is burned in a primary reaction zone therein and flue gases having low NO_x content are formed therefrom;

discharging the remaining portion of said fuel into said secondary reaction zone wherein said remaining portion of fuel mixes with air remaining in said furnace space, with products of combustion from said primary reaction zone and with flue gases contained in said furnace space to form a second fuel-air mixture diluted with products of combustion and flue gases whereby said mixture is burned in said secondary reaction zone and additional flue gases having low NO_x content are formed therefrom.

22. The method of claim 21 wherein a portion of said air is separately conducted to said secondary reaction zone.

23. The method of claim 21 wherein said first fuel-air mixture diluted with flue gases is formed in a fuel jet mixer and discharged into said primary reaction zone through a primary nozzle attached to said mixer.

24. The method of claim 23 wherein said remaining portion of fuel is discharged into said secondary combustion zone by way of at least one secondary fuel nozzle positioned adjacent to said primary nozzle.

25. The method of claim 24 wherein said remaining portion of fuel is discharged into said secondary combustion zone by way of a plurality of secondary nozzles positioned in spaced relationship around said primary nozzle.

26. The method of claim 21 wherein said portion of fuel contained in said first fuel-air mixture diluted with flue gases is an amount in the range of from about 10% to about 50% by volume of the total fuel discharged into said furnace space, and said flue gases which dilute said first fuel-air mixture are present therein in the range of from about 30% to about 400% by volume of said fuel in said mixture.

27. The method of claim 26 wherein said portion of said air in said first fuel-air mixture is an amount in the range of from about 50% to about 500% by volume of said fuel in said mixture.

28. The method of claim 27 wherein a portion of said air is separately conducted to said secondary reaction zone.

29. The method of claim 28 wherein said portion of said air separately conducted to said secondary reaction zone is an amount in the range of from about 10% to about 100% by volume of said fuel discharged into said secondary reaction zone.

* * * * *

US005154596A

United States Patent [19]

Schwartz et al.

[11] Patent Number: 5,154,596

[45] Date of Patent: * Oct. 13, 1992

[54] METHODS AND APPARATUS FOR BURNING FUEL WITH LOW NO_x FORMATION

[75] Inventors: Robert E. Schwartz, Tulsa; Richard T. Waibel, Broken Arrow; Paul M. Rodden, Sand Springs; Samuel O. Napier, Sapulpa, all of Okla.

[73] Assignee: John Zink Company, a Division of Koch Engineering Company, Inc., Tulsa, Okla.

[*] Notice: The portion of the term of this patent subsequent to Mar. 24, 2009 has been disclaimed.

[21] Appl. No.: 836,779

[22] Filed: Feb. 13, 1992

Related U.S. Application Data

[63] Continuation of Ser. No. 578,953, Sep. 7, 1990, Pat. No. 5,098,282.

[51] Int. Cl.[5] F23M 3/00; F23C 7/00

[52] U.S. Cl. 431/9; 431/116; 431/181; 431/187

[58] Field of Search 431/9, 278, 181, 187, 431/188, 115, 116, 8, 10, 174

[56] References Cited

U.S. PATENT DOCUMENTS

3,174,526	3/1965	Von Linde	158/4
3,658,482	4/1972	Evans et al.	23/277 C
3,716,001	2/1973	Potasek et al.	110/8 A
3,794,459	2/1974	Meenan	431/5
4,004,875	1/1977	Zink et al.	431/9
4,130,388	12/1978	Flanagan	431/116
4,277,942	7/1981	Egnell et al.	60/517
4,481,889	11/1984	Sikander et al.	110/212
4,505,666	3/1985	Martin et al.	431/175
4,575,332	3/1986	Oppenberg et al.	431/9
4,645,449	2/1987	Schwartz et al.	431/8
4,699,071	10/1987	Vier et al.	110/345
4,708,638	11/1987	Brazier et al.	431/116
5,044,932	9/1991	Martin et al.	431/116

FOREIGN PATENT DOCUMENTS

89119591.9 10/1989 European Pat. Off. .

Primary Examiner—Larry Jones

Attorney, Agent, or Firm—Laney, Dougherty, Hessin & Beavers

[57] **ABSTRACT**

Improved methods and burner apparatus are provided for discharging mixtures of fuel and air into furnace spaces wherein said mixtures are burned and flue gases having low NO_x content are formed therefrom. The methods basically comprise discharging a first fuel mixture containing a portion of the fuel and flue gases from the furnace space into the furnace space whereby the mixture is burned in a primary reaction zone therein and flue gases having low NO_x content are formed therefrom, and then discharging the remaining portion of the fuel into a secondary reaction zone wherein the remaining portion of fuel mixes with air and flue gases to form a second fuel mixture which is burned in the secondary reaction zone and additional flue gases having low NO_x contents are formed therefrom.

13 Claims, 3 Drawing Sheets

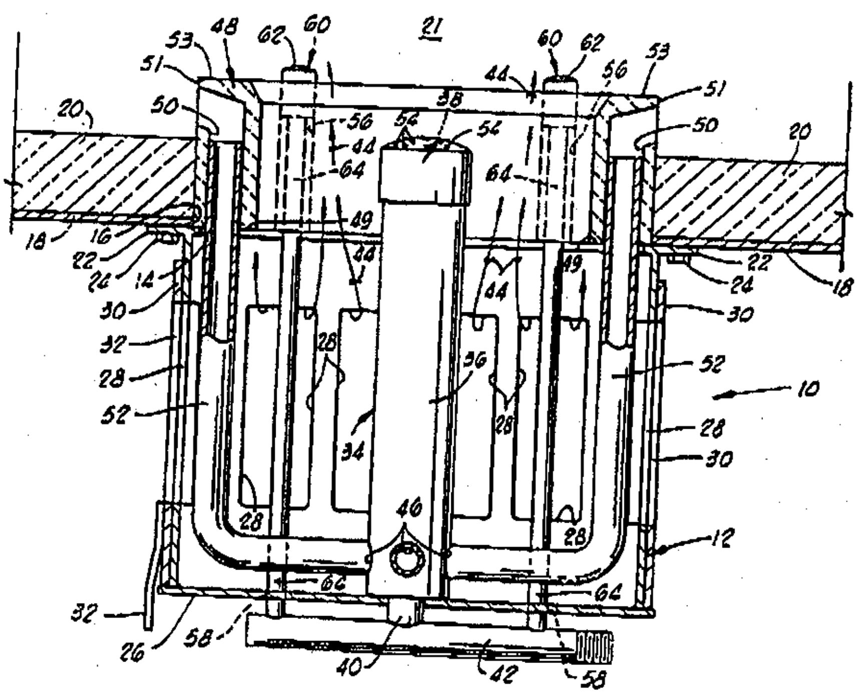

Exhibit 4

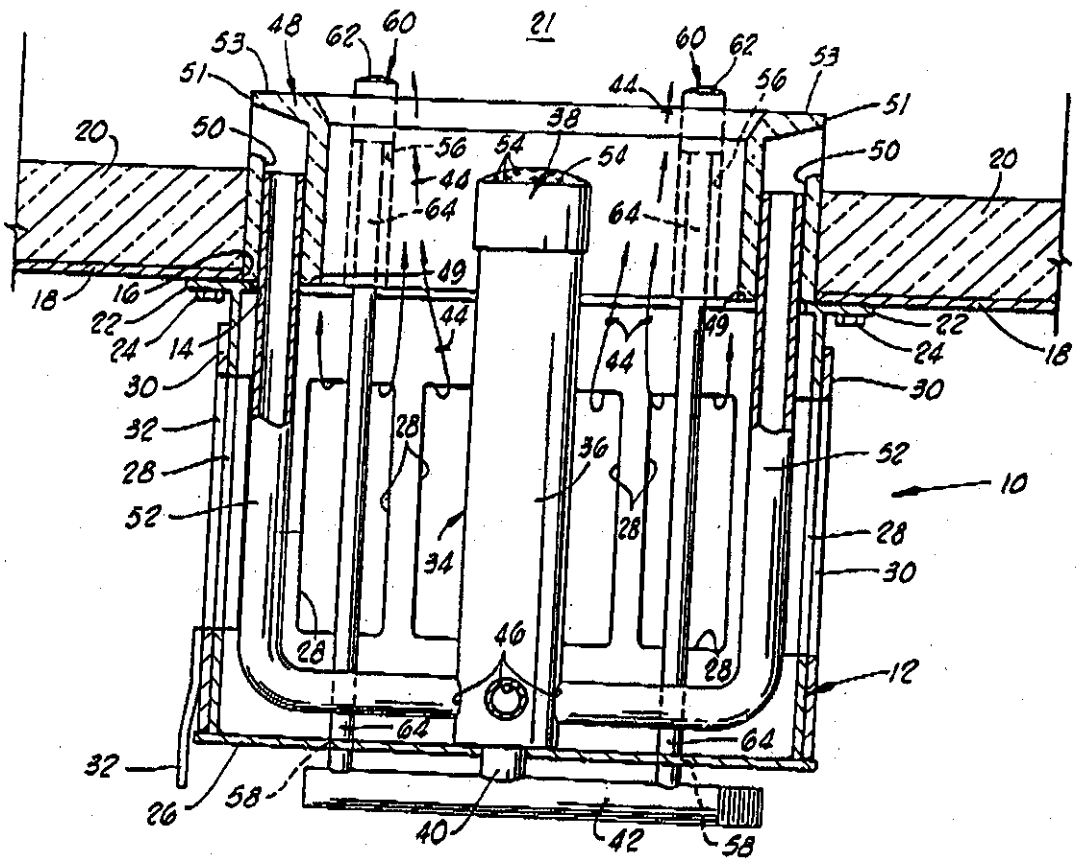

FIG. 1

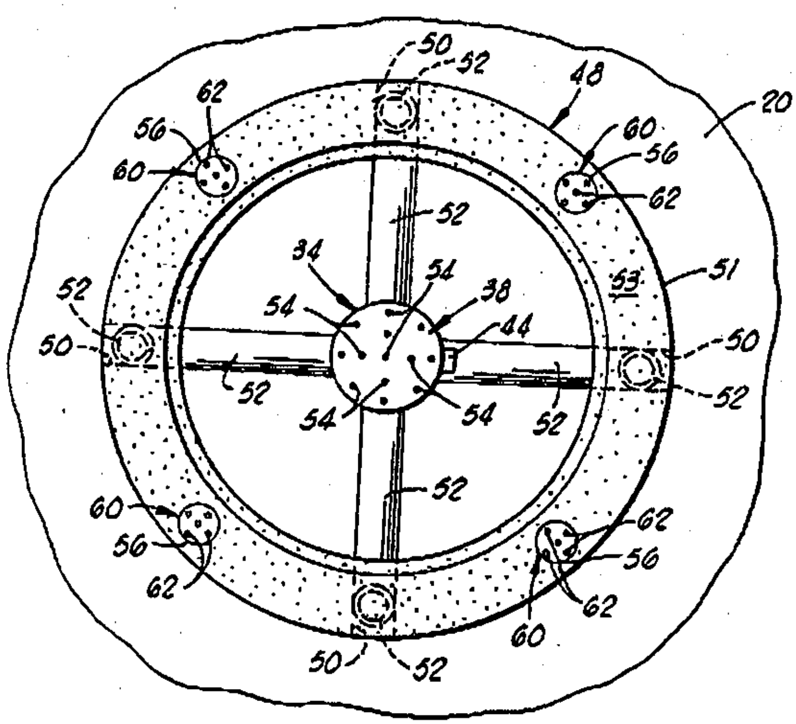

FIG. 2

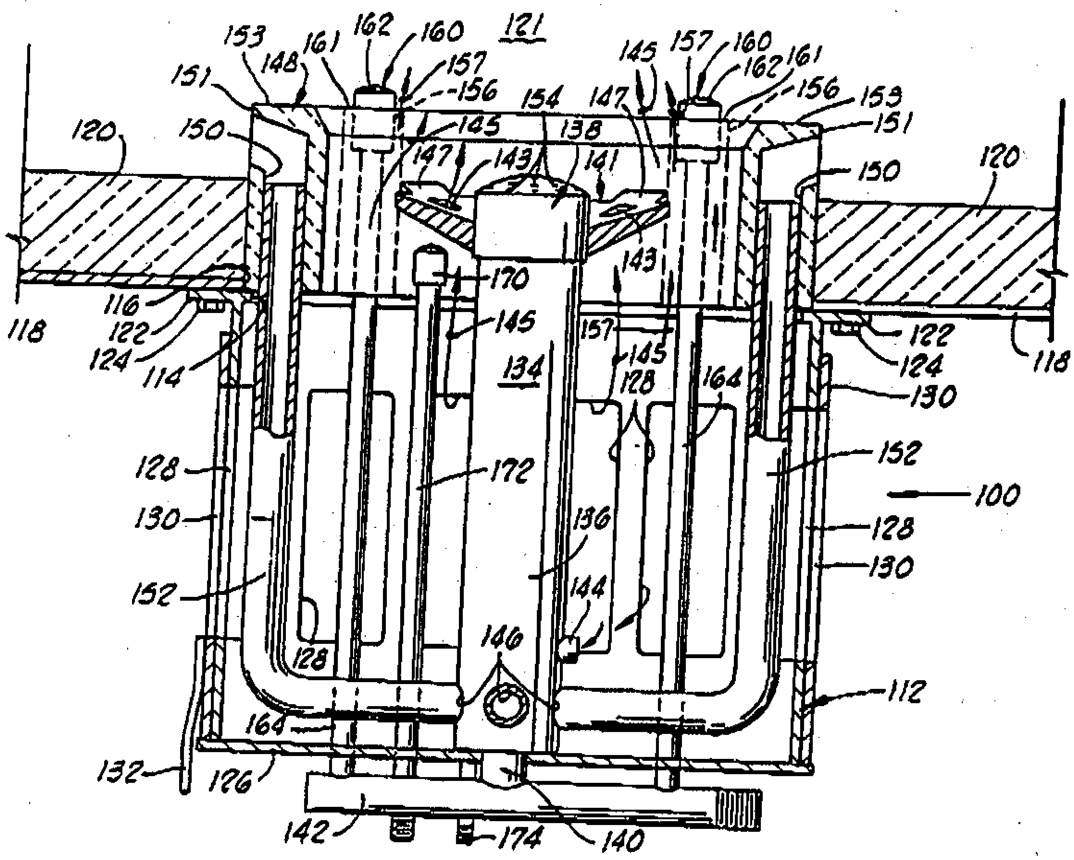
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FIG. 3

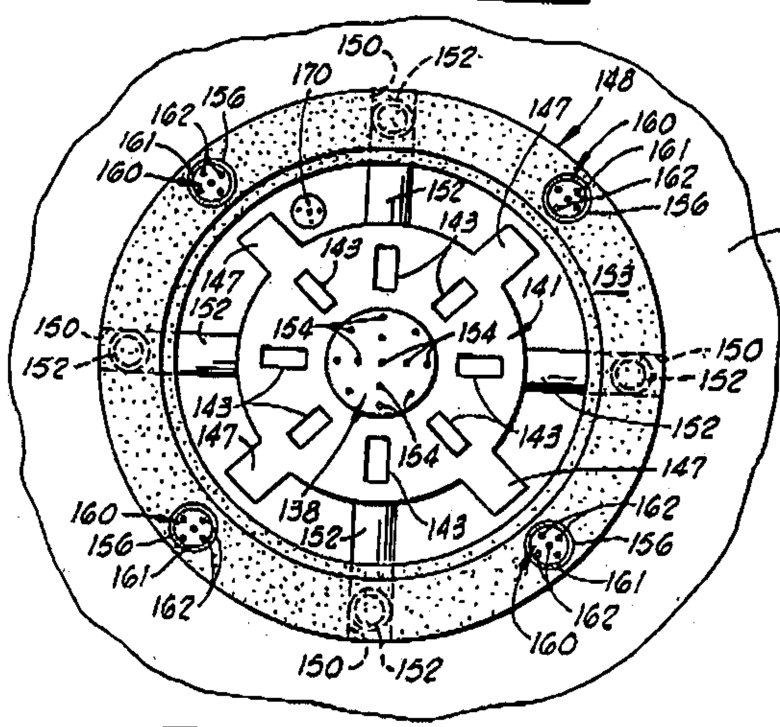
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FIG. 4

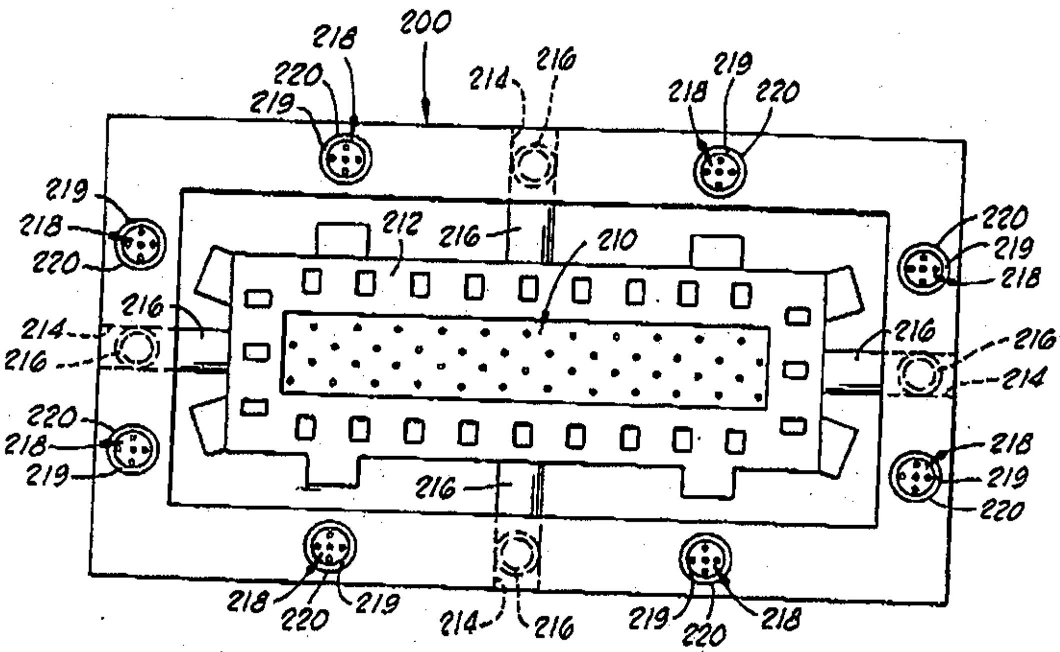
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FIG. 5

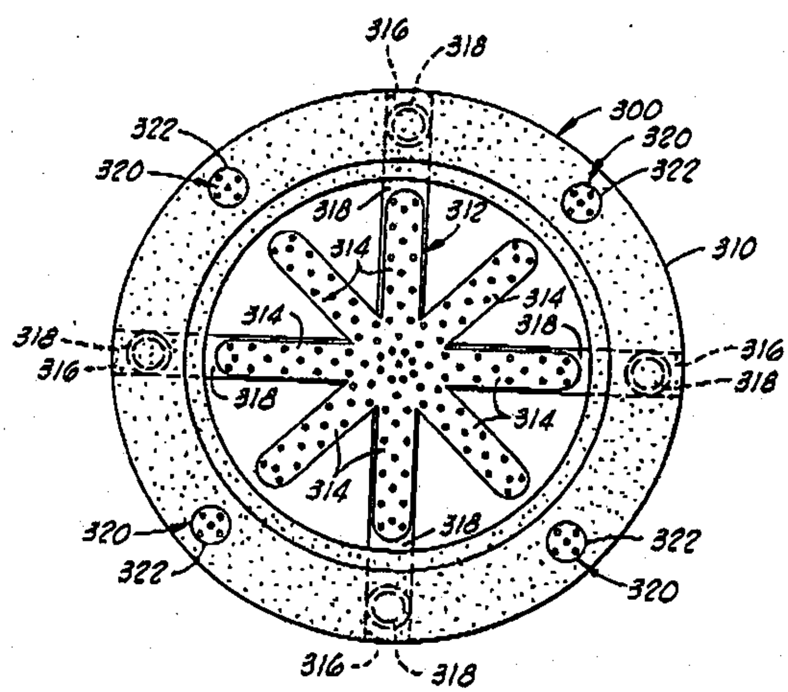
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FIG. 6

METHODS AND APPARATUS FOR BURNING FUEL WITH LOW NO_x FORMATION

This is a continuation of copending application Ser. No. 07/578,953 filed on Sep. 7, 1990, now U.S. Pat. No. 5,098,282.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to methods and apparatus for burning fuel-air mixtures whereby flue gases having low NO_x content are produced.

2. Description of the Prior Art

As a result of the adoption of stringent environmental emission standards by government authorities and agencies, methods and apparatus to suppress the formation of oxides of nitrogen (NO_x) in flue gases produced by the combination of fuel-air mixtures have been developed and used heretofore. For example, methods and apparatus wherein fuel is burned in less than a stoichiometric concentration of oxygen to intentionally produce a reducing environment of CO and H_2 have been proposed. This concept has been utilized in staged air burner apparatus wherein the fuel is burned in a deficiency of air in a first zone producing a reducing environment that suppresses NO_x formation, and then the remaining portion of air is introduced into a second zone. Methods and apparatus have also been developed wherein all of the air and some of the fuel is burned in a first zone with the remaining fuel being introduced into a second zone. In this staged fuel approach, an excess of air in the first zone acts as a diluent which lowers the temperature of the burning gases and thereby reduces the formation of NO_x. Other methods and apparatus have been developed wherein flue gases are combined with fuel-air mixtures to dilute the mixtures and thereby lower their combustion temperatures and the formation of NO_x.

While the prior art methods and burner apparatus for producing flue gases having low NO_x content have achieved varying degrees of success, there still remains a need for improvement in such methods and burner apparatus whereby low NO_x content flue gases are produced and simple economical burner apparatus is utilized.

SUMMARY OF THE INVENTION

By the present invention, the above mentioned needs for improved methods of burning fuel-air mixtures and improved burner apparatus for carrying out the methods are met. That is, the present invention provides improved methods and burner apparatus for discharging mixtures of fuel and air into furnace spaces wherein the mixtures are burned and flue gases having low NO_x content are formed therefrom. The methods each basically comprise the steps of mixing a portion of the total fuel needed for the required heat release in the furnace space and flue gases from the furnace space to form a first fuel mixture. The first fuel mixture is discharged into the furnace space whereby it combines with a portion of the total air required for forming an at least substantially stoichiometric total fuel-total air mixture, and the resultant fuel-flue gases-air mixture is burned in a primary reaction zone therein. Because the fuel and air in the mixture are diluted with flue gases and, as a result, burn at a relatively low temperature, low NO_x content flue gases are formed therefrom. The remaining portion of fuel is discharged into a secondary reaction zone in the furnace space wherein it mixes with cooled flue gases contained in the furnace space and air remaining therein to form a second fuel mixture. The second fuel mixture also burns at a relatively low temperature and flue gases having low NO_x content are formed therefrom. The first fuel mixture can optionally contain a portion of the air mixed simultaneously with the fuel and flue gases, and a portion of the air can optionally be separately conducted to and discharged into the secondary reaction zone with the remaining portion of the fuel.

The improved burner apparatus of the present invention which is relatively simple and economical utilizes a primary fuel jet mixer-nozzle assembly for mixing a portion of the fuel and inspirated flue gases drawn from the furnace space and discharging the resultant first fuel mixture into a primary reaction zone in the furnace space. A portion of the air can optionally be inspirated into the primary mixer-nozzle assembly and simultaneously mixed with the first fuel mixture.

The remaining portion of the fuel is discharged into the furnace space by way of one or more secondary fuel nozzles positioned adjacent to the primary nozzle whereby the fuel enters a secondary reaction zone sequentially following the primary reaction zone. A portion of the air flows into the primary reaction zone wherein it combines with the first fuel mixture discharged from the primary mixer-nozzle assembly, and optionally, a portion of the air can be separately conducted to the location of each secondary fuel nozzle utilized whereby air is discharged along with the fuel into the secondary reaction zone.

It is, therefore, a general object of the present invention to provide an improved method and burner apparatus for discharging a mixture of fuel and air into a furnace space wherein the mixture is burned and flue gases having a low NO_x content are formed therefrom.

A further object of the present invention is the provision of an improved low NO_x burner apparatus which is of simple and economical construction.

Other and further objects, features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the description of preferred embodiments which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side cross-sectional view of a burner apparatus of the present invention attached to a furnace wall.

FIG. 2 is a top plan view of the burner and the furnace wall of FIG. 1.

FIG. 3 is a side cross-sectional view of an alternate embodiment of the burner apparatus of the present invention attached to a furnace wall.

FIG. 4 is a top plan view of the burner and furnace wall of FIG. 3.

FIG. 5 is a top plan view of another alternate embodiment of the burner of the present invention.

FIG. 6 is a top plan view of yet another alternate embodiment of the burner of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawings, a presently preferred embodiment of burner apparatus of the present invention is illustrated and generally designated by the numeral 10. The burner 10 includes a cylindrical housing 12 which is connected at an open end 14 thereof over a complimentary opening 16 in a furnace wall 18. As will be understood by those skilled in the art, the furnace wall 18 generally includes an internal layer of insulation material 20, and the wall 18 and insulation material 20 together with a portion of the interior of a burner tile 48 which will be described further hereinbelow define a furnace space 21 within which fuel and air are burned to form hot flue gases.

As illustrated in FIG. 1, the burner housing 12 includes an annular flange 22 at the open end 14 thereof. The flange 22 is bolted to the furnace wall 18 by a plurality of bolts 24. The opposite end of the housing 12 is closed by an end wall 26, and a plurality of air inlet openings 28 are disposed in spaced relationship around the cylindrical side of the housing 12. A cylindrical damper 30 is rotatably positioned over the cylindrical side of the housing 12 having a handle 32 attached thereto. The damper 30 includes air openings 32 which are complimentary to the air openings 28 whereby the damper 30 can be rotated, using the handle 32, between a closed position whereby the openings 28 are covered by solid portions of the damper 30, a partially open position and a fully open position whereby the openings 28 are in registration with the openings 32 as shown in FIG. 1.

Positioned co-axially within the housing 12 is a primary fuel jet mixer-discharge nozzle assembly generally designated by the numeral 34. The assembly 34 is comprised of an elongated fuel jet mixer 36 connected to a discharge nozzle 38. The mixer 36 attached to the end plate 26 of the housing 12 includes a pressurized fuel inlet connection (not shown) to which a conduit 40 (via an opening in the end plate 26) is connected. The conduit 40 is in turn connected to a header or conduit 42 which conducts pressurized fuel from a source thereof to the burner 10. The mixer 36 also includes four flue gases inlet connections 46 which are positioned in equally spaced relationship around the base thereof.

At the open end 14 of the housing 12 is an annular burner tile 48 formed of flame and heat resistant material. As shown in FIGS. 1 and 2, the burner tile 48 includes four passageways 50 which extend from the end 49 thereof adjacent the open end 14 of the housing 12 to the exterior side 51 thereof within the furnace space 21. Connected to each of the flue gases inlet connections 46 of the mixer 36 are the ends of four conduits 52 which are disposed within the housing 12, the other ends of which extend into the passageways 50 formed in the burner tile 48. Thus, the four conduits 52 connect the four flue gases inlet connections 46 of the primary mixer-nozzle assembly 34 to the passageways 50 in the burner tile 48. As best shown in FIG. 2, the passageways 50 with the conduits 52 extending therein are positioned in equally spaced relationship around the primary mixer-nozzle assembly 34. As will be understood, more or less than four conduits 52 and inlet connections 46 may be utilized in the burner apparatus 10 depending upon various design considerations known to those skilled in the art.

The nozzle 38 of the primary mixer-nozzle assembly 34 includes one or more orifices 54 formed therein through which, as will be described further hereinbelow, a mixture of fuel and flue gases is discharged into a primary reaction zone in the furnace space 21.

Four additional passageways 56 are disposed in the burner tile 48 extending from the end 49 thereof to the other end 53 thereof. As best shown in FIG. 2, the openings 56 are positioned in spaced relationship around the burner tile 48 between the passageways 50 therein. Disposed within the passageways 56 are four secondary fuel discharge nozzles 60. The discharge nozzles 60 each include one or more discharge orifices 62 in the external ends thereof, and are each snugly fitted within a passageway 56. The internal ends of the nozzles 60 are connected to conduits 64 which extend through the passageways 56 of the burner tile 48, through the interior of the housing 12 and through complimentary openings 58 in the end wall 26 of the housing 12. The conduits 64 are connected to a pressurized fuel source by way of the conduit 42. As will be described further hereinbelow, the fuel nozzles 60 discharge fuel into the furnace space 21 wherein the fuel mixes with cool flue gases contained in the furnace space 21 and air remaining therein. The resulting mixture is burned in a secondary reaction zone in the furnace space 21 adjacent to and downstream from the primary reaction zone. More or less than four fuel nozzles 60 can also be utilized in the apparatus 10 based on known design considerations.

In the operation of the furnace of which the burner apparatus 10 is a part, fuel and air are discharged into the furnace space 21 and burned therein to form hot flue gases. The hot flue gases are cooled as they circulate through the furnace space 21 and lose heat prior to being vented to the atmosphere. In order to meet environmental emission standards, the flue gases must have low NO_x content.

The required flue gases low NO_x content is accomplished in accordance with the present invention by: (a) discharging into the furnace space 21 the air required for producing at least a substantially stoichiometric mixture of fuel and air therein by way of the opening 14 in the housing 12; (b) mixing, within the primary mixer-nozzle assembly 34, a portion of the total fuel needed for the required heat release within the furnace space 21 and flue gases from the furnace space 21 to thereby form a first fuel mixture, i.e., fuel diluted with flue gases; (c) discharging the first fuel mixture into the furnace space 21 by way of the orifices 54 of the nozzle 38 whereby the mixture combines with air discharged into the furnace space 21, the resulting fuel-flue gases-air mixture is burned in a primary reaction zone therein and flue gases having low NO_x content are formed therefrom; and (d) discharging the remaining portion of the fuel by way of the nozzles 60 into a secondary reaction zone which sequentially follows the primary reaction zone in the furnace space 21 whereby the fuel combines with cooled flue gases from the furnace space 21, with the products of combustion from the primary reaction zone and with air in the furnace space 21 to form a second fuel mixture which is burned in the secondary reaction zone and additional flue gases having low NO_x content are formed therefrom.

Referring to FIGS. 1 and 2, atmospheric air is introduced into the housing 12 of the burner apparatus 10 by way of the openings 28 therein and is discharged, in accordance with step (a) described above, through the open end 14 of the housing 12, through the open interior of the burner tile 48 and into the furnace space 21. As is well understood, the damper 30 is utilized to control the rate of total air introduced into the housing 12 at a level whereby at least a substantially stoichiometric mixture of total air and total fuel results in the furnace space 21.

In accordance with step (b), pressurized fuel flows by way of the conduit 40 into the primary mixer-nozzle assembly 34. The pressurized fuel, which can be fuel gas or vaporized liquid fuel, is formed into a high velocity jet as it enters the mixer 36 which causes a suction to be created at the flue gases inlet connections 46, the conduits 52 and the passageways 50. This in turn causes flue gases contained within the furnace space 21 to be drawn into the passageways 50 from the furnace space 21 and to flow by way of the conduits 52 to the mixer 36 wherein the flue gases are inspirated into and mixed with the fuel to form a first fuel mixture.

In accordance with step (c) described above, the first fuel mixture is discharged through the orifices 54 of the discharge nozzle 38 of the primary mixer-nozzle assembly 34 into a primary reaction zone adjacent thereto. Upon being discharged from the nozzle 38, the first fuel mixture combines with air flowing into the furnace space 21 by way of the open end 14 of the housing 12 and the interior of the burner tile 48 (as shown by the arrows 44), and the resultant flue gases-fuel-air mixture is burned in the primary reaction zone. Because the burning of the mixture takes place at a relatively low temperature due, at least in part, to the presence of the flue gases therein, the flue gases formed have a low NO_x content. The term "relatively low temperature" is used herein to mean a temperature that is lower than the temperature at which the same fuel-air mixture, but undiluted with fuel gases, would burn.

Generally, the portion of fuel introduced into the primary mixer-nozzle assembly 34 and contained in the first fuel mixture discharged into the primary reaction zone is an amount in the range of from about 10% to about 50% by volume of the total fuel required. The flue gases which are drawn into and mixed with the fuel in the primary mixer-nozzle assembly 34 are preferably present in an amount in the range of from about 30% to about 400% by volume of the fuel depending on the composition of the fuel and other factors. As will be understood, the fuel utilized in a burner or furnace apparatus is normally expressed as a rate, i.e., a volume of fuel per unit time. The term "% by volume" as used herein means the stated % of the rate of fuel referred to. While the rate of the air discharged into the furnace space 21 can be varied, the rate of air utilized preferably results in an at least substantially stoichiometric fuel-air mixture. The term "stoichiometric fuel-air mixture" is used herein to mean a mixture in which the relative portions of fuel and air are such that when the mixture is burned to completion, no excess oxygen or fuel remains.

In accordance with step (d), the remaining portion of the fuel flows to the secondary nozzles 60 by way of the conduits 64 connected thereto and to the conduit 42. The fuel is discharged by way of the orifices 62 in the secondary nozzles 60 into the furnace space 21. That is, the portion of the fuel discharged by the secondary fuel nozzles 60 into the furnace space 21 mixes with air therein, with cooled flue gases contained within the furnace space 21 and with products of combustion, i.e., flue gases, from the primary reaction zone to form a second fuel mixture. Like the first fuel mixture, the second fuel mixture, at least in part as a result of the dilution thereof with flue gases, is burned in the secondary reaction zone at a relatively low temperature whereby the flue gases formed have a low NO_x content.

Because the secondary fuel nozzles 60 are located adjacent to and downstream from the nozzle 38 of the primary mixer-nozzle assembly 34, the secondary reaction zone in which the second fuel mixture is burned sequentially follows the primary reaction zone in which the first fuel mixture is burned. Stated another way, the primary reaction zone extends from the primary nozzle 38 into the furnace space 21 and the secondary reaction zone substantially surrounds and extends outwardly from the primary reaction zone.

Referring now to FIGS. 3 and 4, an alternate embodiment of the burner apparatus of the present invention is shown and generally designated by the numeral 100. The burner 100 includes a cylindrical housing 112 which is connected at an open end 114 over a complimentary opening 116 in a furnace wall 118. An internal layer of insulation material 120 is provided adjacent the wall 118; and the wall 118, the insulation material 120 and a portion of the interior of a burner tile 148 define a furnace space 121 within which fuel and air are burned to form hot flue gases. The burner housing 112 includes an annular flange 122 at the open end 114 thereof which is bolted to the furnace wall 118 by a plurality of bolts 124. The opposite end of the housing 112 is closed by an end wall 126, and a plurality of air inlet openings 128 are disposed in spaced relationship around a cylindrical side of the housing 112. Like the burner apparatus 10, the apparatus 100 includes a cylindrical damper 130 rotatably positioned over the cylindrical side of the housing 112 having a handle 132 attached thereto.

A primary fuel jet mixer-discharge nozzle assembly generally designated by the numeral 134 is positioned co-axially within the housing 112. The assembly 134 is comprised of an elongated fuel jet mixture 136 connected to a discharge nozzle 138. The mixer 136 includes a pressurized fuel inlet connection to which a conduit 140 is connected. The conduit 140 is in turn connected to a source of pressurized fuel by a conduit 142. The primary mixer-nozzle assembly 134 also includes an air inlet 144, and four flue gases inlet connections 146 which are positioned in equally spaced relationship around the mixer 136.

In the embodiment illustrated in FIGS. 3 and 4, a conical shield 141 is attached to the nozzle 138 to enhance flame stability thereto. The shielding cone 141 is dish-shaped and includes a plurality of openings 143 formed therein for allowing the passage of a limited amount of air therethrough. The shielding cone 141 functions to create a protected area adjacent the nozzle 138 whereby air flowing in the direction indicated by the arrows 145 is deflected and instability of flame adjacent the nozzle 138 is reduced. The shielding cone 141 further includes tabs 147 extending therefrom towards and adjacent the secondary fuel nozzles 160 to be described further hereinbelow. The shielding tabs 147 function to enhance flame stability to the secondary fuel nozzles 160 by deflecting the flow of air in areas adjacent thereto.

An annular burner tile 148 is connected at the open end 114 of the housing 112. Like the burner tile 48 of the apparatus 10, the burner tile 148 includes four passageways 150 which extend from the inner end 149 thereof to the exterior side 151 within the furnace space 121. Connected to each of the flue gases inlet connections 146 of the mixer 136 are the ends of four conduits 152, the other ends of which extend into the passageways 150 formed in the burner tile 148. The four conduits 152 connect the four flue gases inlet connections 146 of the mixer 136 to the passageways 150 in the burner tile 148. The passageways 150 with the conduits 152 extending therein are positioned in equally spaced relationship around the primary mixer-nozzle assembly 134. The nozzle 138 of the primary mixer-nozzle assembly 134 includes one or more orifices 154 formed therein through which a fuel-air mixture diluted with flue gases is discharged into a primary reaction zone in the furnace space 121.

Four enlarged passageways 156 are disposed in the burner tile 148 extending from the inner end 149 thereof to the exterior end 153 thereof. The passageways 156 are positioned in spaced relationship around the burner tile 148 between the passageways 150 therein. Disposed within the passageways 156 are four secondary fuel discharge nozzles 160, each including one or more discharge orifices 162 in the external ends thereof. The nozzles 160 are connected by conduits 164 to the pressurized fuel conducting conduit 142. The diameters of the passageways 156 are sized with respect to the external sizes of the secondary fuel nozzles 160 such that annular air conducting conduits 161 are provided between the external surfaces of the nozzles 160 and the interiors of the passageways 156. Thus, as indicated by the arrows 157 in FIG. 3, air from within the housing 12 flows by way of the annular conduits 161 provided between the passageways 156 and the nozzles 160 into the secondary reaction zone above and adjacent to the secondary fuel nozzles 160. The particular rate of air which flows through the annular conduits 161 is controlled by the sizes of the annular conduits 161.

The fuel nozzles 160 discharge fuel into the furnace space 121 wherein the fuel mixes with the air entering the furnace space 121 by way of the annular conduits 161. As described above in connection with the burner apparatus 10, the fuel-air mixture combines with cool flue gases contained in the furnace space 121, products of combustion from the primary reaction zone and with any air remaining in the furnace space 121, and the resulting mixture is burned in a secondary reaction zone within the furnace space 121.

In order to further lower the production of NO_x within the furnace space 121, a steam injection nozzle 170 connected to a steam conduit 172 is disposed within the housing 112. Alternatively the steam can be introduced into the primary mixer nozzle assembly 134 by way of a conduit 174 connected thereto. The steam injection contributes to low NO_x production as is well known by those skilled in the art.

The operation of the apparatus 100 is similar to the operation of the apparatus 10 described above, except that a portion of the air which flows into the housing 112 by way of the openings 128 is drawn into the primary mixer-nozzle assembly 134, mixed with the fuel and flue gases therein and the resulting flue gases-fuel-air mixture is discharged into the furnace space 121 by way of the nozzle 138. In addition, a portion of the air within the housing 112 flows by way of the annular conduits 161 directly into the secondary reaction zone in the furnace space 121. More specifically, a portion of the total fuel needed for the required heat release is mixed within the primary mixer-nozzle assembly 134 with a portion of the total air required for at least the substantial stoichiometric combustion of the total fuel and with flue gases from the furnace space 21 to thereby form a first fuel-air mixture diluted with flue gases.

Generally, the portion of the total fuel which is introduced into the primary mixer-nozzle 134 and contained in the first fuel-air mixture diluted with flue gases discharged into the primary reaction zone is an amount in the range of from about 10% to about 50% by volume of the total fuel. The flue gases which dilute the first fuel-air mixture are preferably present therein in an amount in the range of from about 30% to about 400% by volume of the fuel in the fuel-air mixture depending on the composition of the fuel and other factors. The portion of the total air which is drawn into the mixer 136 by way of the air inlet 144 and which is contained in the first fuel-air mixture diluted with flue gases discharged into the furnace space 121 is an amount in the range of from about 50% to about 500% by volume of the fuel in the first fuel-air mixture depending on the composition of the fuel and other factors. As will be understood, the amounts of flue gases and air drawn into the mixer 136 are substantially set when the design of the burner apparatus 100 is finalized and the number and sizes of the various inlets, passageways, conduits, etc. are selected. However, some adjustments are normally possible.

The first fuel-air mixture diluted with flue gases is discharged into the furnace space 121 by way of the orifices 154 of the nozzle 138 whereby the mixture combines with a further portion of the total air which is discharged from the housing 112 into the furnace space 121 by way of the open end 114 of the housing 112 as illustrated by the arrows 145. The flow of air is deflected and slowed down adjacent the nozzle 138 by the shielding cone 141 to insure stability of the flame adjacent the burner 138 in the primary reaction zone. The resulting fuel-air mixture diluted with flue gases is burned in the primary reaction zone and flue gases are formed therein having low NO_x content as a result at least in part of the presence of the diluting flue gases causing the burning to take place at a relatively low temperature.

The remaining portion of the fuel is discharged by way of the fuel nozzles 160 into a secondary reaction zone which sequentially follows the primary reaction zone. The discharged fuel combines with the air which is separately conducted to the secondary reaction zone by way of the annular conduits 161 formed within the passageways 156 around the nozzles 160. The air mixes with the fuel, with the products of combustion from the primary reaction zone and with cooled flue gases and any air contained in the furnace space to form a second fuel-air mixture diluted with flue gases. The second diluted fuel-air mixture is burned in the secondary reaction zone at a relatively low temperature thereby forming additional flue gases having a low NO_x content.

Generally, the portion of the air which flows by way of the annular conduits 161 directly to the secondary reaction zone is an amount of air in the range of from about 10% to about 100% by volume of the fuel which is discharged into the secondary reaction zone by way of the nozzles 160.

Referring now to FIGS. 5 and 6, alternate forms of burner apparatus of the present invention are illustrated. Referring to FIG. 5, a rectangular shaped burner apparatus 200, often referred to as a flat flame burner, is illustrated. The burner apparatus 200 is generally the same design as the burner apparatus 100 described above except that it includes an elongated rectangular primary nozzle 210 with a rectangular shield 212 for providing flame stability attached thereto. Flue gases passageways 214 and conduits 216 are provided for drawing flue gases into the primary mixer-nozzle assembly, and a plurality of secondary fuel nozzles 218 are disposed in passageways 220. Air is discharged around the nozzles 218 by way of annular conduits 219 formed between the passageways 220 and nozzles 218. The passageways 214 and 220 are disposed in a rectangular burner tile 222 attached to the burner housing (not shown).

FIG. 6 illustrates another alternate form of burner apparatus of the present invention generally designated by the numeral 300. The apparatus 300 is similar to the apparatus 10 and includes a cylindrical burner tile 310 attached to a cylindrical burner housing (not shown). Instead of a circular burner nozzle with or without a flame stability shield the apparatus 300 includes a primary mixer-nozzle assembly wherein the nozzle 312 thereof includes a plurality of radially extending fingers 314. The configuration of the nozzle 312 is commonly referred to as a "spider" configuration. The apparatus 300 includes a plurality of flue gas intake passageways 316 and conduits 318 as well as a plurality of secondary fuel nozzles 320 disposed in passageways 322.

The burner apparatus 200 and 300 can include the structure and can be operated as described above in connection with the burner apparatus 10, or the burners 200 and 300 can include the structure and be operated as described above in connection with the burner 100, or various combinations of the structure and operation steps can be utilized depending upon the particular applications in which the burners are used. That is, for a particular application, a burner apparatus of the present invention may be rectangular, cylindrical or other shape, may or may not include a nozzle flame stabilizing shield, may or may not inspirate air into the primary mixer-nozzle assembly, may or may not separately conduct air directly to the secondary reaction zone or may or may not inject steam. Also, the apparatus may utilize natural air draft or forced air draft. The term "air" is used herein to mean atmospheric air, oxygen enriched atmospheric air or air which otherwise includes more or less oxygen therein than atmospheric air. The selection of a particular embodiment of the burner apparatus of this invention and its operation depends on the particular application in which the burner apparatus is used and various design considerations relating to that application which are well known to those skilled in the art.

In order to facilitate a clear understanding of the methods and apparatus of the present invention, the following examples are given.

EXAMPLE I

A burner apparatus 10 designed for a heat release of 10,000,000 BTU/hour by burning natural gas having a caloric value of 1,000 BTU/SCF is fired into the furnace space 21.

Pressurized fuel gas is supplied to the burner 10 at a pressure of about 30 PSIG and at a rate of 10,000 SCF/hour. A 30% by volume portion of the fuel (3,000 SCF/hour) flows into and through the primary mixer-nozzle assembly 34 wherein it is mixed with about 7,500 SCF/hour of flue gases (about 250% by volume of the fuel gas present in the mixture). The remaining portion of the fuel gas i.e., 7,000 SCF/hour flows from the conduit 42 to the four secondary fuel nozzles 60 from where the fuel gas is discharged into the furnace space 21. The rate of air introduced into the housing 12 is controlled by means of the damper 30 such that the total rate of air introduced into the furnace space 21 is an amount which results in at least a substantially stoichiometric total fuel-total air mixture therein.

The air flows through the open end 14 of the housing 12 into the furnace space 21 by way of the interior of the burner tile 48.

The fuel discharged from the secondary fuel nozzles 60 mixes with the remaining air, products of combustion (flue gases) from the primary reaction zone and relatively cool flue gases in the furnace space 21 to form a second combustion products and flue gases diluted fuel-air mixture which is burned in a secondary reaction zone adjacent to and surrounding the primary reaction zone in the furnace space 21.

Because of the dilution of the first and second fuel mixtures with flue gases, such mixtures burn at a relatively low temperature whereby the additional flue gases formed have a low NO_x content. That is, the mixture of flue gases withdrawn from the furnace space 21 has a NO_x content of less than about 25 ppm.

EXAMPLE II

A burner apparatus 100 designed for a heat release of 10,000,000 BTU/hour by burning natural gas having a caloric value of 1,000 BTU/SCF is fired into the furnace space 121.

Pressurized fuel-gas is supplied to the burner 100 at a pressure of about 30 PSIG and at a rate of 10,000 SCF/hour. A 30% by volume portion of the fuel (3,000 SCF/hour) flows into and through the primary mixer-nozzle assembly 34 wherein it mixes with 3,000 SCF/hour of air and about 7,500 SCF/hour of flue gases. The portion of the total air mixed with the fuel gas in the primary mixer-nozzle assembly and discharged therefrom results in a sub-stoichiometric fuel-air mixture.

The first flue gases diluted fuel-air mixture discharged from the nozzle 138 mixes with additional air flowing into the furnace space 121 by way of the open end 114 of the housing 112. The resulting mixture is burned in the primary reaction zone, and because, at least in part of the presence of flue gases, the additional flue gases produced have a low NO_x content.

The remaining portion of fuel, i.e., 7,000 SCF/hour, flows to the nozzles 160 from where the fuel gas is discharged into a secondary reaction zone within the furnace space 121. A 1,000 SCF/hour amount of air is conducted directly to the secondary reaction zone by way of the annular conduits 161. The air flows from the annular conduits 161, mixes with the fuel discharged from the nozzles 160, mixes with products of combustion (flue gases) from the primary reaction zone and mixes with relatively cool flue gas and any air contained in the furnace space 121 to form a second products of combustion and flue gases diluted fuel-air mixture which is burned in the secondary reaction zone at a relatively low temperature.

The mixture of flue gases formed in the furnace space 121 and withdrawn therefrom has a NO_x content of less than about 25 ppm.

Thus, the present invention is well adapted to carry out the objects and attain the advantages mentioned as well as those inherent therein. While presently preferred embodiments of the invention have been described for purposes of this disclosure, numerous changes in construction and in the arrangement of parts and steps will suggest themselves to those skilled in the art which are encompassed within the spirit of this invention as defined by the appended claims.

What is claimed is:

1. An improved burner apparatus for discharging a mixture of fuel and air into a furnace space wherein said mixture is burned and flue gases having low NO_x content are formed therefrom comprising:

a housing having an open end attached to said furnace space;

means for introducing a controlled quantity of air into said housing and into said furnace space attached to said housing;

primary mixer-nozzle means for mixing fuel with flue gases from said furnace space and discharging the resulting mixture into the open end of said housing and into said furnace space disposed within said housing, said primary mixer-nozzle means including a pressurized fuel inlet for connection to a source of pressurized fuel;

flue gases passageway means disposed in said housing extending into said furnace space whereby flue gases from within said furnace space are drawn into said passageway means and conducted to said primary mixer-nozzle means thereby; and

at least one secondary fuel nozzle means attached to said housing having a pressurized fuel inlet for connection to a source of pressurized fuel for introducing additional fuel into said furnace space which mixes with flue gases and air therein.

2. An improved burner apparatus for discharging a mixture of fuel and air into a furnace space wherein said mixture is burned and flue gases having low NO_x content are formed therefrom comprising:

a housing having an open end attached to said furnace space;

means for introducing a controlled quantity of air into said housing and into said furnace space;

fuel jet mixer means for mixing fuel with flue gases from said furnace space and discharging the resulting mixture into the open end of said housing and into a primary reaction zone in said furnace space adjacent thereto, said fuel jet mixer means being attached to said housing and including a conduit for connection to a source of pressurized fuel having a fuel gas jet forming end, and at least one flue gases passageway communicating said fuel jet forming end of said conduit with flue gases in said furnace space and with the interior of said housing whereby flue gases from within said furnace space are drawn into said passageway, mixed with fuel and discharged into said housing; and

at least one secondary fuel nozzle means attached to said housing for connection to a source of pressurized fuel and for introducing additional fuel into said furnace space.

3. The apparatus of claim 2 wherein the open end of said housing is an annular burner tile formed of flame and heat resistant material.

4. The apparatus of claim 3 wherein said flue gases passageway is at least partially comprised of a passageway disposed in said burner tile.

5. The apparatus of claim 4 wherein said secondary fuel nozzle means extends into another passageway disposed in said burner tile.

6. The apparatus of claim 5 wherein a flame stability shield having a plurality of openings therein is disposed within the interior of said annular burner tile.

7. The apparatus of claim 6 wherein said flame stability shield is dish-shaped.

8. A method of discharging an at least substantially stoichiometric mixture of fuel and air into a furnace space wherein said mixture is burned and flue gases having low NO_x content are formed therefrom comprising the steps of:

discharging said air into said furnace space;

mixing a portion of said fuel with flue gases from said furnace space to form a fuel and flue gases mixture;

discharging said fuel and flue gases mixture into said furnace space whereby said mixture combines with air and is burned in a primary reaction zone therein and flue gases having low NO_x content are formed therefrom; and

discharging the remaining portion of said fuel into a secondary reaction zone in said furnace space whereby said fuel mixes with flue gases and air contained in said furnace space and is burned in said secondary reaction zone.

9. The method of claim 8 wherein said secondary reaction zone sequentially follows said primary reaction zone in said furnace space.

10. The method of claim 8 wherein said fuel and flue gases mixture discharged and burned in said primary reaction zone is formed by a fuel jet mixer.

11. The method of claim 9 wherein said remaining portion of fuel is discharged into said secondary combustion zone by way of at least one secondary fuel nozzle.

12. The method of claim 11 wherein said remaining portion of fuel is discharged into said secondary combustion zone by way of a plurality of secondary fuel nozzles.

13. The method of claim 8 wherein said portion of said fuel contained in said fuel and flue gases mixture discharged and burned in said primary reaction zone is an amount in the range of from about 10% to about 50% by volume of the total fuel discharged into said furnace space, and said flue gases in said fuel mixture are present therein in the range of from about 30% to about 400% by volume of said fuel in said mixture.

* * * * *

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[54] METHODS AND APPARATUS FOR BURNING FUEL WITH LOW NO_x FORMATION

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[*] Notice: The portion of the term of this patent subsequent to Oct. 13, 2009 has been disclaimed.

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Related U.S. Application Data

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[51] Int. Cl.[5] F23M 3/00; F23C 7/00

[52] U.S. Cl. 431/9; 431/116; 431/174; 431/181; 431/187

[58] Field of Search 431/9, 116, 181, 187, 431/10, 174, 115, 188

[56] References Cited

U.S. PATENT DOCUMENTS

3,794,459	2/1974	Meenan	431/5
4,004,875	1/1977	Zink et al.	431/9
4,130,388	12/1978	Flanagan	431/116
4,453,913	6/1984	Gitman	431/175 X
4,505,666	3/1985	Martin et al.	431/175
4,575,332	3/1986	Oppenberg et al.	431/9
4,645,449	2/1987	Schwartz et al.	431/8
4,708,637	11/1987	Dutescu	431/116
4,708,638	11/1987	Brazier et al.	431/116
5,154,596	10/1992	Schwartz et al.	431/9

Primary Examiner—Larry Jones

Attorney, Agent, or Firm—Dougherty, Hessin, Beavers & Gilbert

[57] ABSTRACT

Improved methods and burner apparatus are provided for discharging mixtures of fuel and air into furnace spaces wherein said mixtures are burned and flue gases having low NO_x content are formed therefrom. The methods basically comprise discharging a first fuel mixture containing a portion of the fuel and flue gases from the furnace space into the furnace space whereby the mixture is burned in a primary reaction zone therein and flue gases having low NO_x content are formed therefrom, and then discharging the remaining portion of the fuel into a secondary reaction zone wherein the remaining portion of fuel mixes with air and flue gases to form a second fuel mixture which is burned in the secondary reaction zone and additional flue gases having low NO_x content are formed therefrom.

12 Claims, 3 Drawing Sheets

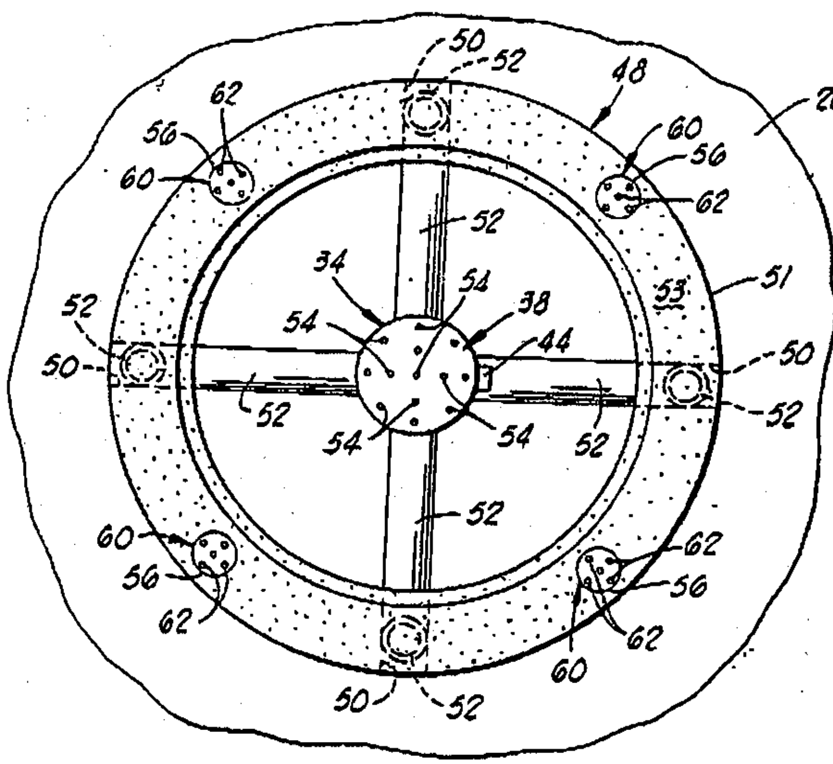

Exhibit 5

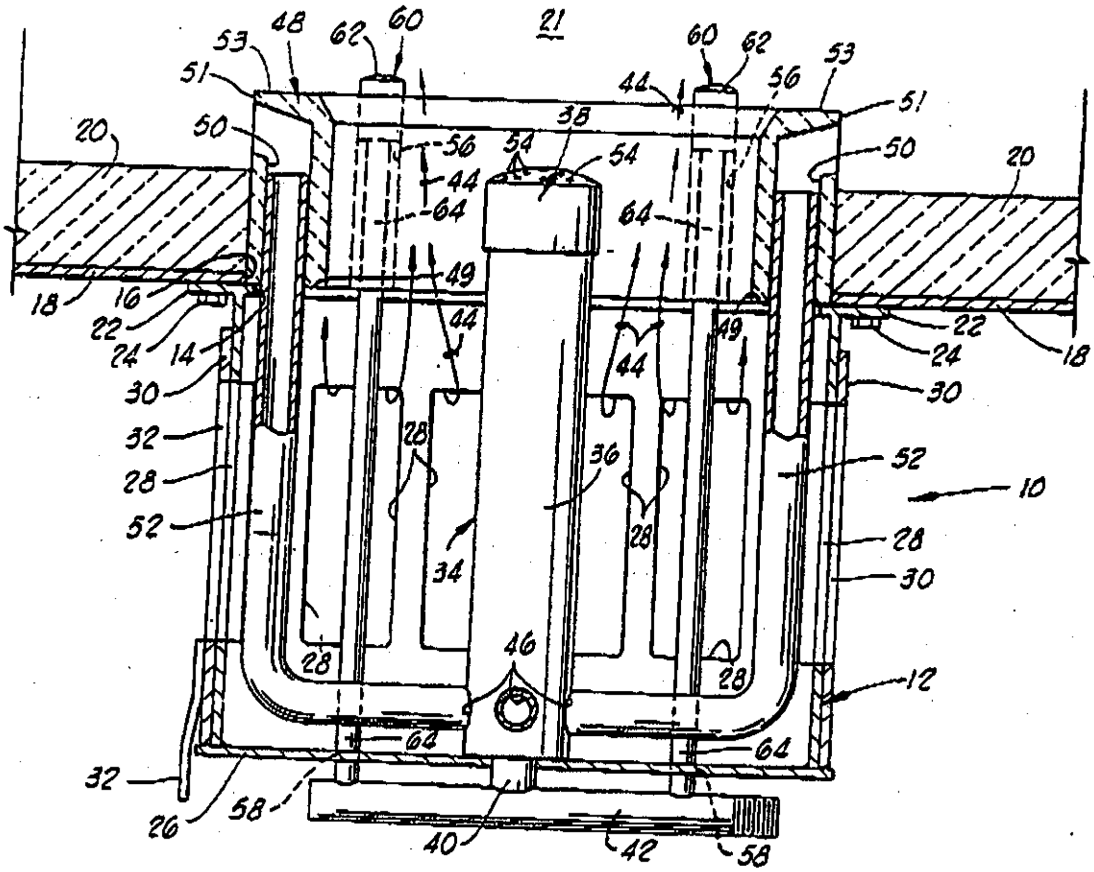

FIG. 1

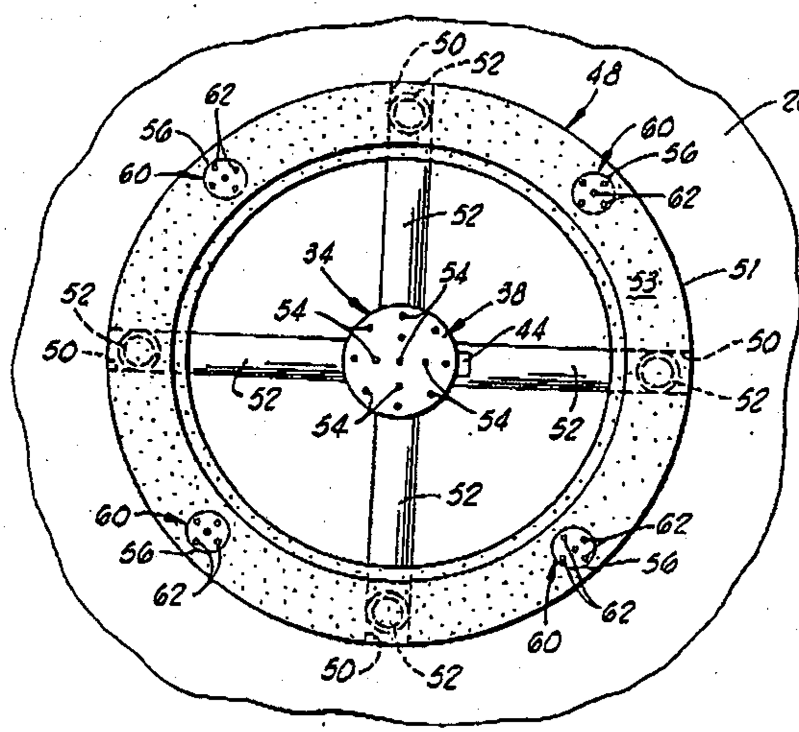

FIG. 2

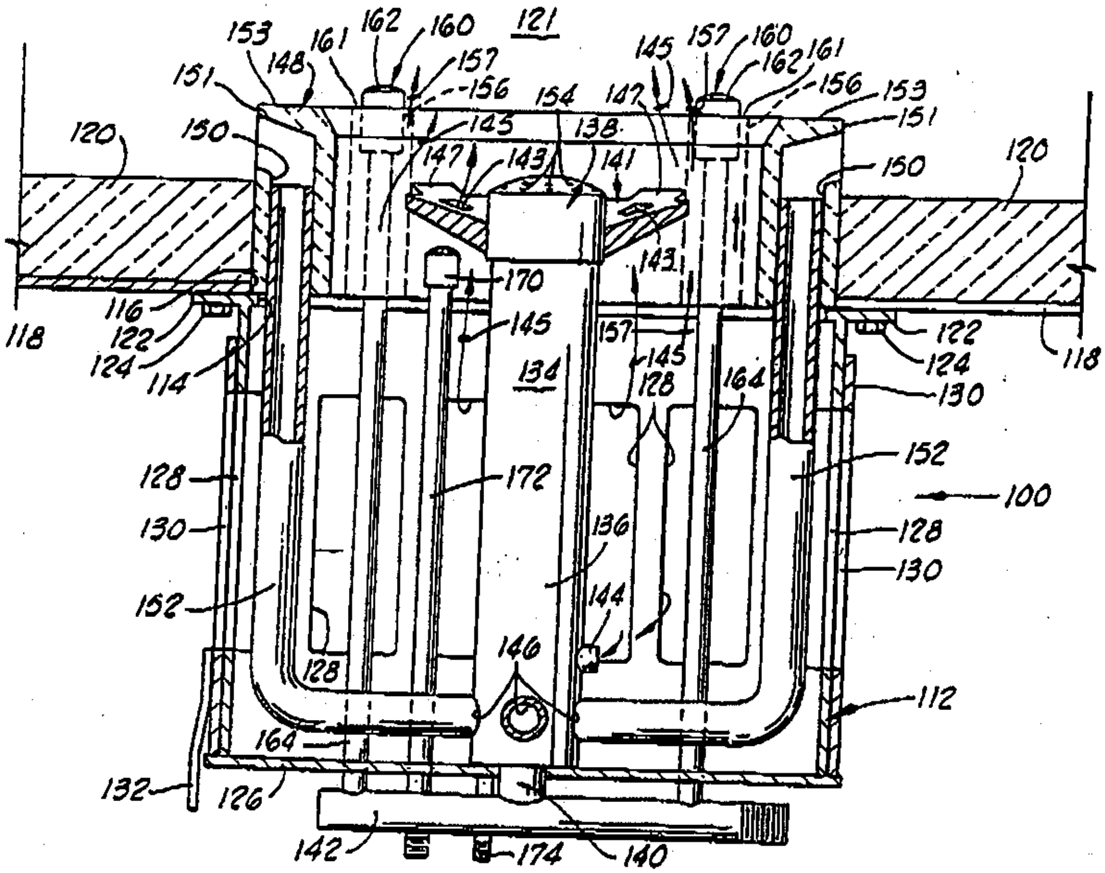

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FIG. 3

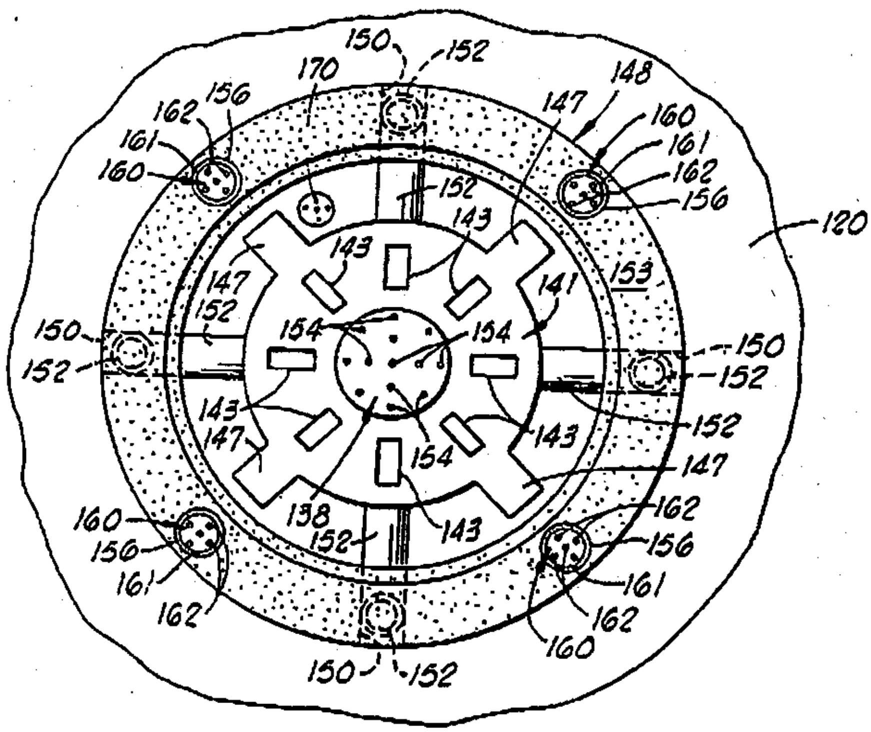

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FIG. 4

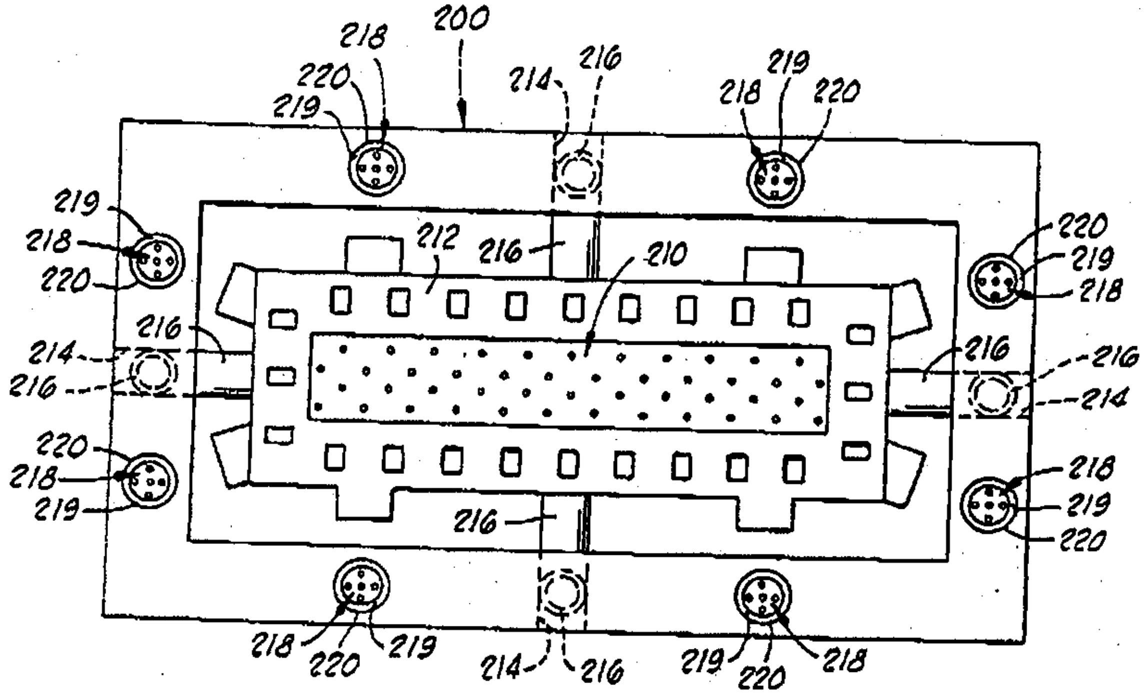

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FIG. 5

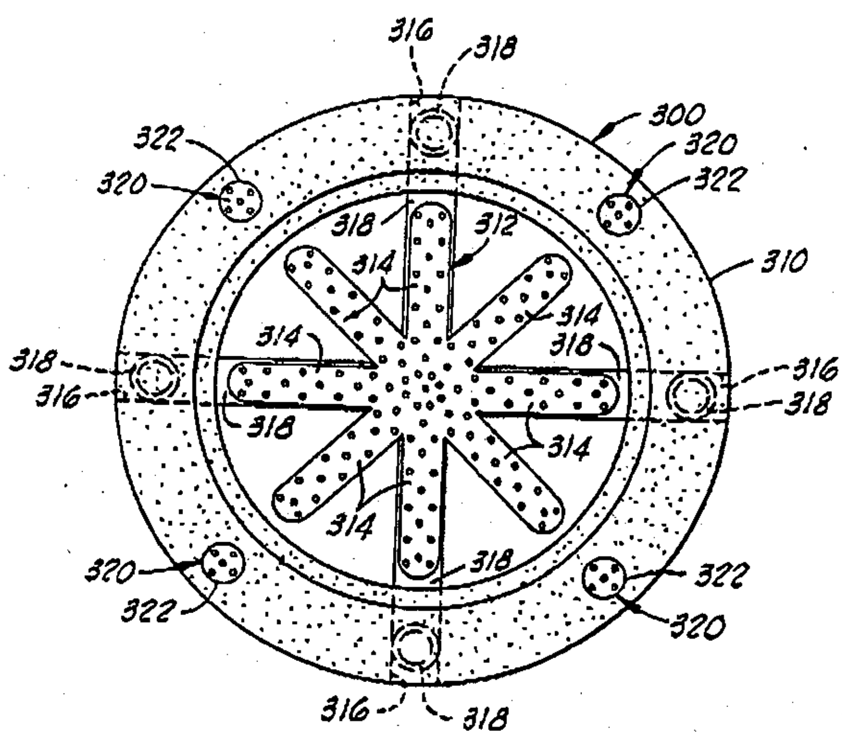

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FIG. 6

METHODS AND APPARATUS FOR BURNING FUEL WITH LOW NO_x FORMATION

This is a continuation of copending application Ser. No. 07/836,779 filed on Feb. 13, 1992 (now U.S. Pat. No. 5,154,596) which is a continuation of application Ser. No. 07/578,953 filed on Sep. 7, 1990 (now U.S. Pat. No. 5,098,282).

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to methods and apparatus for burning fuel-air mixtures whereby flue gases having low NO_x content are produced.

2. Description of the Prior Art

As a result of the adoption of stringent environmental emission standards by government authorities and agencies, methods and apparatus to suppress the formation of oxides of nitrogen (NO_x) in flue gases produced by the combustion of fuel-air mixtures have been developed and used heretofore. For example, methods and apparatus wherein fuel is burned in less than a stoichiometric concentration of oxygen to intentionally produce a reducing environment of CO and H_2 have been proposed. This concept has been utilized in staged air burner apparatus wherein the fuel is burned in a deficiency of air in a first zone producing a reducing environment that suppresses NO_x formation, and then the remaining portion of air is introduced into a second zone. Methods and apparatus have also been developed wherein all of the air and some of the fuel is burned in a first zone with the remaining fuel being introduced into a second zone. In this staged fuel approach, an excess of air in the first zone acts as a diluent which lowers the temperature of the burning gases and thereby reduces the formation of NO_x. Other methods and apparatus have been developed wherein flue gases are combined with fuel-air mixtures to dilute the mixtures and thereby lower their combustion temperatures and the formation of NO_x.

While the prior art methods and burner apparatus for producing flue gases having low NO_x content have achieved varying degrees of success, there still remains a need for improvement in such methods and burner apparatus whereby low NO_x content flue gases are produced and simple economical burner apparatus is utilized.

SUMMARY OF THE INVENTION

By the present invention, the above mentioned needs for improved methods of burning fuel-air mixtures and improved burner apparatus for carrying out the methods are met. That is, the present invention provides improved methods and burner apparatus for discharging mixtures of fuel and air into furnace spaces wherein the mixtures are burned and flue gases having low NO_x content are formed therefrom. The methods each basically comprise the steps of mixing a portion of the total fuel needed for the required heat release in the furnace space and flue gases from the furnace space to form a first fuel mixture. The first fuel mixture is discharged into the furnace space whereby it combines with a portion of the total air required for forming an at least substantially stoichiometric total fuel-total air mixture, and the resultant fuel-flue gases-air mixture is burned in a primary reaction zone therein. Because the fuel and air in the mixture are diluted with flue gases and, as a result, burn at a relatively low temperature, low NO_x content flue gases are formed therefrom. The remaining portion of fuel is discharged into a secondary reaction zone in the furnace space wherein it mixes with cooled flue gases contained in the furnace space and air remaining therein to form a second fuel mixture. The second fuel mixture also burns at a relatively low temperature and flue gases having low NO_x content are formed therefrom. The first fuel mixture can optionally contain a portion of the air mixed simultaneously with the fuel and flue gases, and a portion of the air can optionally be separately conducted to and discharged into the secondary reaction zone with the remaining portion of the fuel.

The improved burner apparatus of the present invention which is relatively simple and economical utilizes a primary fuel jet mixer-nozzle assembly for mixing a portion of the fuel and inspirated flue gases drawn from the furnace space and discharging the resultant first fuel mixture into a primary reaction zone in the furnace space. A portion of the air can optionally be inspirated into the primary mixer-nozzle assembly and simultaneously mixed with the first fuel mixture.

The remaining portion of the fuel is discharged into the furnace space by way of one or more secondary fuel nozzles positioned adjacent to the primary nozzle whereby the fuel enters a secondary reaction zone sequentially following the primary reaction zone. A portion of the air flows into the primary reaction zone wherein it combines with the first fuel mixture discharged from the primary mixer-nozzle assembly, and optionally, a portion of the air can be separately conducted to the location of each secondary fuel nozzle utilized whereby air is discharged along with the fuel into the secondary reaction zone.

It is, therefore, a general object of the present invention to provide an improved method and burner apparatus for discharging a mixture of fuel and air into a furnace space wherein the mixture is burned and flue gases having a low NO_x content are formed therefrom.

A further object of the present invention is the provision of an improved low NO_x burner apparatus which is of simple and economical construction.

Other and further objects, features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the description of preferred embodiments which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side cross-sectional view of a burner apparatus of the present invention attached to a furnace wall.

FIG. 2 is a top plan view of the burner and the furnace wall of FIG. 1.

FIG. 3 is a side cross-sectional view of an alternate embodiment of the burner apparatus of the present invention attached to a furnace wall.

FIG. 4 is a top plan view of the burner and furnace wall of FIG. 3.

FIG. 5 is a top plan view of another alternate embodiment of the burner of the present invention.

FIG. 6 is a top plan view of yet another alternate embodiment of the burner of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawings, a presently preferred embodiment of burner apparatus of the present invention is illustrated and generally designated by the numeral 10. The burner 10 includes a cylindrical housing 12 which is connected at an open end 14 thereof over a complimentary opening 16 in a furnace wall 18. As will be understood by those skilled in the art, the furnace wall 18 generally includes an internal layer of insulation material 20, and the wall 18 and insulation material 20 together with a portion of the interior of a burner tile 48 which will be described further hereinbelow define a furnace space 21 within which fuel and air are burned to form hot flue gases.

As illustrated in FIG. 1, the burner housing 12 includes an annular flange 22 at the open end 14 thereof. The flange 22 is bolted to the furnace wall 18 by a plurality of bolts 24. The opposite end of the housing 12 is closed by an end wall 26, and a plurality of air inlet openings 28 are disposed in spaced relationship around the cylindrical side of the housing 12. A cylindrical damper 30 is rotatably positioned over the cylindrical side of the housing 12 having a handle 32 attached thereto. The damper 30 includes air openings 32 which are complimentary to the air openings 28 whereby the damper 30 can be rotated, using the handle 32, between a closed position whereby the openings 28 are covered by solid portions of the damper 30, a partially open position and a fully open position whereby the openings 28 are in registration with the openings 32 as shown in FIG. 1.

Positioned co-axially within the housing 12 is a primary fuel jet mixer-discharge nozzle assembly generally designated by the numeral 34. The assembly 34 is comprised of an elongated fuel jet mixer 36 connected to a discharge nozzle 38. The mixer 36 attached to the end plate 26 of the housing 12 includes a pressurized fuel inlet connection (not shown) to which a conduit 40 (via an opening in the end plate 26) is connected. The conduit 40 is in turn connected to a header or conduit 42 which conducts pressurized fuel from a source thereof to the burner 10. The mixer 36 also includes four flue gases inlet connections 46 which are positioned in equally spaced relationship around the base thereof.

At the open end 14 of the housing 12 is an annular burner tile 48 formed of flame and heat resistant material. As shown in FIGS. 1 and 2, the burner tile 48 includes four passageways 50 which extend from the end 49 thereof adjacent the open end 14 of the housing 12 to the exterior side 51 thereof within the furnace space 21. Connected to each of the flue gases inlet connections 46 of the mixer 36 are the ends of four conduits 52 which are disposed within the housing 12, the other ends of which extend into the passageways 50 formed in the burner tile 48. Thus, the four conduits 52 connect the four flue gases inlet connections 46 of the primary mixer-nozzle assembly 34 to the passageways 50 in the burner tile 48. As best shown in FIG. 2, the passageways 50 with the conduits 52 extending therein are positioned in equally spaced relationship around the primary mixer-nozzle assembly 34. As will be understood, more or less than four conduits 52 and inlet connections 46 may be utilized in the burner apparatus 10 depending upon various design considerations known to those skilled in the art.

The nozzle 38 of the primary mixer-nozzle assembly 34 includes one or more orifices 54 formed therein through which, as will be described further hereinbelow, a mixture of fuel and flue gases is discharged into a primary reaction zone in the furnace space 21.

Four additional passageways 56 are disposed in the burner tile 48 extending from the end 49 thereof to the other end 53 thereof. As best shown in FIG. 2, the openings 56 are positioned in spaced relationship around the burner tile 48 between the passageways 50 therein. Disposed within the passageways 56 are four secondary fuel discharge nozzles 60. The discharge nozzles 60 each include one or more discharge orifices 62 in the external ends thereof, and are each snugly fitted within a passageway 56. The internal ends of the nozzles 60 are connected to conduits 64 which extend through the passageways 56 of the burner tile 48, through the interior of the housing 12 and through complimentary openings 58 in the end wall 26 of the housing 12. The conduits 64 are connected to a pressurized fuel source by way of the conduit 42. As will be described further hereinbelow, the fuel nozzles 60 discharge fuel into the furnace space 21 wherein the fuel mixes with cool flue gases contained in the furnace space 21 and air remaining therein. The resulting mixture is burned in a secondary reaction zone in the furnace space 21 adjacent to and downstream from the primary reaction zone. More or less than four fuel nozzles 60 can also be utilized in the apparatus 10 based on known design considerations.

In the operation of the furnace of which the burner apparatus 10 is a part, fuel and air are discharged into the furnace space 21 and burned therein to form hot flue gases. The hot flue gases are cooled as they circulate through the furnace space 21 and lose heat prior to being vented to the atmosphere. In order to meet environmental emission standards, the flue gases must have low NO_x content.

The required flue gases low NO_x content is accomplished in accordance with the present invention by: (a) discharging into the furnace space 21 the air required for producing at least a substantially stoichiometric mixture of fuel and air therein by way of the opening 14 in the housing 12; (b) mixing, within the primary mixer-nozzle assembly 34, a portion of the total fuel needed for the required heat release within the furnace space 21 and flue gases from the furnace space 21 to thereby form a first fuel mixture, i.e., fuel diluted with flue gases; (c) discharging the first fuel mixture into the furnace space 21 by way of the orifices 54 of the nozzle 38 whereby the mixture combines with air discharged into the furnace space 21, the resulting fuel-flue gases-air mixture is burned in a primary reaction zone therein and flue gases having low NO_x content are formed therefrom; and (d) discharging the remaining portion of the fuel by way of the nozzles 60 into a secondary reaction zone which sequentially follows the primary reaction zone in the furnace space 21 whereby the fuel combines with cooled flue gases from the furnace space 21, with the products of combustion from the primary reaction zone and with air in the furnace space 21 to form a second fuel mixture which is burned in the secondary reaction zone and additional flue gases having low NO_x content are formed therefrom.

Referring to FIGS. 1 and 2, atmospheric air is introduced into the housing 12 of the burner apparatus 10 by way of the openings 28 therein and is discharged, in accordance with step (a) described above, through the open end 14 of the housing 12, through the open interior of the burner tile 48 and into the furnace space 21. As is well understood, the damper 30 is utilized to control the rate of total air introduced into the housing 12 at a level whereby at least a substantially stoichiometric mixture of total air and total fuel results in the furnace space 21.

In accordance with step (b), pressurized fuel flows by way of the conduit 40 into the primary mixer-nozzle assembly 34. The pressurized fuel, which can be fuel gas or vaporized liquid fuel, is formed into a high velocity jet as it enters the mixer 36 which causes a suction to be created at the flue gases inlet connections 46, the conduits 52 and the passageways 50. This in turn causes flue gases contained within the furnace space 21 to be drawn into the passageways 50 from the furnace space 21 and to flow by way of the conduits 52 to the mixer 36 wherein the flue gases are inspirated into and mixed with the fuel to form a first fuel mixture.

In accordance with step (c) described above, the first fuel mixture is discharged through the orifices 54 of the discharge nozzle 38 of the primary mixer-nozzle assembly 34 into a primary reaction zone adjacent thereto. Upon being discharged from the nozzle 38, the first fuel mixture combines with air flowing into the furnace space 21 by way of the open end 14 of the housing 12 and the interior of the burner tile 48 (as shown by the arrows 44), and the resultant flue gases-fuel-air mixture is burned in the primary reaction zone. Because the burning of the mixture takes place at a relatively low temperature due, at least in part, to the presence of the flue gases therein, the flue gases formed have a low NO_x content. The term "relatively low temperature" is used herein to mean a temperature that is lower than the temperature at which the same fuel-air mixture, but undiluted with fuel gases, would burn.

Generally, the portion of fuel introduced into the primary mixer-nozzle assembly 34 and contained in the first fuel mixture discharged into the primary reaction zone is an amount in the range of from about 10% to about 50% by volume of the total fuel required. The flue gases which are drawn into and mixed with the fuel in the primary mixer-nozzle assembly 34 are preferably present in an amount in the range of from about 30% to about 400% by volume of the fuel depending on the composition of the fuel and other factors. As will be understood, the fuel utilized in a burner or furnace apparatus is normally expressed as a rate, i.e., a volume of fuel per unit time. The term "% by volume" as used herein means the stated % of the rate of fuel referred to. While the rate of the air discharged into the furnace space 21 can be varied, the rate of air utilized preferably results in an at least substantially stoichiometric fuel-air mixture. The term "stoichiometric fuel-air mixture" is used herein to mean a mixture in which the relative portions of fuel and air are such that when the mixture is burned to completion, no excess oxygen or fuel remains.

In accordance with step (d), the remaining portion of the fuel flows to the secondary nozzles 60 by way of the conduits 64 connected thereto and to the conduit 42. The fuel is discharged by way of the orifices 62 in the secondary nozzles 60 into the furnace space 21. That is, the portion of the fuel discharged by the secondary fuel nozzles 60 into the furnace space 21 mixes with air therein, with cooled flue gases contained within the furnace space 21 and with products of combustion, i.e., flue gases, from the primary reaction zone to form a second fuel mixture. Like the first fuel mixture, the second fuel mixture, at least in part as a result of the dilution thereof with flue gases, is burned in the secondary reaction zone at a relatively low temperature whereby the flue gases formed have a low NO_x content.

Because the secondary fuel nozzles 60 are located adjacent to and downstream from the nozzle 38 of the primary mixer-nozzle assembly 34, the secondary reaction zone in which the second fuel mixture is burned sequentially follows the primary reaction zone in which the first fuel mixture is burned. Stated another way, the primary reaction zone extends from the primary nozzle 38 into the furnace space 21 and the secondary reaction zone substantially surrounds and extends outwardly from the primary reaction zone.

Referring now to FIGS. 3 and 4, an alternate embodiment of the burner apparatus of the present invention is shown and generally designated by the numeral 100. The burner 100 includes a cylindrical housing 112 which is connected at an open end 114 over a complimentary opening 116 in a furnace wall 118. An internal layer of insulation material 120 is provided adjacent the wall 118; and the wall 118, the insulation material 120 and a portion of the interior of a burner tile 148 define a furnace space 121 within which fuel and air are burned to form hot flue gases. The burner housing 112 includes an annular flange 122 at the open end 114 thereof which is bolted to the furnace wall 118 by a plurality of bolts 124. The opposite end of the housing 112 is closed by an end wall 126, and a plurality of air inlet openings 128 are disposed in spaced relationship around a cylindrical side of the housing 112. Like the burner apparatus 10, the apparatus 100 includes a cylindrical damper 130 rotatably positioned over the cylindrical side of the housing 112 having a handle 132 attached thereto.

A primary fuel jet mixer-discharge nozzle assembly generally designated by the numeral 134 is positioned co-axially within the housing 112. The assembly 134 is comprised of an elongated fuel jet mixture 136 connected to a discharge nozzle 138. The mixer 136 includes a pressurized fuel inlet connection to which a conduit 140 is connected. The conduit 140 is in turn connected to a source of pressurized fuel by a conduit 142. The primary mixer-nozzle assembly 134 also includes an air inlet 144, and four flue gases inlet connections 146 which are positioned in equally spaced relationship around the mixer 136.

In the embodiment illustrated in FIGS. 3 and 4, a conical shield 141 is attached to the nozzle 138 to enhance flame stability thereto. The shielding cone 141 is dish-shaped and includes a plurality of openings 143 formed therein for allowing the passage of a limited amount of air therethrough. The shielding cone 141 functions to create a protected area adjacent the nozzle 138 whereby air flowing in the direction indicated by the arrows 145 is deflected and instability of flame adjacent the nozzle 138 is reduced. The shielding cone 141 further includes tabs 147 extending therefrom towards and adjacent the secondary fuel nozzles 160 to be described further hereinbelow. The shielding tabs 147 function to enhance flame stability to the secondary fuel nozzles 160 by deflecting the flow of air in areas adjacent thereto.

An annular burner tile 148 is connected at the open end 114 of the housing 112. Like the burner tile 48 of the apparatus 10, the burner tile 148 includes four passageways 150 which extend from the inner end 149 thereof to the exterior side 151 within the furnace space 121. Connected to each of the flue gases inlet connections 146 of the mixer 136 are the ends of four conduits 152, the other ends of which extend into the passageways 150 formed in the burner tile 148. The four conduits 152 connect the four flue gases inlet connections 146 of the mixer 136 to the passageways 150 in the burner tile 148.

The passageways 150 with the conduits 152 extending therein are positioned in equally spaced relationship around the primary mixer-nozzle assembly 134. The nozzle 138 of the primary mixer-nozzle assembly 134 includes one or more orifices 154 formed therein through which a fuel-air mixture diluted with flue gases is discharged into a primary reaction zone in the furnace space 121.

Four enlarged passageways 156 are disposed in the burner tile 148 extending from the inner end 149 thereof to the exterior end 153 thereof. The passageways 156 are positioned in spaced relationship around the burner tile 148 between the passageways 150 therein. Disposed within the passageways 156 are four secondary fuel discharge nozzles 160, each including one or more discharge orifices 162 in the external ends thereof. The nozzles 160 are connected by conduits 164 to the pressurized fuel conducting conduit 142. The diameters of the passageways 156 are sized with respect to the external sizes of the secondary fuel nozzles 160 such that annular air conducting conduits 161 are provided between the external surfaces of the nozzles 160 and the interiors of the passageways 156. Thus, as indicated by the arrows 157 in FIG. 3, air from within the housing 12 flows by way of the annular conduits 161 provided between the passageways 156 and the nozzles 160 into the secondary reaction zone above and adjacent to the secondary fuel nozzles 160. The particular rate of air which flows through the annular conduits 161 is controlled by the sizes of the annular conduits 161.

The fuel nozzles 160 discharge fuel into the furnace space 121 wherein the fuel mixes with the air entering the furnace space 121 by way of the annular conduits 161. As described above in connection with the burner apparatus 10, the fuel-air mixture combines with cool flue gases contained in the furnace space 121, products of combustion from the primary reaction zone and with any air remaining in the furnace space 121, and the resulting mixture is burned in a secondary reaction zone within the furnace space 121.

In order to further lower the production of NO_x within the furnace space 121, a steam injection nozzle 170 connected to a steam conduit 172 is disposed within the housing 112. Alternatively the steam can be introduced into the primary mixer nozzle assembly 134 by way of a conduit 174 connected thereto. The steam injection contributes to low NO_x production as is well known by those skilled in the art.

The operation of the apparatus 100 is similar to the operation of the apparatus 10 described above, except that a portion of the air which flows into the housing 112 by way of the openings 128 is drawn into the primary-nozzle assembly 134, mixed with the fuel and flue gases therein and the resulting flue gases-fuel-air mixture is discharged into the furnace space 121 by way of the nozzle 138. In addition, a portion of the air within the housing 112 flows by way of the annular conduits 161 directly into the secondary reaction zone in the furnace space 121. More specifically, a portion of the total fuel needed for the required heat release is mixed within the primary mixer-nozzle assembly 134 with a portion of the total air required for at least the substantial stoichiometric combustion of the total fuel and with flue gases from the furnace space 21 to thereby form a first fuel-air mixture diluted with flue gases.

Generally, the portion of the total fuel which is introduced into the primary mixer-nozzle 134 and contained in the first fuel-air mixture diluted with flue gases discharged into the primary reaction zone is an amount in the range of from about 10% to about 50% by volume of the total fuel. The flue gases which dilute the first fuel-air mixture are preferably present therein in an amount in the range of from about 30% to about 400% by volume of the fuel in the fuel-air mixture depending on the composition of the fuel and other factors. The portion of the total air which is drawn into the mixer 136 by way of the air inlet 144 and which is contained in the first fuel-air mixture diluted with flue gases discharged into the furnace space 121 is an amount in the range of from about 50% to about 500% by volume of the fuel in the first fuel-air mixture depending on the composition of the fuel and other factors. As will be understood, the amounts of flue gases and air drawn into the mixer 136 are substantially set when the design of the burner apparatus 100 is finalized and the number and sizes of the various inlets, passageways, conduits, etc. are selected. However, some adjustments are normally possible.

The first fuel-air mixture diluted with flue gases is discharged into the furnace space 121 by way of the orifices 154 of the nozzle 138 whereby the mixture combines with a further portion of the total air which is discharged from the housing 112 into the furnace space 121 by way of the open end 114 of the housing 112 as illustrated by the arrows 145. The flow of air is deflected and slowed down adjacent the nozzle 138 by the shielding cone 141 to insure stability of the flame adjacent the burner 138 in the primary reaction zone. The resulting fuel-air mixture diluted with flue gases is burned in the primary reaction zone and flue gases are formed therein having low NO_x content as a result at least in part of the presence of the diluting flue gases causing the burning to take place at a relatively low temperature.

The remaining portion of the fuel is discharged by way of the fuel nozzles 160 into a secondary reaction zone which sequentially follows the primary reaction zone. The discharged fuel combines with the air which is separately conducted to the secondary reaction zone by way of the annular conduits 161 formed within the passageways 156 around the nozzles 160. The air mixes with the fuel, with the products of combustion from the primary reaction zone and with cooled flue gases and any air contained in the furnace space to form a second fuel-air mixture diluted with flue gases. The second diluted fuel-air mixture is burned in the secondary reaction zone at a relatively low temperature thereby forming additional flue gases having a low NO_x content.

Generally, the portion of the air which flows by way of the annular conduits 161 directly to the secondary reaction zone is an amount of air in the range of from about 10% to about 100% by volume of the fuel which is discharged into the secondary reaction zone by way of the nozzles 160.

Referring now to FIGS. 5 and 6, alternate forms of burner apparatus of the present invention are illustrated. Referring to FIG. 5, a rectangular shaped burner apparatus 200, often referred to as a flat flame burner, is illustrated. The burner apparatus 200 is generally the same design as the burner apparatus 100 described above except that it includes an elongated rectangular primary nozzle 210 with a rectangular shield 212 for providing flame stability attached thereto. Flue gases passageways 214 and conduits 216 are provided for drawing flue gases into the primary mixer-nozzle assembly, and a plurality of secondary fuel nozzles 218 are disposed in passageways 220. Air is discharged around the nozzles 218 by way of annular conduits 219 formed between the passageways 220 and nozzles 218. The passageways 214 and 220 are disposed in a rectangular burner tile 222 attached to the burner housing (not shown).

FIG. 6 illustrates another alternate form of burner apparatus of the present invention generally designated by the numeral 300. The apparatus 300 is similar to the apparatus 10 and includes a cylindrical burner tile 310 attached to a cylindrical burner housing (not shown). Instead of a circular burner nozzle with or without a flame stability shield the apparatus 300 includes a primary mixer-nozzle assembly wherein the nozzle 312 thereof includes a plurality of radially extending fingers 314. The configuration of the nozzle 312 is commonly referred to as a "spider" configuration. The apparatus 300 includes a plurality of flue gas intake passageways 316 and conduits 318 as well as a plurality of secondary field nozzles 320 disposed in passageways 322.

The burner apparatus 200 and 300 can include the structure and can be operated as described above in connection with the burner apparatus 10, or the burners 200 and 300 can include the structure and be operated as described above in connection with the burner 100, or various combinations of the structure and operation steps can be utilized depending upon the particular applications in which the burners are used. That is, for a particular application, a burner apparatus of the present invention may be rectangular, cylindrical or other shape, may or may not include a nozzle flame stabilizing shield, may or may not inspirate air into the primary mixer-nozzle assembly, may or may not separately conduct air directly to the secondary reaction zone or may or may not inject steam. Also, the apparatus may utilize natural air draft or forced air draft. The term "air" is used herein to mean atmospheric air, oxygen enriched atmospheric air or air which otherwise includes more or less oxygen therein than atmospheric air. The selection of a particular embodiment of the burner apparatus of this invention and its operation depends on the particular application in which the burner apparatus is used and various design considerations relating to that application which are well known to those skilled in the art.

In order to facilitate a clear understanding of the methods and apparatus of the present invention, the following examples are given.

EXAMPLE I

A burner apparatus 10 designed for a heat release of 10,000,000 BTU/hour by burning natural gas having a caloric value of 1,000 BTU/SCF is fired into the furnace space 21.

Pressurized fuel gas is supplied to the burner 10 at a pressure of about 30 PSIG and at a rate of 10,000 SCF/hour. A 30% by volume portion of the fuel (3,000 SCF/hour) flows into and through the primary mixer-nozzle assembly 34 wherein it is mixed with about 7,500 SCF/hour of flue gases (about 250% by volume of the fuel gas present in the mixture). The remaining portion of the fuel gas i.e., 7,000 SCF/hour flows from the conduit 42 to the four secondary fuel nozzles 60 from where the fuel gas is discharged into the furnace space 21. The rate of air introduced into the housing 12 is controlled by means of the damper 30 such that the total rate of air introduced into the furnace space 21 is an amount which results in at least a substantially stoichiometric total fuel-total air mixture therein.

The air flows through the open end 14 of the housing 12 into the furnace space 21 by way of the interior of the burner tile 48.

The fuel discharged from the secondary fuel nozzles 60 mixes with the remaining air, products of combustion (flue gases) from the primary reaction zone and relatively cool flue gases in the furnace space 21 to form a second combustion products and flue gases diluted fuel-air mixture which is burned in a secondary reaction zone adjacent to and surrounding the primary reaction zone in the furnace space 21.

Because of the dilution of the first and second fuel mixtures with flue gases, such mixtures burn at a relatively low temperature whereby the additional flue gases formed have a low NO_x content. That is, the mixture of flue gases withdrawn from the furnace space 21 has a NO_x content of less than about 25 ppm.

EXAMPLE II

A burner apparatus 100 designed for a heat release of 10,000,000 BTU/hour by burning natural gas having a caloric value of 1,000 BTU/SCF is fired into the furnace space 121.

Pressurized fuel-gas is supplied to the burner 100 at a pressure of about 30 PSIG and at a rate of 10,000 SCF/hour. A 30% by volume portion of the fuel (3,000 SCF/hour) flows into and through the primary mixer-nozzle assembly 34 wherein it mixes with 3,000 SCF/hour of air and about 7,500 SCF/hour of flue gases. The portion of the total air mixed with the fuel gas in the primary mixer-nozzle assembly and discharged therefrom results in a sub-stoichiometric fuel-air mixture.

The first flue gases diluted fuel-air mixture discharged from the nozzle 138 mixes with additional air flowing into the furnace space 121 by way of the open end 114 of the housing 112. The resulting mixture is burned in the primary reaction zone, and because, at least in part of the presence of flue gases, the additional flue gases produced have a low NO_x content.

The remaining portion of fuel, i.e., 7,000 SCF/hour, flows to the nozzles 160 from where the fuel gas is discharged into a secondary reaction zone within the furnace space 121. A 1,000 SCF/hour amount of air is conducted directly to the secondary reaction zone by way of the annular conduits 161. The air flows from the annular conduits 161, mixes with the fuel discharged from the nozzles 160, mixes with products of combustion (flue gases) from the primary reaction zone and mixes with relatively cool flue gas and any air contained in the furnace space 121 to form a second products of combustion and flue gases diluted fuel-air mixture which is burned in the secondary reaction zone at a relatively low temperature.

The mixture of flue gases formed in the furnace space 121 and withdrawn therefrom has a NO_x content of less than about 25 ppm.

Thus, the present invention is well adapted to carry out the objects and attain the advantages mentioned as well as those inherent therein. While presently preferred embodiments of the invention have been described for purposes of this disclosure, numerous changes in construction and in the arrangement of parts and steps will suggest themselves to those skilled in the art which are encompassed within the spirit of this invention as defined by the appended claims.

What is claimed is:

1. An improved furnace wherein fuel and air are burned and effluent flue gases having a low NO_x content are formed therefrom comprising:

a furnace space within which said fuel and air are burned to form hot flue gases, within which a portion of said flue gases are recirculated and cooled and from which said flue gases are vented to the atmosphere, said furnace space being comprised of a wall having an opening therein;

a burner housing having an open end attached to said furnace space;

means for introducing a controlled quantity of air into said housing and into said furnace space;

fuel jet mixer means for mixing fuel with said recirculated and cooled flue gases from said furnace space and discharging the resulting mixture into the open end of said housing and into a primary reaction zone in said furnace space adjacent thereto, said fuel jet mixer means being attached to said housing and including a conduit for connection to a source of pressurized fuel having a fuel gas jet forming end, and at least one flue gases passageway communicating said fuel jet forming end of said conduit with flue gases in said furnace space and with the interior of said housing whereby flue gases from within said furnace space are drawn into said passageway, mixed with fuel and discharged into said housing; and

at least one secondary fuel nozzle means attached to said housing for connection to a source of pressurized fuel and for introducing additional fuel into said furnace space.

2. The apparatus of claim 1 wherein the open end of said housing comprises an annular burner tile formed of flame and heat resistant material.

3. The apparatus of claim 2 wherein said flue gases passageway is comprised of a passageway disposed in said burner tile.

4. The apparatus of claim 3 wherein said secondary fuel nozzle means extends into another passageway disposed in said burner tile.

5. The apparauts of claim 4 wherein a flame stability shield having a plurality of openings therein is disposed within the interior of said annular burner tile.

6. The apparatus of claim 5 wherein said flame stability shield is dish-shaped.

7. A method of burning substantially stoichiometric amounts of fuel and air in a furnace whereby the effluent flue gases produced by said furnace have a low NO_x content comprising the steps of:

discharging said air into a furnace space in said furnace within which said fuel and air mixture is burned to form hot flue gases, within which a portion of said flue gases are recirculated and cooled and from which said flue gases are withdrawn and vented;

mixing a portion of said fuel with recirculated and cooled flue gases from said furnace space to form a fuel and flue gases mixture;

discharging said fuel and flue gases mixture into said furnace space whereby said mixture combines with air and is burned in a primary reaction zone therein and flue gases having low NO_x content are formed therefrom; and

discharging the remaining portion of said fuel into a secondary reaction zone in said furnace space whereby said fuel mixes with flue gases and air contained in said furnace space and is burned in said secondary reaction zone.

8. The method of claim 7 wherein said secondary reaction zone sequentially follows said primary reaction zone in said furnace space.

9. The method of claim 7 wherein said fuel and flue gases mixture discharged and burned in said primary reaction zone is formed by a fuel jet mixer.

10. The method of claim 8 wherein said remaining portion of fuel is discharged into said secondary combustion zone by way of at least one secondary fuel nozzle.

11. The method of claim 10 wherein said remaining portion of fuel is discharged into said secondary combustion zone by way of a plurality of secondary fuel nozzles.

12. The method of claim 7 wherein said portion of said fuel contained in said fuel and flue gases mixture discharged and burned in said primary reaction zone is an amount in the range of from about 10% to about 50% by volume of the total fuel discharged into said furnace space, and said flue gases in said fuel mixture are present therein in the range of from about 30% to about 400% by volume of said fuel in said mixture.

* * * * *

US005344307A

United States Patent [19]

Schwartz et al.

[11] Patent Number: 5,344,307

[45] Date of Patent: * Sep. 6, 1994

[54] METHODS AND APPARATUS FOR BURNING FUEL WITH LOW NO_x FORMATION

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[73] Assignee: Koch Engineering Company, Inc., Wichita, Kans.

[*] Notice: The portion of the term of this patent subsequent to Oct. 13, 2009 has been disclaimed.

[21] Appl. No.: 111,447

[22] Filed: Aug. 25, 1993

Related U.S. Application Data

[63] Continuation of Ser. No. 921,064, Jul. 29, 1992, Pat. No. 5,269,678, which is a continuation of Ser. No. 836,779, Feb. 13, 1992, Pat. No. 5,154,596, which is a continuation of Ser. No. 578,953, Sep. 7, 1990, Pat. No. 5,098,282.

[51] Int. Cl.[5] F23M 3/00

[52] U.S. Cl. 431/9; 431/174; 431/181; 431/187; 431/116

[58] Field of Search 431/9, 8, 10, 187, 188, 431/115, 116, 174, 278, 181

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,174,526	3/1965	Von Linde	158/4
3,658,482	4/1972	Evans et al.	23/277 C
3,716,001	2/1973	Potasek et al.	110/8 A
3,794,459	2/1974	Meenan	431/5
4,004,875	1/1977	Zink et al.	431/9
4,130,388	12/1978	Flanagan	431/116
4,277,942	7/1981	Egnell et al.	60/517
4,395,223	7/1983	Okigami et al.	431/10
4,445,842	5/1984	Syska	431/115
4,481,889	11/1984	Sikander et al.	110/212
4,505,666	3/1985	Martin et al.	431/175
4,575,332	3/1986	Oppenberg et al.	431/9
4,645,449	2/1987	Schwartz et al.	431/8
4,699,071	10/1987	Vier et al.	110/345
4,708,638	11/1987	Brazier et al.	431/116
4,983,118	1/1991	Hovis et al.	431/115
5,044,932	9/1991	Martin et al.	431/116

OTHER PUBLICATIONS

Paper entitled "The NOXLESS Solution" by Heat Technology International, Divisione Della Kinetics Technology International S.p.A., Viale Tunisia, 13-20124 Milano, Italy (date unknown).

Primary Examiner—Larry Jones
Attorney, Agent, or Firm—Dougherty, Hessin Beavers & Gilbert

[57] **ABSTRACT**

Improved methods and burner apparatus are provided for discharging mixtures of fuel and air into furnace spaces wherein said mixtures are burned and flue gases having low NO_x content are formed therefrom. The methods basically comprise discharging a first fuel mixture containing a portion of the fuel and flue gases from the furnace space into the furnace space whereby the mixture is burned in a primary reaction zone therein and flue gases having low NO_x content are formed therefrom, and then discharging the remaining portion of the fuel into a secondary reaction zone wherein the remaining portion of fuel mixes with air and flue gases to form a second fuel mixture which is burned in the secondary reaction zone and additional flue gases having low NO_x content are formed therefrom.

13 Claims, 3 Drawing Sheets

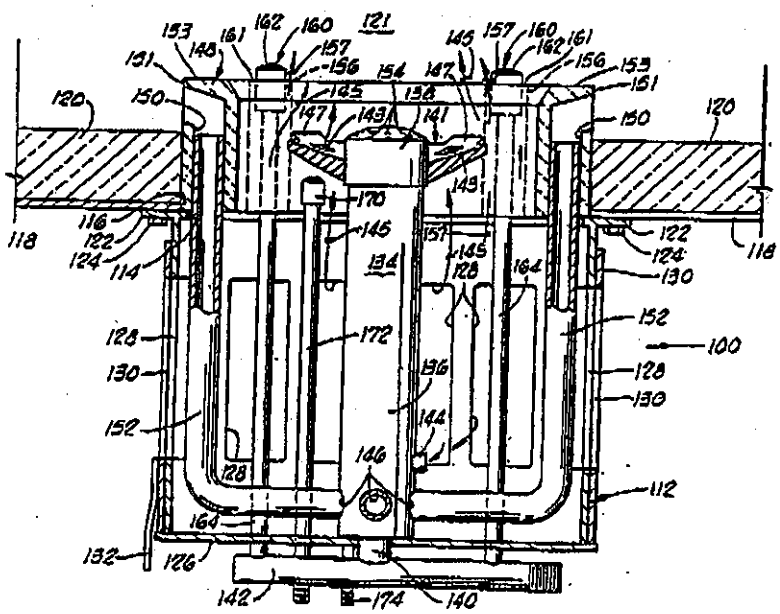

Exhibit 6

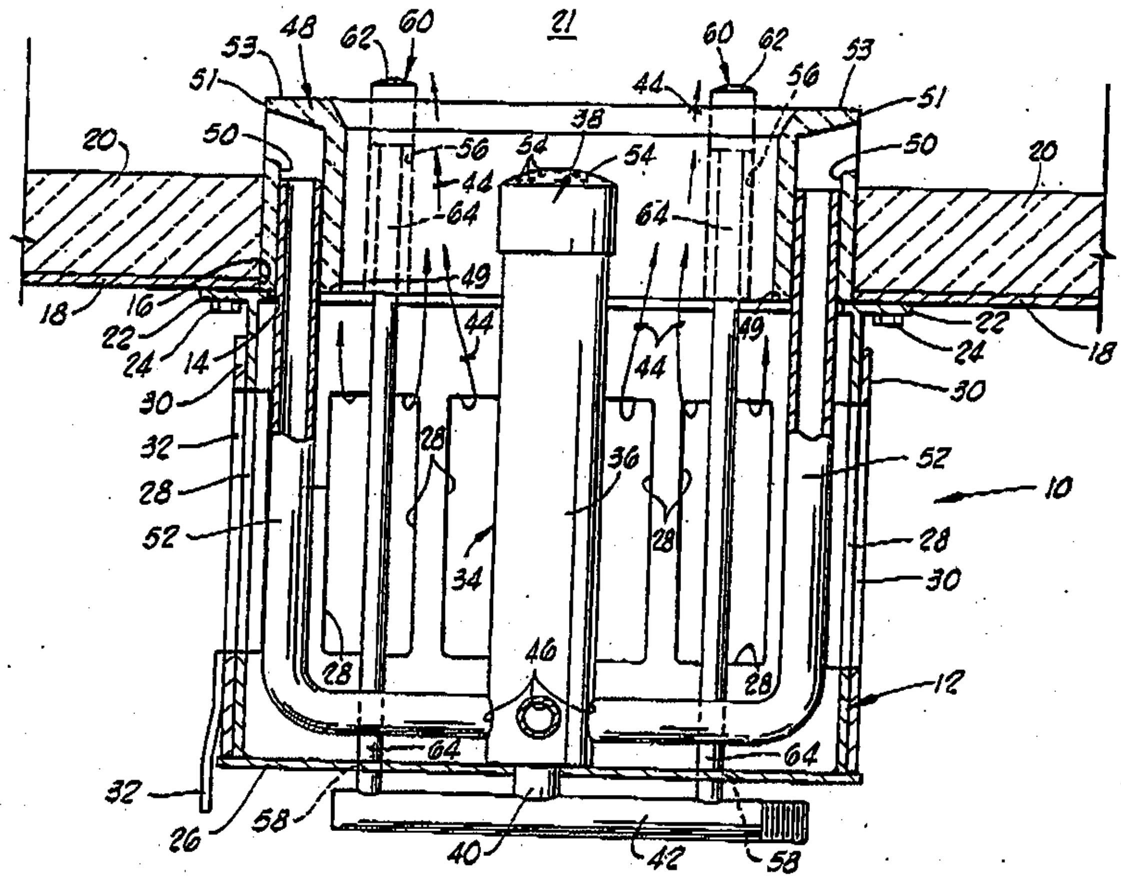
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FIG. 1

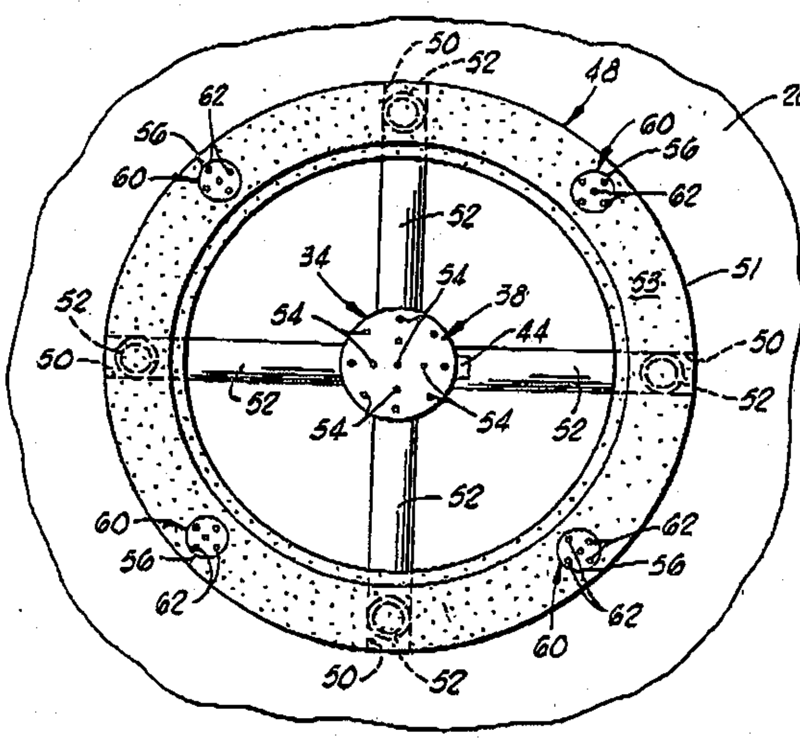
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FIG. 2

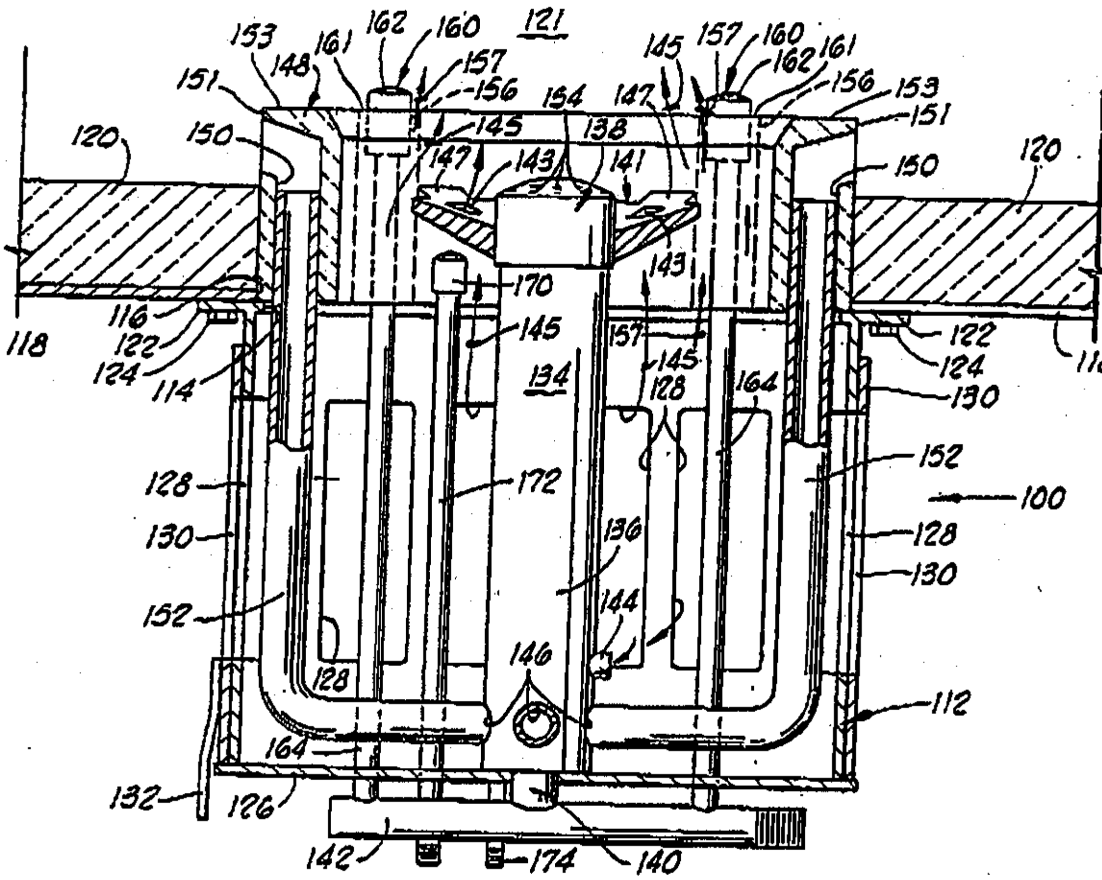
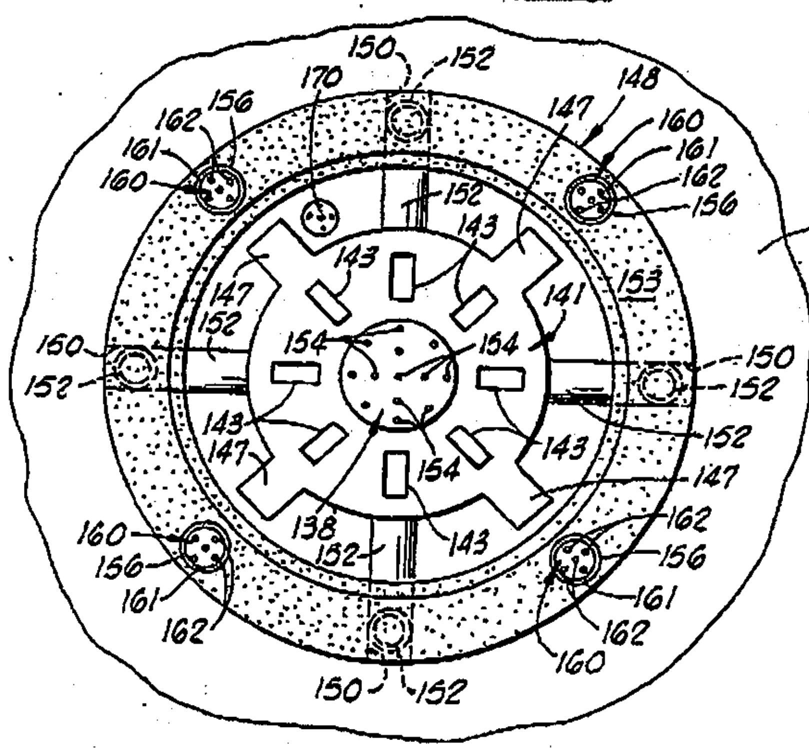


FIG. 3



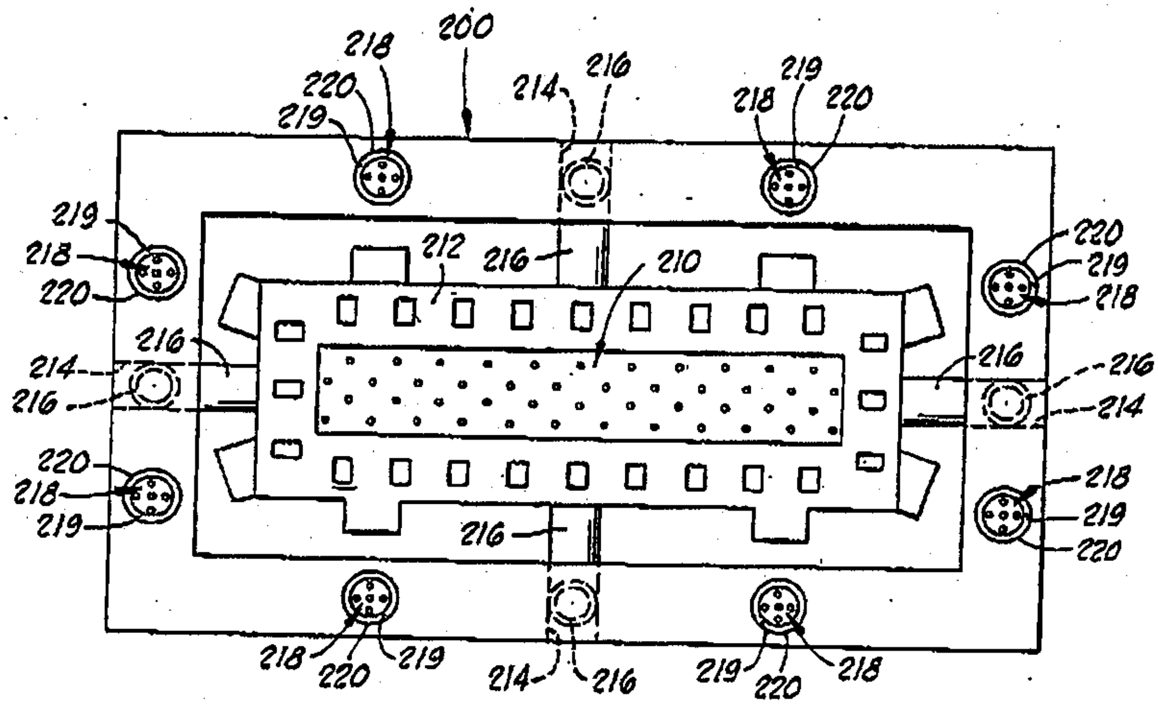


FIG. 5

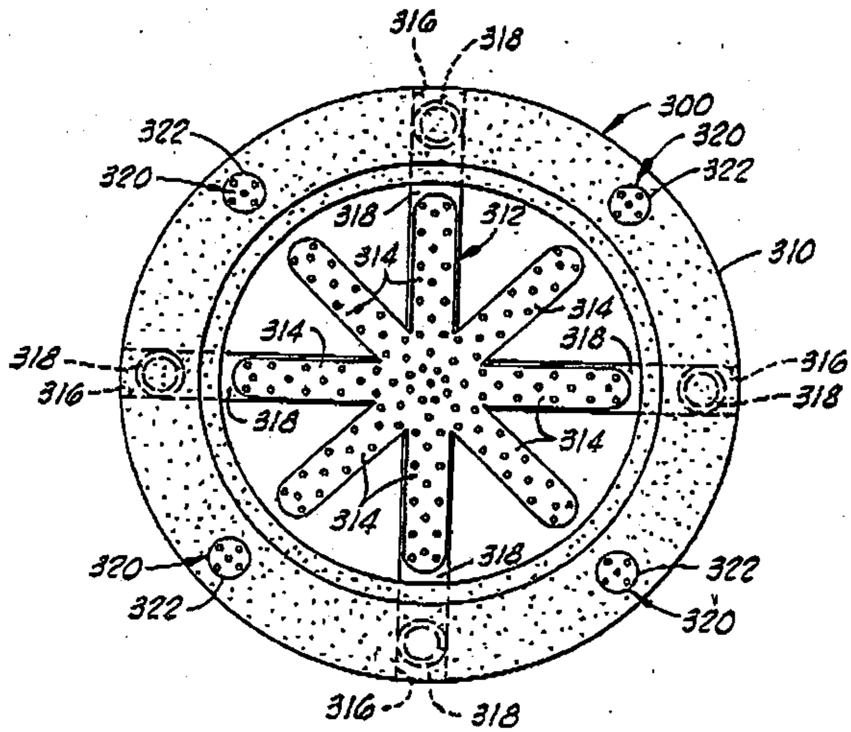


FIG. 6

METHODS AND APPARATUS FOR BURNING FUEL WITH LOW NO_x FORMATION

Continuation of Ser. No. 07/921,064 filed on Jul. 29, 1992 (now U.S. Pat. No. 5,269,678) which is a continuation of Ser. No. 07/836,779 filed on Feb. 13, 1992 (now U.S. Pat. No. 5,154,596) which is a continuation of Ser. No. 07/578,953 filed on Sep. 7, 1990 (now U.S. Pat. No. 5,098,282).

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to methods and apparatus for burning fuel-air mixtures whereby flue gases having low NO_x content are produced.

2. Description of the Prior Art

As a result of the adoption of stringent environmental emission standards by government authorities and agencies, methods and apparatus to suppress the formation of oxides of nitrogen (NO_x) in flue gases produced by the combustion of fuel-air mixtures have been developed and used heretofore. For example, methods and apparatus wherein fuel is burned in less than a stoichiometric concentration of oxygen to intentionally produce a reducing environment of CO and H_2 have been proposed. This concept has been utilized in staged air burner apparatus wherein the fuel is burned in a deficiency of air in a first zone producing a reducing environment that suppresses NO_x formation, and then the remaining portion of air is introduced into a second zone. Methods and apparatus have also been developed wherein all of the air and some of the fuel is burned in a first zone with the remaining fuel being introduced into a second zone. In this staged fuel approach, an excess of air in the first zone acts as a diluent which lowers the temperature of the burning gases and thereby reduces the formation of NO_x. Other methods and apparatus have been developed wherein flue gases are combined with fuel-air mixtures to dilute the mixtures and thereby lower their combustion temperatures and the formation of NO_x.

While the prior art methods and burner apparatus for producing flue gases having low NO_x content have achieved varying degrees of success, there still remains a need for improvement in such methods and burner apparatus whereby low NO_x content flue gases are produced and simple economical burner apparatus is utilized.

SUMMARY OF THE INVENTION

By the present invention, the above mentioned needs for improved methods of burning fuel-air mixtures and improved burner apparatus for carrying out the methods are met. That is, the present invention provides improved methods and burner apparatus for discharging mixtures of fuel and air into furnace spaces wherein the mixtures are burned and flue gases having low NO_x content are formed therefrom. The methods each basically comprise the steps of mixing a portion of the total fuel needed for the required heat release in the furnace space and flue gases from the furnace space to form a first fuel mixture. The first fuel mixture is discharged into the furnace space whereby it combines with a portion of the total air required for forming an at least substantially stoichiometric total fuel-total air mixture, and the resultant fuel-flue gases-air mixture is burned in a primary reaction zone therein. Because the fuel and air in the mixture are diluted with flue gases and, as a result, burn at a relatively low temperature, low NO_x content flue gases are formed therefrom. The remaining portion of fuel is discharged into a secondary reaction zone in the furnace space wherein it mixes with cooled flue gases contained in the furnace space and air remaining therein to form a second fuel mixture. The second fuel mixture also burns at a relatively low temperature and flue gases having low NO_x content are formed therefrom. The first fuel mixture can optionally contain a portion of the air mixed simultaneously with the fuel and flue gases, and a portion of the air can optionally be separately conducted to and discharged into the secondary reaction zone with the remaining portion of the fuel.

The improved burner apparatus of the present invention which is relatively simple and economical utilizes a primary fuel jet mixer-nozzle assembly for mixing a portion of the fuel and inspirated flue gases drawn from the furnace space and discharging the resultant first fuel mixture into a primary reaction zone in the furnace space. A portion of the air can optionally be inspirated into the primary mixer-nozzle assembly and simultaneously mixed with the first fuel mixture.

The remaining portion of the fuel is discharged into the furnace space by way of one or more secondary fuel nozzles positioned adjacent to the primary nozzle whereby the fuel enters a secondary reaction zone sequentially following the primary reaction zone. A portion of the air flows into the primary reaction zone wherein it combines with the first fuel mixture discharged from the primary mixer-nozzle assembly, and optionally, a portion of the air can be separately conducted to the location of each secondary fuel nozzle utilized whereby air is discharged along with the fuel into the secondary reaction zone.

It is, therefore, a general object of the present invention to provide an improved method and burner apparatus for discharging a mixture of fuel and air into a furnace space wherein the mixture is burned and flue gases having a low NO_x content are formed therefrom.

A further object of the present invention is the provision of an improved low NO_x burner apparatus which is of simple and economical construction.

Other and further objects, features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the description of preferred embodiments which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side cross-sectional view of a burner apparatus of the present invention attached to a furnace wall.

FIG. 2 is a top plan view of the burner and the furnace wall of FIG. 1.

FIG. 3 is a side cross-sectional view of an alternate embodiment of the burner apparatus of the present invention attached to a furnace wall.

FIG. 4 is a top plan view of the burner and furnace wall of FIG. 3.

FIG. 5 is a top plan view of another alternate embodiment of the burner of the present invention.

FIG. 6 is a top plan view of yet another alternate embodiment of the burner of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawings, a presently preferred embodiment of burner apparatus of the present invention is illustrated and generally designated by the numeral 10. The burner 10 includes a cylindrical housing 12 which is connected at an open end 14 thereof over a complimentary opening 16 in a furnace wall 18. As will be understood by those skilled in the art, the furnace wall 18 generally includes an internal layer of insulation material 20, and the wall 18 and insulation material 20 together with a portion of the interior of a burner tile 48 which will be described further hereinbelow define a furnace space 21 within which fuel and air are burned to form hot flue gases.

As illustrated in FIG. 1, the burner housing 12 includes an annular flange 22 at the open end 14 thereof. The flange 22 is bolted to the furnace wall 18 by a plurality of bolts 24. The opposite end of the housing 12 is closed by an end wall 26, and a plurality of air inlet openings 28 are disposed in spaced relationship around the cylindrical side of the housing 12. A cylindrical damper 30 is rotatably positioned over the cylindrical side of the housing 12 having a handle 32 attached thereto. The damper 30 includes air openings 32 which are complimentary to the air openings 28 whereby the damper 30 can be rotated, using the handle 32, between a closed position whereby the openings 28 are covered by solid portions of the damper 30, a partially open position and a fully open position whereby the openings 28 are in registration with the openings 32 as shown in FIG. 1.

Positioned co-axially within the housing 12 is a primary fuel jet mixer-discharge nozzle assembly generally designated by the numeral 34. The assembly 34 is comprised of an elongated fuel jet mixer 36 connected to a discharge nozzle 38. The mixer 36 attached to the end plate 26 of the housing 12 includes a pressurized fuel inlet connection (not shown) to which a conduit 40 (via an opening in the end plate 26) is connected. The conduit 40 is in turn connected to a header or conduit 42 which conducts pressurized fuel from a source thereof to the burner 10. The mixer 36 also includes four flue gases inlet connections 46 which are positioned in equally spaced relationship around the base thereof.

At the open end 14 of the housing 12 is an annular burner tile 48 formed of flame and heat resistant material. As shown in FIGS. 1 and 2, the burner tile 48 includes four passageways 50 which extend from the end 49 thereof adjacent the open end 14 of the housing 12 to the exterior side 51 thereof within the furnace space 21. Connected to each of the flue gases inlet connections 46 of the mixer 36 are the ends of four conduits 52 which are disposed within the housing 12, the other ends of which extend into the passageways 50 formed in the burner tile 48. Thus, the four conduits 52 connect the four flue gases inlet connections 46 of the primary mixer-nozzle assembly 34 to the passageways 50 in the burner tile 48. As best shown in FIG. 2, the passageways 50 with the conduits 52 extending therein are positioned in equally spaced relationship around the primary mixer-nozzle assembly 34. As will be understood, more or less than four conduits 52 and inlet connections 46 may be utilized in the burner apparatus 10 depending upon various design considerations known to those skilled in the art.

The nozzle 38 of the primary mixer-nozzle assembly 34 includes one or more orifices 54 formed therein through which, as will be described further hereinbelow, a mixture of fuel and flue gases is discharged into a primary reaction zone in the furnace space 21.

Four additional passageways 56 are disposed in the burner tile 48 extending from the end 49 thereof to the other end 53 thereof. As best shown in FIG. 2, the openings 56 are positioned in spaced relationship around the burner tile 48 between the passageways 50 therein. Disposed within the passageways 56 are four secondary fuel discharge nozzles 60. The discharge nozzles 60 each include one or more discharge orifices 62 in the external ends thereof, and are each snugly fitted within a passageway 56. The internal ends of the nozzles 60 are connected to conduits 64 which extend through the passageways 56 of the burner tile 48, through the interior of the housing 12 and through complimentary openings 58 in the end wall 26 of the housing 12. The conduits 64 are connected to a pressurized fuel source by way of the conduit 42. As will be described further hereinbelow, the fuel nozzles 60 discharge fuel into the furnace space 21 wherein the fuel mixes with cool flue gases contained in the furnace space 21 and air remaining therein. The resulting mixture is burned in a secondary reaction zone in the furnace space 21 adjacent to and downstream from the primary reaction zone. More or less than four fuel nozzles 60 can also be utilized in the apparatus 10 based on known design considerations.

In the operation of the furnace of which the burner apparatus 10 is a part, fuel and air are discharged into the furnace space 21 and burned therein to form hot flue gases. The hot flue gases are cooled as they circulate through the furnace space 21 and lose heat prior to being vented to the atmosphere. In order to meet environmental emission standards, the flue gases must have low NO_x content.

The required flue gases low NO_x content is accomplished in accordance with the present invention by: (a) discharging into the furnace space 21 the air required for producing at least a substantially stoichiometric mixture of fuel and air therein by way of the opening 14 in the housing 12; (b) mixing, within the primary mixer-nozzle assembly 34, a portion of the total fuel needed for the required heat release within the furnace space 21 and flue gases from the furnace space 21 to thereby form a first fuel mixture, i.e., fuel diluted with flue gases; (c) discharging the first fuel mixture into the furnace space 21 by way of the orifices 54 of the nozzle 38 whereby the mixture combines with air discharged into the furnace space 21, the resulting fuel-flue gases-air mixture is burned in a primary reaction zone therein and flue gases having low NO_x content are formed therefrom; and (d) discharging the remaining portion of the fuel by way of the nozzles 60 into a secondary reaction zone which sequentially follows the primary reaction zone in the furnace space 21 whereby the fuel combines with cooled flue gases from the furnace space 21, with the products of combustion from the primary reaction zone and with air in the furnace space 21 to form a second fuel mixture which is burned in the secondary reaction zone and additional flue gases having low NO_x content are formed therefrom.

Referring to FIGS. 1 and 2, atmospheric air is introduced into the housing 12 of the burner apparatus 10 by way of the openings 28 therein and is discharged, in accordance with step (a) described above, through the open end 14 of the housing 12, through the open interior of the burner tile 48 and into the furnace space 21. As is well understood, the damper 30 is utilized to control the rate of total air introduced into the housing 12 at a level whereby at least a substantially stoichiometric mixture of total air and total fuel results in the furnace space 21.

In accordance with step (b), pressurized fuel flows by way of the conduit 40 into the primary mixer-nozzle assembly 34. The pressurized fuel, which can be fuel gas or vaporized liquid fuel, is formed into a high velocity jet as it enters the mixer 36 which causes a suction to be created at the flue gases inlet connections 46, the conduits 52 and the passageways 50. This in turn causes flue gases contained within the furnace space 21 to be drawn into the passageways 50 from the furnace space 21 and to flow by way of the conduits 52 to the mixer 36 wherein the flue gases are inspirated into and mixed with the fuel to form a first fuel mixture.

In accordance with step (c) described above, the first fuel mixture is discharged through the orifices 54 of the discharge nozzle 38 of the primary mixer-nozzle assembly 34 into a primary reaction zone adjacent thereto. Upon being discharged from the nozzle 38, the first fuel mixture combines with air flowing into the furnace space 21 by way of the open end 14 of the housing 12 and the interior of the burner tile 48 (as shown by the arrows 44), and the resultant flue gases-fuel-air mixture is burned in the primary reaction zone. Because the burning of the mixture takes place at a relatively low temperature due, at least in part, to the presence of the flue gases therein, the flue gases formed have a low NO_x content. The term "relatively low temperature" is used herein to mean a temperature that is lower than the temperature at which the same fuel-air mixture, but undiluted with fuel gases, would burn.

Generally, the portion of fuel introduced into the primary mixer-nozzle assembly 34 and contained in the first fuel mixture discharged into the primary reaction zone is an amount in the range of from about 10% to about 50% by volume of the total fuel required. The flue gases which are drawn into and mixed with the fuel in the primary mixer-nozzle assembly 34 are preferably present in an amount in the range of from about 30% to about 400% by volume of the fuel depending on the composition of the fuel and other factors. As will be understood, the fuel utilized in a burner or furnace apparatus is normally expressed as a rate, i.e., a volume of fuel per unit time. The term "% by volume" as used herein means the stated % of the rate of fuel referred to. While the rate of the air discharged into the furnace space 21 can be varied, the rate of air utilized preferably results in an at least substantially stoichiometric fuel-air mixture. The term "stoichiometric fuel-air mixture" is used herein to mean a mixture in which the relative portions of fuel and air are such that when the mixture is burned to completion, no excess oxygen or fuel remains.

In accordance with step (d), the remaining portion of the fuel flows to the secondary nozzles 60 by way of the conduits 64 connected thereto and to the conduit 42. The fuel is discharged by way of the orifices 62 in the secondary nozzles 60 into the furnace space 21. That is, the portion of the fuel discharged by the secondary fuel nozzles 60 into the furnace space 21 mixes with air therein, with cooled flue gases contained within the furnace space 21 and with products of combustion, i.e., flue gases, from the primary reaction zone to form a second fuel mixture. Like the first fuel mixture, the second fuel mixture, at least in part as a result of the dilution thereof with flue gases, is burned in the secondary reaction zone at a relatively low temperature whereby the flue gases formed have a low NO_x content.

Because the secondary fuel nozzles 60 are located adjacent to and downstream from the nozzle 38 of the primary mixer-nozzle assembly 34, the secondary reaction zone in which the second fuel mixture is burned sequentially follows the primary reaction zone in which the first fuel mixture is burned. Stated another way, the primary reaction zone extends from the primary nozzle 38 into the furnace space 21 and the secondary reaction zone substantially surrounds and extends outwardly from the primary reaction zone.

Referring now to FIGS. 3 and 4, an alternate embodiment of the burner apparatus of the present invention is shown and generally designated by the numeral 100. The burner 100 includes a cylindrical housing 112 which is connected at an open end 114 over a complimentary opening 116 in a furnace wall 118. An internal layer of insulation material 120 is provided adjacent the wall 118; and the wall 118, the insulation material 120 and a portion of the interior of a burner tile 148 define a furnace space 121 within which fuel and air are burned to form hot flue gases. The burner housing 112 includes an annular flange 122 at the open end 114 thereof which is bolted to the furnace wall 118 by a plurality of bolts 124. The opposite end of the housing 112 is closed by an end wall 126, and a plurality of air inlet openings 128 are disposed in spaced relationship around a cylindrical side of the housing 112. Like the burner apparatus 10, the apparatus 100 includes a cylindrical damper 130 rotatably positioned over the cylindrical side of the housing 112 having a handle 132 attached thereto.

A primary fuel jet mixer-discharge nozzle assembly generally designated by the numeral 134 is positioned co-axially within the housing 112. The assembly 134 is comprised of an elongated fuel jet mixture 136 connected to a discharge nozzle 138. The mixer 136 includes a pressurized fuel inlet connection to which a conduit 140 is connected. The conduit 140 is in turn connected to a source of pressurized fuel by a conduit 142. The primary mixer-nozzle assembly 134 also includes an air inlet 144, and four flue gases inlet connections 146 which are positioned in equally spaced relationship around the mixer 136.

In the embodiment illustrated in FIGS. 3 and 4, a conical shield 141 is attached to the nozzle 138 to enhance flame stability thereto. The shielding cone 141 is dish-shaped and includes a plurality of openings 143 formed therein for allowing the passage of a limited amount of air therethrough. The shielding cone 141 functions to create a protected area adjacent the nozzle 138 whereby air flowing in the direction indicated by the arrows 145 is deflected and instability of flame adjacent the nozzle 138 is reduced. The shielding cone 141 further includes tabs 147 extending therefrom towards and adjacent the secondary fuel nozzles 160 to be described further hereinbelow. The shielding tabs 147 function to enhance flame stability to the secondary fuel nozzles 160 by deflecting the flow of air in areas adjacent thereto.

An annular burner tile 148 is connected at the open end 114 of the housing 112. Like the burner tile 48 of the apparatus 10, the burner tile 148 includes four passageways 150 which extend from the inner end 149 thereof to the exterior side 151 within the furnace space 121. Connected to each of the flue gases inlet connections 146 of the mixer 136 are the ends of four conduits 152, the other ends of which extend into the passageways 150 formed in the burner tile 148. The four conduits 152 connect the four flue gases inlet connections 146 of the mixer 136 to the passageways 150 in the burner tile 148. The passageways 150 with the conduits 152 extending therein are positioned in equally spaced relationship around the primary mixer-nozzle assembly 134. The nozzle 138 of the primary mixer-nozzle assembly 134 includes one or more orifices 154 formed therein through which a fuel-air mixture diluted with flue gases is discharged into a primary reaction zone in the furnace space 121.

Four enlarged passageways 156 are disposed in the burner tile 148 extending from the inner end 149 thereof to the exterior end 153 thereof. The passageways 156 are positioned in spaced relationship around the burner tile 148 between the passageways 150 therein. Disposed within the passageways 156 are four secondary fuel discharge nozzles 160, each including one or more discharge orifices 162 in the external ends thereof. The nozzles 160 are connected by conduits 164 to the pressurized fuel conducting conduit 142. The diameters of the passageways 156 are sized with respect to the external sizes of the secondary fuel nozzles 160 such that annular air conducting conduits 161 are provided between the external surfaces of the nozzles 160 and the interiors of the passageways 156. Thus, as indicated by the arrows 157 in FIG. 3, air from within the housing 12 flows by way of the annular conduits 161 provided between the passageways 156 and the nozzles 160 into the secondary reaction zone above and adjacent to the secondary fuel nozzles 160. The particular rate of air which flows through the annular conduits 161 is controlled by the sizes of the annular conduits 161.

The fuel nozzles 160 discharge fuel into the furnace space 121 wherein the fuel mixes with the air entering the furnace space 121 by way of the annular conduits 161. As described above in connection with the burner apparatus 10, the fuel-air mixture combines with cool flue gases contained in the furnace space 121, products of combustion from the primary reaction zone and with any air remaining in the furnace space 121, and the resulting mixture is burned in a secondary reaction zone within the furnace space 121.

In order to further lower the production of NO_x within the furnace space 121, a steam injection nozzle 170 connected to a steam conduit 172 is disposed within the housing 112. Alternatively the steam can be introduced into the primary mixer nozzle assembly 134 by way of a conduit 174 connected thereto. The steam injection contributes to low NO_x production as is well known by those skilled in the art.

The operation of the apparatus 100 is similar to the operation of the apparatus 10 described above, except that a portion of the air which flows into the housing 112 by way of the openings 128 is drawn into the primary mixer-nozzle assembly 134, mixed with the fuel and flue gases therein and the resulting flue gases-fuel-air mixture is discharged into the furnace space 121 by way of the nozzle 138. In addition, a portion of the air within the housing 112 flows by way of the annular conduits 161 directly into the secondary reaction zone in the furnace space 121. More specifically, a portion of the total fuel needed for the required heat release is mixed within the primary mixer-nozzle assembly 134 with a portion of the total air required for at least the substantial stoichiometric combustion of the total fuel and with flue gases from the furnace space 21 to thereby form a first fuel-air mixture diluted with flue gases.

Generally, the portion of the total fuel which is introduced into the primary mixer-nozzle 134 and contained in the first fuel-air mixture diluted with flue gases discharged into the primary reaction zone is an amount in the range of from about 10% to about 50% by volume of the total fuel. The flue gases which dilute the first fuel-air mixture are preferably present therein in an amount in the range of from about 30% to about 400% by volume of the fuel in the fuel-air mixture depending on the composition of the fuel and other factors. The portion of the total air which is drawn into the mixer 136 by way of the air inlet 144 and which is contained in the first fuel-air mixture diluted with flue gases discharged into the furnace space 121 is an amount in the range of from about 50% to about 500% by volume of the fuel in the first fuel-air mixture depending on the composition of the fuel and other factors. As will be understood, the amounts of flue gases and air drawn into the mixer 136 are substantially set when the design of the burner apparatus 100 is finalized and the number and sizes of the various inlets, passageways, conduits, etc. are selected. However, some adjustments are normally possible.

The first fuel-air mixture diluted with flue gases is discharged into the furnace space 121 by way of the orifices 154 of the nozzle 138 whereby the mixture combines with a further portion of the total air which is discharged from the housing 112 into the furnace space 121 by way of the open end 114 of the housing 112 as illustrated by the arrows 145. The flow of air is deflected and slowed down adjacent the nozzle 138 by the shielding cone 141 to insure stability of the flame adjacent the burner 138 in the primary reaction zone. The resulting fuel-air mixture diluted with flue gases is burned in the primary reaction zone and flue gases are formed therein having low NO_x content as a result at least in part of the presence of the diluting flue gases causing the burning to take place at a relatively low temperature.

The remaining portion of the fuel is discharged by way of the fuel nozzles 160 into a secondary reaction zone which sequentially follows the primary reaction zone. The discharged fuel combines with the air which is separately conducted to the secondary reaction zone by way of the annular conduits 161 formed within the passageways 156 around the nozzles 160. The air mixes with the fuel, with the products of combustion from the primary reaction zone and with cooled flue gases and any air contained in the furnace space to form a second fuel-air mixture diluted with flue gases. The second diluted fuel-air mixture is burned in the secondary reaction zone at a relatively low temperature thereby forming additional flue gases having a low NO_x content.

Generally, the portion of the air which flows by way of the annular conduits 161 directly to the secondary reaction zone is an amount of air in the range of from about 10% to about 100% by volume of the fuel which is discharged into the secondary reaction zone by way of the nozzles 160.

Referring now to FIGS. 5 and 6, alternate forms of burner apparatus of the present invention are illustrated. Referring to FIG. 5, a rectangular shaped burner apparatus 200, often referred to as a flat flame burner, is illustrated. The burner apparatus 200 is generally the same design as the burner apparatus 100 described above except that it includes an elongated rectangular primary nozzle 210 with a rectangular shield 212 for providing flame stability attached thereto. Flue gases passageways 214 and conduits 216 are provided for drawing flue gases into the primary mixer-nozzle assembly, and a plurality of secondary fuel nozzles 218 are disposed in passageways 220. Air is discharged around the nozzles 218 by way of annular conduits 219 formed between the passageways 220 and nozzles 218. The passageways 214 and 220 are disposed in a rectangular burner tile 222 attached to the burner housing (not shown).

FIG. 6 illustrates another alternate form of burner apparatus of the present invention generally designated by the numeral 300. The apparatus 300 is similar to the apparatus 10 and includes a cylindrical burner tile 310 attached to a cylindrical burner housing (not shown). Instead of a circular burner nozzle with or without a flame stability shield the apparatus 300 includes a primary mixer-nozzle assembly wherein the nozzle 312 thereof includes a plurality of radially extending fingers 314. The configuration of the nozzle 312 is commonly referred to as a "spider" configuration. The apparatus 300 includes a plurality of flue gas intake passageways 316 and conduits 318 as well as a plurality of secondary fuel nozzles 320 disposed in passageways 322.

The burner apparatus 200 and 300 can include the structure and can be operated as described above in connection with the burner apparatus 10, or the burners 200 and 300 can include the structure and be operated as described above in connection with the burner 100, or various combinations of the structure and operation steps can be utilized depending upon the particular applications in which the burners are used. That is, for a particular application, a burner apparatus of the present invention may be rectangular, cylindrical or other shape, may or may not include a nozzle flame stabilizing shield, may or may not inspirate air into the primary mixer-nozzle assembly, may or may not separately conduct air directly to the secondary reaction zone or may or may not inject steam. Also, the apparatus may utilize natural air draft or forced air draft. The term "air" is used herein to mean atmospheric air, oxygen enriched atmospheric air or air which otherwise includes more or less oxygen therein than atmospheric air. The selection of a particular embodiment of the burner apparatus of this invention and its operation depends on the particular application in which the burner apparatus is used and various design considerations relating to that application which are well known to those skilled in the art.

In order to facilitate a clear understanding of the methods and apparatus of the present invention, the following examples are given.

EXAMPLE I

A burner apparatus 10 designed for a heat release of 10,000,000 BTU/hour by burning natural gas having a caloric value of 1,000 BTU/SCF is fired into the furnace space 21.

Pressurized fuel gas is supplied to the burner 10 at a pressure of about 30 PSIG and at a rate of 10,000 SCF/hour. A 30% by volume portion of the fuel (3,000 SCF/hour) flows into and through the primary mixer-nozzle assembly 34 wherein it is mixed with about 7,500 SCF/hour of flue gases (about 250% by volume of the fuel gas present in the mixture). The remaining portion of the fuel gas i.e., 7,000 SCF/hour flows from the conduit 42 to the four secondary fuel nozzles 60 from where the fuel gas is discharged into the furnace space 21. The rate of air introduced into the housing 12 is controlled by means of the damper 30 such that the total rate of air introduced into the furnace space 21 is an amount which results in at least a substantially stoichiometric total fuel-total air mixture therein.

The air flows through the open end 14 of the housing 12 into the furnace space 21 by way of the interior of the burner tile 48.

The fuel discharged from the secondary fuel nozzles 60 mixes with the remaining air, products of combustion (flue gases) from the primary reaction zone and relatively cool flue gases in the furnace space 21 to form a second combustion products and flue gases diluted fuel-air mixture which is burned in a secondary reaction zone adjacent to and surrounding the primary reaction zone in the furnace space 21.

Because of the dilution of the first and second fuel mixtures with flue gases, such mixtures burn at a relatively low temperature whereby the additional flue gases formed have a low NO_x content. That is, the mixture of flue gases withdrawn from the furnace space 21 has a NO_x content of less than about 25 ppm.

EXAMPLE II

A burner apparatus 100 designed for a heat release of 10,000,000 BTU/hour by burning natural gas having a caloric value of 1,000 BTU/SCF is fired into the furnace space 121.

Pressurized fuel-gas is supplied to the burner 100 at a pressure of about 30 PSIG and at a rate of 10,000 SCF/hour. A 30% by volume portion of the fuel (3,000 SCF/hour) flows into and through the primary mixer-nozzle assembly 34 wherein it mixes with 3,000 SCF/hour of air and about 7,500 SCF/hour of flue gases. The portion of the total air mixed with the fuel gas in the primary mixer-nozzle assembly and discharged therefrom results in a sub-stoichiometric fuel-air mixture.

The first flue gases diluted fuel-air mixture discharged from the nozzle 138 mixes with additional air flowing into the furnace space 121 by way of the open end 114 of the housing 112. The resulting mixture is burned in the primary reaction zone, and because, at least in part of the presence of flue gases, the additional flue gases produced have a low NO_x content.

The remaining portion of fuel, i.e., 7,000 SCF/hour, flows to the nozzles 160 from where the fuel gas is discharged into a secondary reaction zone within the furnace space 121. A 1,000 SCF/hour amount of air is conducted directly to the secondary reaction zone by way of the annular conduits 161. The air flows from the annular conduits 161, mixes with the fuel discharged from the nozzles 160, mixes with products of combustion (flue gases) from the primary reaction zone and mixes with relatively cool flue gas and any air contained in the furnace space 121 to form a second products of combustion and flue gases diluted fuel-air mixture which is burned in the secondary reaction zone at a relatively low temperature.

The mixture of flue gases formed in the furnace space 121 and withdrawn therefrom has a NO_x content of less than about 25 ppm.

Thus, the present invention is well adapted to carry out the objects and attain the advantages mentioned as well as those inherent therein. While presently preferred embodiments of the invention have been described for purposes of this disclosure, numerous changes in construction and in the arrangement of parts and steps will suggest themselves to those skilled in the art which are encompassed within the spirit of this invention as defined by the appended claims.

What is claimed is:

1. A method of discharging an at least substantially stoichiometric mixture of fuel and air from a burner into a furnace space wherein said mixture is burned and flue gases having low NO_x content are formed therefrom comprising the steps of:

(a) discharging said air from said burner into said furnace space;

(b) discharging a portion of said fuel in the form of a fuel jet in a passageway in said burner communicated with said furnace space whereby flue gases in said furnace space are drawn into said passageway with said fuel;

(c) discharging said fuel and flue gases from said passageway into said furnace space whereby said fuel and flue gases mix with air and the mixture is burned in a primary reaction zone in said furnace space; and

(d) discharging the remaining portion of said fuel into a secondary reaction zone in said furnace space whereby said fuel mixes with flue gases and air contained in said furnace space and is burned in said secondary reaction zone.

2. The method of claim 1 wherein said secondary reaction zone sequentially follows said primary reaction zone in said furnace space.

3. The method of claim 2 wherein said remaining portion of fuel is discharged into said secondary combustion zone by way of at least one secondary fuel nozzle.

4. The method of claim 2 wherein said remaining portion of fuel is discharged into said secondary combustion zone by way of a plurality of secondary fuel nozzles.

5. The method of claim 1 wherein said portion of said fuel discharged in accordance with step (b) is discharged in the form of a plurality of fuel jets in said primary passageways in said burner.

6. The method of claim 1 wherein said portion of said fuel discharged in accordance with step (c) and burned in said primary reaction zone is an amount in the range of from about 10% to about 50% by volume of the total fuel discharged into said furnace space, and said flue gases discharged with said fuel is an amount in the range of from about 30% to about 400% by volume of said fuel.

7. An improved burner apparatus for discharging a mixture of fuel and air into a furnace space wherein said mixture is burned and flue gases having low NO_x content are formed therefrom comprising:

a housing having an open end attached to said furnace space;

means for introducing a controlled quantity of air into said housing and into said furnace space attached to said housing;

primary fuel nozzle means disposed within said housing for discharging primary fuel into the open end of said housing and into said furnace space and for drawing cooled flue gases from said furnace space and discharging said flue gases into said open end of said housing and into said furnace space along with said primary fuel, said primary fuel nozzle means including a pressurized fuel inlet for connection to a source of pressurized fuel;

flue gases passageway means disposed in said housing extending from said furnace space into said housing through which said cooled flue gases from within said furnace space are drawn and conducted to said primary fuel nozzle means; and

at least one secondary fuel nozzle means attached to said housing having a pressurized fuel inlet for connection to a source of pressurized fuel for introducing additional fuel into said furnace space which mixes with flue gases and air therein.

8. An improved burner apparatus for discharging a mixture of fuel and air into a furnace space wherein said mixture is burned and flue gases having low NO_x content are formed therefrom comprising:

a housing having an open end attached to said furnace space;

means for introducing a controlled quantity of air into said housing and into said furnace space;

fuel jet means for drawing flue gases from said furnace space and discharging fuel and flue gases into the open end of said housing and into a primary reaction zone in said furnace space adjacent thereto, said fuel jet means being attached to said housing and including a conduit for connection to a source of pressurized fuel having a fuel gas jet forming end and at least one passageway communicating said fuel jet forming end of said conduit with flue gases in said furnace space and with the interior of said housing whereby flue gases from within said furnace space are drawn into said passageway and discharged along with fuel into said housing; and

at least one secondary fuel nozzle means attached to said housing for connection to a source of pressurized fuel and for introducing additional fuel into said furnace space.

9. The apparatus of claim 8 wherein the open end of said housing is an annular burner tile formed of flame and heat resistant material.

10. The apparatus of claim 9 wherein said passageway is at least partially comprised of a passageway disposed in said burner tile.

11. The apparatus of claim 10 wherein said secondary fuel nozzle means extends into another passageway disposed in said burner tile.

12. The apparatus of claim 11 wherein a flame stability shield having a plurality of openings therein is disposed within the interior of said annular burner tile.

13. The apparatus of claim 12 wherein said flame stability shield is dish-shaped.

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