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Neumeier

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(54) **LOW NOX BURNER WITH LOW PRESSURE DROP**

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(51) **Int. Cl.**

B05B 1/34	(2006.01)
F23D 14/02	(2006.01)
F23D 14/62	(2006.01)
F23D 14/70	(2006.01)

(52) **U.S. Cl.**

CPC ***F23D 14/02*** (2013.01); ***F23D 14/62*** (2013.01); ***F23D 14/70*** (2013.01); *F23D 2900/14021* (2013.01)

(58) **Field of Classification Search**

CPC F23D 14/64; F23D 14/70
USPC 239/494, 497, 483, 406
See application file for complete search history.

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Primary Examiner — Davis Hwu

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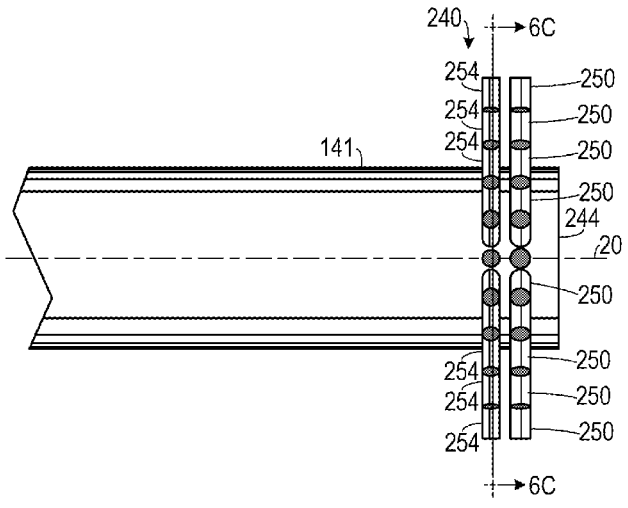
(57) **ABSTRACT**

A burner includes a cylindrical tube that terminates in a burner discharge end. An annular disk, affixed to the discharge end, defines a hole. An oxidizer intake delivers oxidizer into the tube. A fuel nozzle delivers fuel into the tube. A cylindrical slotted member has an interrupted outer surface and is disposed within a portion of the tube. The slotted member is affixed to the annular disk and defines an interior void that opens to the hole. The tube and the slotted member define an annular passage therebetween. Elongated slots pass through the outer surface of the slotted member, each directed along a different non-diametrical chord of the slotted member. The elongated slots direct a gaseous stream into the interior void so as to impart both an inwardly-directed radial velocity component and a tangential velocity component to the gaseous stream.

20 Claims, 7 Drawing Sheets



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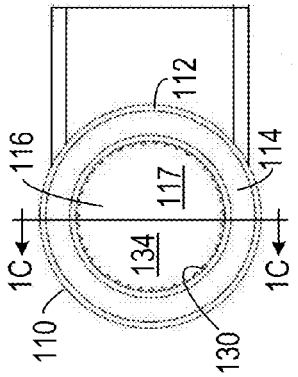

FIG. 1B

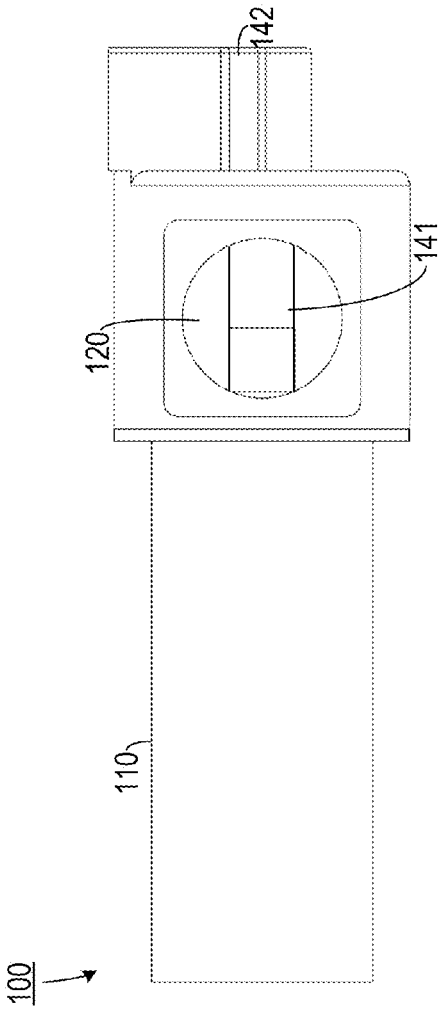

FIG. 1A

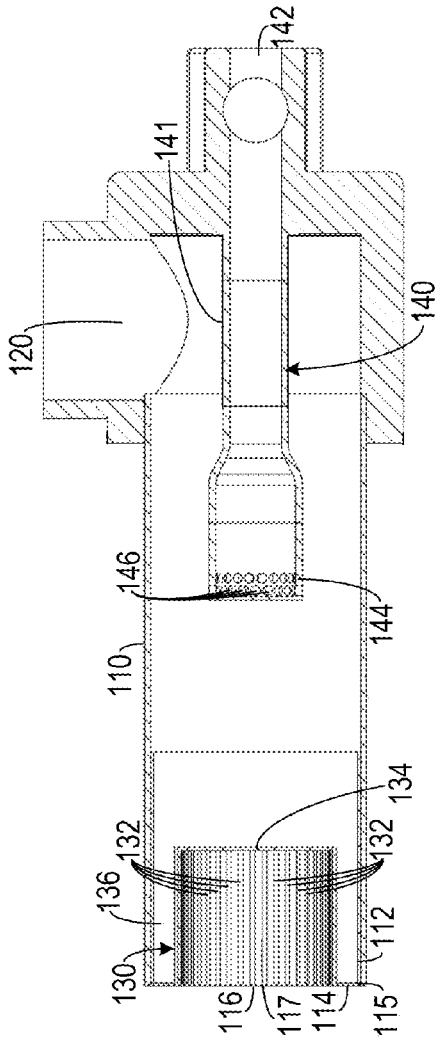

FIG. 1C

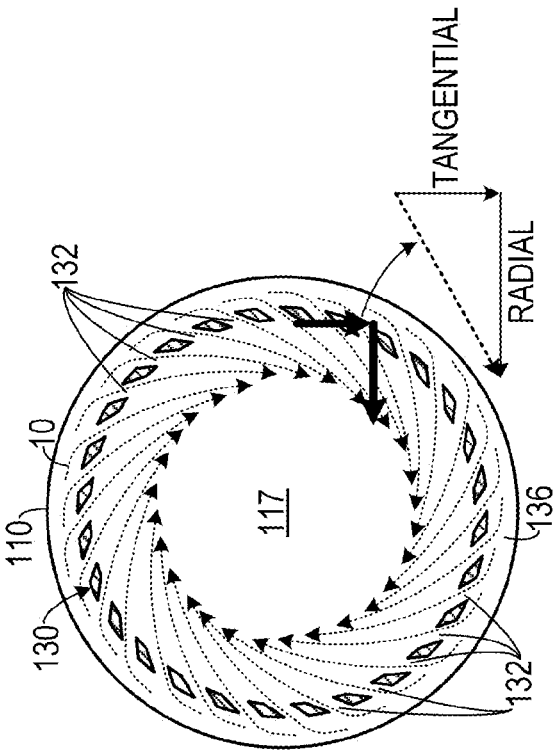
TANGENTIAL
RADIAL
132
10
110
130
117
136
132

FIG. 2B

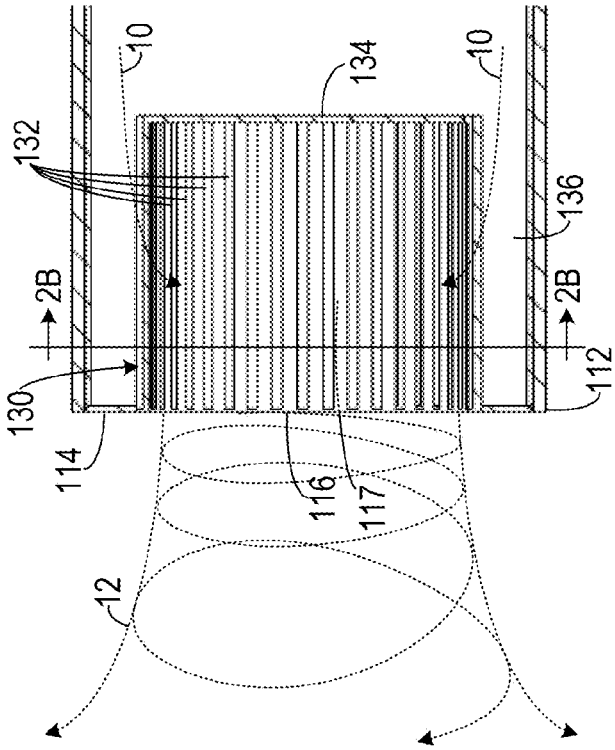
10
134
10
132
136
2B
2B
130
112
114
116
117
12

FIG. 2A

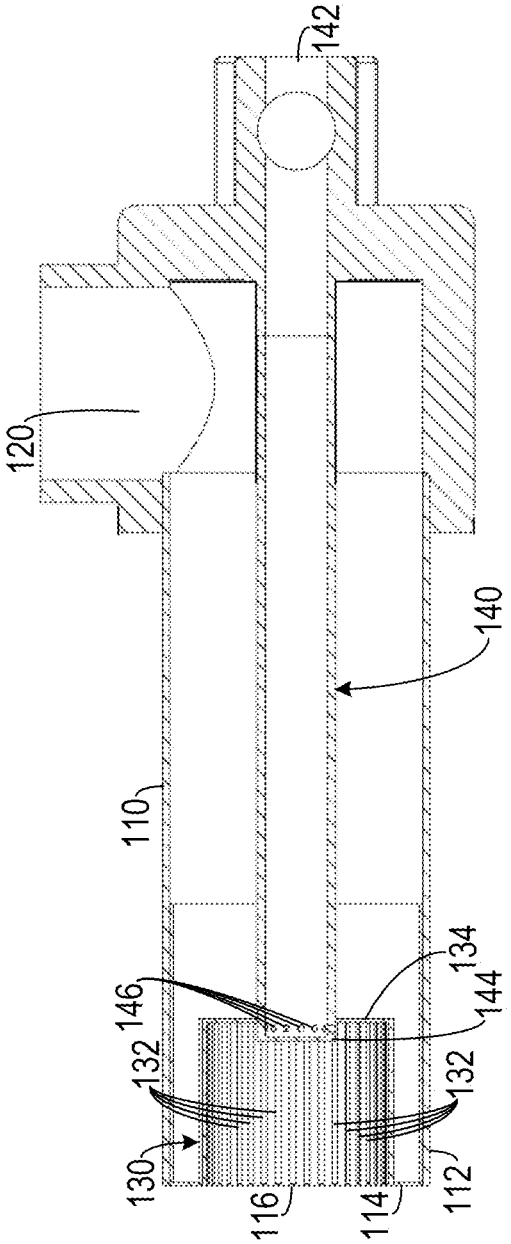

FIG. 3

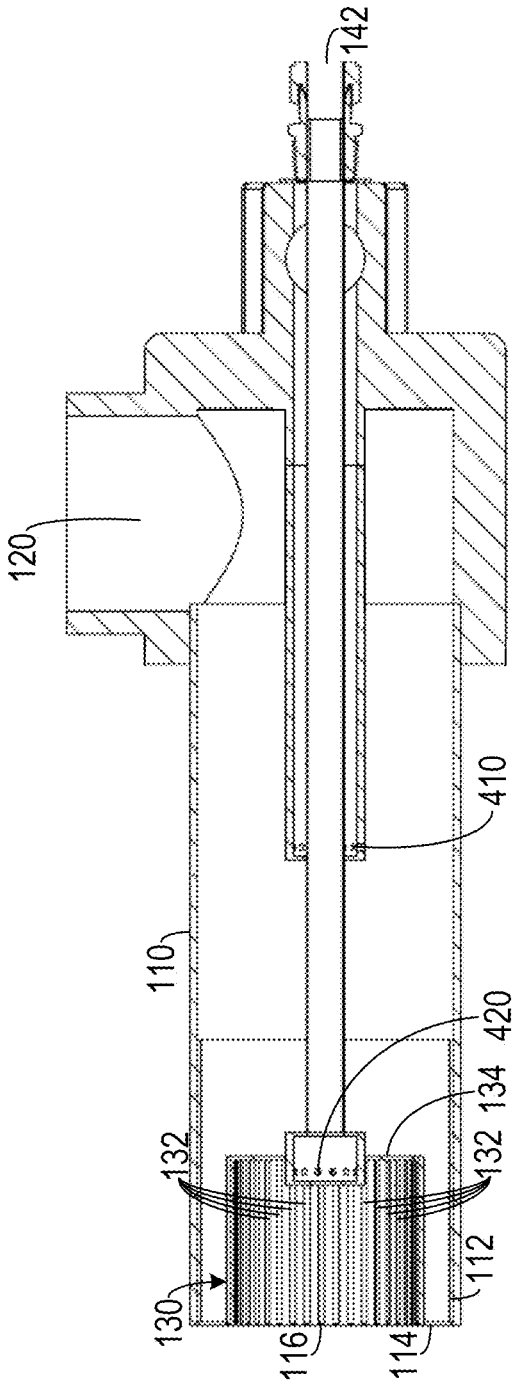

FIG. 4

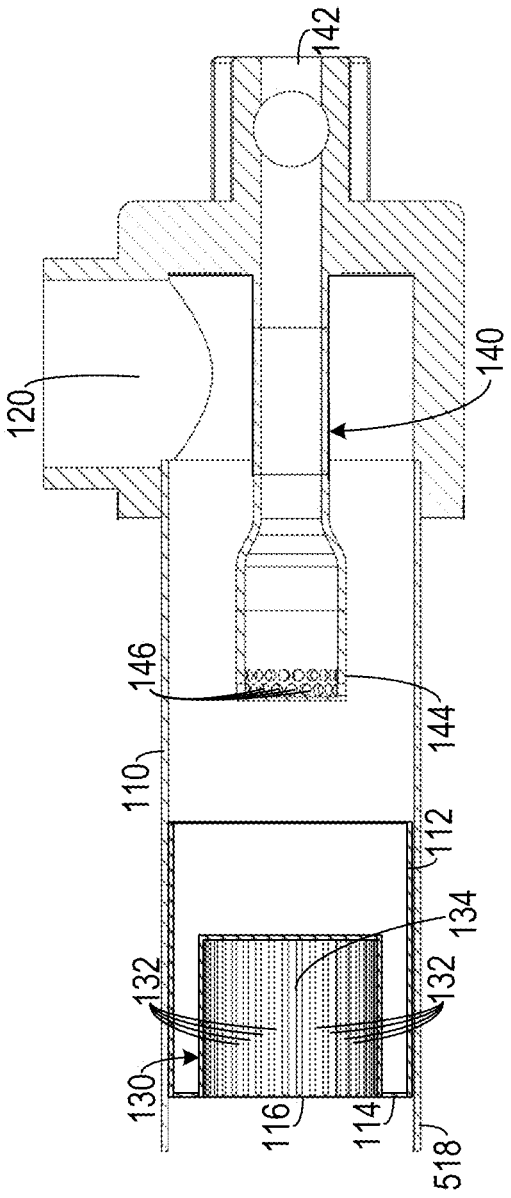

FIG. 5

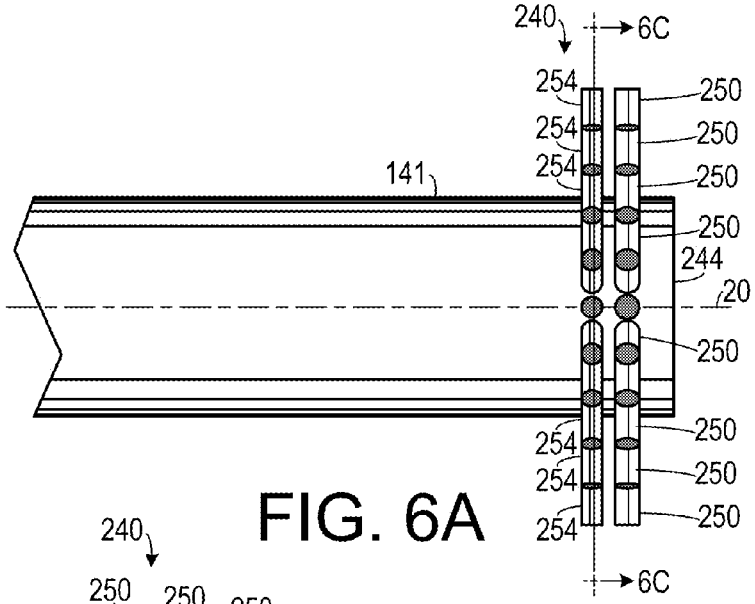

FIG. 6A

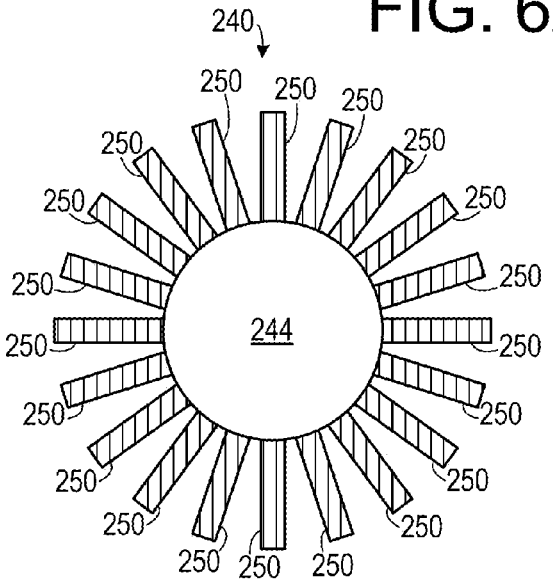

FIG. 6B

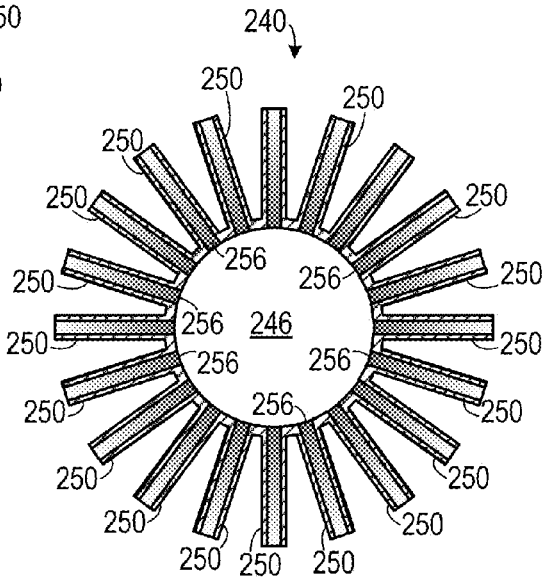

FIG. 6C

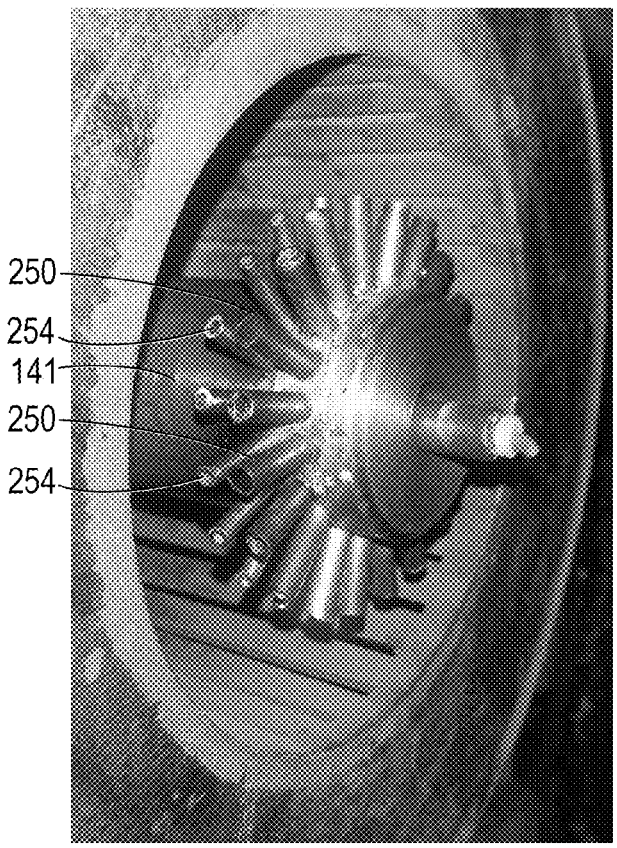

FIG. 7

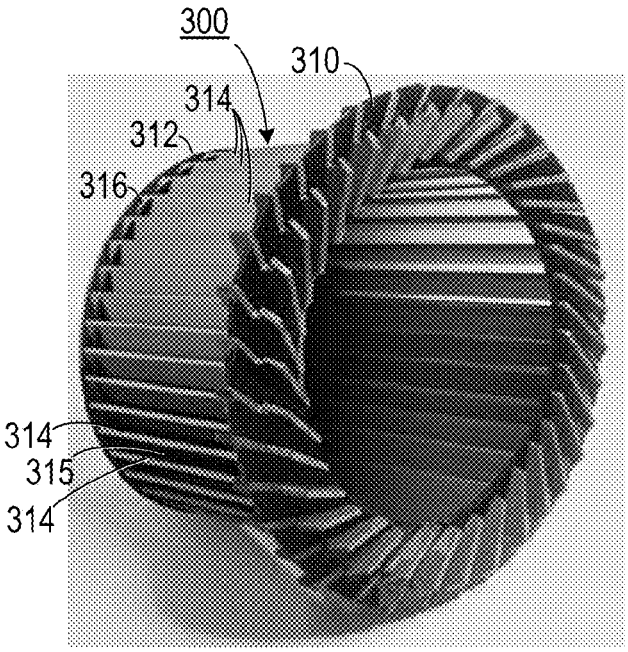

FIG. 8

LOW NOX BURNER WITH LOW PRESSURE DROP

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a continuation-in-part of, and claims the benefit of, U.S. patent application Ser. No. 14/045,345, filed Oct. 3, 2013, the entirety of which is hereby incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to fuel burners and, more specifically, to a burner that produces low NOx levels in industrial heating application where low oxygen is desired.

2. Description of the Related Art

Industrial heating applications utilize thermal processing where elevated temperatures are needed by the burners. Many existing burners generate high temperature flames that cause nitrogen to react with oxygen in the combustion air so as to form mono-nitrogen oxides (referred to as "NOx"), which are pollutants. Some burners employ configurations to reduce heat concentration of the flame, thereby reducing the flame temperature and, thus, reducing the amount of NOx produced during combustion. Many such burners employ complicated systems for combining fuel and combustion air.

Therefore, there is a need for a simple combustion system that produces low NOx levels during combustion even at high flame temperatures.

SUMMARY OF THE INVENTION

The disadvantages of the prior art are overcome by the present invention which, in one aspect, is a burner for burning a fuel and an oxidizer in a gaseous stream. A tube, having an inner dimension, is configured to allow passage therethrough of the gaseous stream. A selected end of the tube terminates in a burner discharge end. A disk is affixed to the burner discharge end of the tube. The disk defines a hole therethrough. An oxidizer intake is configured to deliver the oxidizer into the tube. A fuel nozzle is configured to deliver the fuel into the tube. A slotted member has an interrupted outer surface having an outer dimension and also has a length. The cylindrical slotted member is disposed within a portion of the tube and is affixed to the disk. The slotted member defines an interior void therein that opens to the hole defined by the disk. The outer dimension is less than the inner dimension of the tube thereby defining a passage therebetween. A plurality of elongated slots is defined through the outer surface of the slotted member along the length of the slotted member. Each slot is directed along a different non-diametrical chord of the slotted member and fluidly couples the interior void to the passage so that the plurality of elongated slots direct the gaseous stream from the tube into the interior void of the slotted member so as to impart both an inwardly-directed radial velocity component and a tangential velocity component to the gaseous stream.

In another aspect, the invention is a burner for burning a mixture of a flammable gas and an air stream. A cylindrical tube, having an inner diameter, is configured to allow passage therethrough of an air stream. The cylindrical tube terminates in a burner end. An annular disk defines a hole therethrough affixed to the burner end of the cylindrical tube. An air intake is configured to deliver the air stream into the cylindrical tube. A fuel pipe is in fluid communication with a fuel supply. The fuel pipe includes an end portion defining at least one orifice configured to distribute the flammable gas into the air stream. A cylindrical slotted member, having an outer surface and a length, is disposed within a portion of the cylindrical tube and is affixed to the annular disk. The slotted member defines an interior void therein that opens to the hole defined by the annular disk. The slotted member includes an outer surface having an outer diameter that is less than the inner diameter of the cylindrical tube thereby defining an annular passage therebetween. A plurality of elongated slots is defined through the outer surface of the slotted member along the length of the slotted member. Each slot is directed along a different non-diametrical chord of the slotted member and fluidly couples the interior void to the annular passage so that the plurality of elongated slots direct the air stream from the tube into the interior void of the slotted member so as to impart both an inwardly-directed radial velocity component and a tangential velocity component on the air stream.

In another aspect, the invention is a method of burning a mixture of a fuel and an oxidizer, in which at least the oxidizer is directed along a first axis. The fuel is entrained in the oxidizer thereby generating the mixture of the fuel and the oxidizer. The oxidizer is diverted so as to cause the oxidizer to have an inwardly-directed velocity component and a tangentially-directed velocity component corresponding to a plurality of tangents of a circle that is transverse to the first axis. The mixture of the fuel and the oxidizer is ignited.

In another aspect, the fuel pipe defines a plurality of orifices adjacent the end portion and passing therethrough. A corresponding plurality of hollow tubes extends radially outwardly therefrom. Each of the plurality of hollow tubes is in fluid communication with the interior space defined by the fuel pipe and is configured to deliver fuel from the interior space defined by the fuel pipe into the tube.

In another aspect, the front disk defines a plurality of elongated slits and each elongated slit is directed along a different non-diametrical chord of the front disk. The slotted member includes a plurality of elongated sheet metal blades, each of which has a front end and an opposite back end. The front end of each elongated sheet metal blade is engaged in a different one of the elongated slits defined by the front disk so that each two adjacent ones of the sheet metal blades define one of the slots therebetween. A back wall is coupled to the back end of each one of the plurality of elongated sheet metal blades. A mechanism is configured to maintain each of the plurality of elongated sheet metal blades engaged with the front disk and the back wall.

These and other aspects of the invention will become apparent from the following description of the preferred embodiments taken in conjunction with the following drawings. As would be obvious to one skilled in the art, many variations and modifications of the invention may be effected without departing from the spirit and scope of the novel concepts of the disclosure.

BRIEF DESCRIPTION OF THE FIGURES OF THE DRAWINGS

FIG. **1**A is a side elevational view of one premix embodiment of a burner.

FIG. **1**B is an end elevational view of the embodiment shown in FIG. **1**A.

FIG. **1**C is a cross sectional view of the embodiment shown in FIGS. **1**A and **1**B, taken along line **1**C-**1**C.

FIG. **2**A is a schematic side view of a burner demonstrating flow through the burner.

FIG. **2**B is a cross sectional schematic end view of the burner shown in FIG. **2**A, taken along line **2**B-**2**B, demonstrating flow through the burner.

FIG. **3** is a cross sectional view of a non-premix embodiment.

FIG. **4** is a cross sectional view of a hybrid mix embodiment.

FIG. **5** is a cross sectional view of an adjustable embodiment.

FIG. **6**A is a schematic side view of a fuel nozzle with hollow tubes extending from the end of the fuel nozzle.

FIG. **6**B is a schematic end view of the fuel nozzle shown in FIG. **6**A.

FIG. **6**C is a schematic view of the embodiment shown in FIG. **6**A in which the nozzle is disposed within a cylindrical slotted member.

FIG. **7** is a perspective view of a fuel nozzle of the type shown in FIG. **6**A.

FIG. **8** is a perspective view of an embodiment of a cylindrical slotted member employing sheet metal blades to define slots.

DETAILED DESCRIPTION OF THE INVENTION

A preferred embodiment of the invention is now described in detail. Referring to the drawings, like numbers indicate like parts throughout the views. Unless otherwise specifically indicated in the disclosure that follows, the drawings are not necessarily drawn to scale. As used in the description herein and throughout the claims, the following terms take the meanings explicitly associated herein, unless the context clearly dictates otherwise: the meaning of "a," "an," and "the" includes plural reference, the meaning of "in" includes "in" and "on."

As shown in FIG. **1**, one embodiment of a burner **100** includes a cylindrical tube **112**, which may be disposed in tight fitting concentric a sleeve **110**. (In certain embodiments, the tube **112** is a portion of the sleeve **110** and is not distinct therefrom.) The tube **112** ends in a burner discharge end **115** to which an annular disk **114** is affixed. The annular disk **114** defines a hole **116** passing there through. A cylindrical slotted member **130** is disposed within the tube **112** and is affixed to the annular disk **114**. The cylindrical slotted member **130** defines an interior void **117** therein that opens to the hole **116** and has a back wall **134**. The slotted member **130** also defines a plurality of elongated slots **132** defined through the outer surface of the slotted member **130** along its length. The outer diameter of the slotted member **130** is less than the inner diameter of the cylindrical tube **112** so that there is an annular passage **136** therebetween. An oxidizer intake **120** delivers an oxidizer (which could be, for example, air, oxygen enriched air, or oxygen of any purity) into the tube **112** and a fuel nozzle **140** delivers a fuel (such as a burnable gas) into the tube **112**. The fuel nozzle includes a fuel pipe **141** that is in fluid communication with a fuel supply **142**. The fuel pipe **141** includes an end portion **144** that defines a plurality of orifices **146** that distribute the fuel into the oxidizer. In this embodiment, the end portion **144** of the nozzle is disposed outside of the slotted member **132** so that fuel and the oxidizer premix in the gaseous stream prior to entering the slotted member **132**.

As shown in FIGS. **2**A-**2**B, each slot **132** is directed along a different non-diametrical chord of the cylindrical slotted member **130** and fluidly couples the interior void **117** to the annular passage **136**. As a result, the plurality of elongated slots **132** direct the gaseous stream **10** from inside the cylindrical tube **112** into the interior void **117** of the slotted member **130**. This imparts both an inwardly-directed radial velocity component and a tangential velocity component to the gaseous stream **10**, which results in a swirling gaseous stream. Once the swirling gaseous stream exits the hole **116**, it becomes a radially outwardly growing stream **12**.

As shown in FIG. **3**, the end portion **144** of the nozzle **140** can be disposed inside of the slotted member **130** so that the fuel and oxidizer mix inside of the slotted member **130**. In another embodiment, the end portion **144** position can be adjusted to any position within the slotted member **140**. As shown in FIG. **4**, one embodiment allows for a portion of the fuel to premix with the oxidizer by injecting a portion of the fuel into the tube **112** through a first nozzle **410**. This portion premixes with the oxidizer prior to entering the slotted member **130**. The rest of the fuel is injected directly into the slotted member **130** through a second nozzle **420** and mixes with the balance of the oxidizer inside of the slotted member **130**.

As shown in FIG. **5**, the tube **112** can be adjustably moved within the sleeve **110** to be able to adapt to different applications. In one embodiment, the tube **112** is recessed so as to form a lip **518** at the end of the sleeve **110**. The tube **112** may be adjusted in the factory and then welded to the sleeve **110**. In other embodiments, the position of the tube **112** may be adjusted by the end user during installation. In certain embodiments, the annular disk **114** is welded directly to the sleeve **110** and there is no separate tube; in these embodiments, the entire sleeve is referred to as the tube.

The embodiments disclosed above can be fabricated from any material from which burners are typically constructed. For example, stainless steel can be used. The slotted member **130** can be made by first forming a cylinder from sheet metal and then by milling the slots **132** into the cylinder.

These embodiments direct the oxidizer—or the oxidizer and the fuel—along a first axis along the length of the tube **112**. The fuel is entrained in the oxidizer, so as to generate a fuel/oxidizer mixture. At least the oxidizer (and in some embodiments, both the fuel and the oxidizer) are diverted by the slots **132** of the slotted member **130** so as to have an inwardly-directed velocity components and a tangentially-directed velocity components. The mixture is ignited and a flame directed outwardly through the hole **116** is stabilized. The resulting flame expands radially once it escapes the slotted member **130** resulting in enhanced heat transfer followed by fast cooling of the products.

In one embodiment, as shown in FIGS. **6**A-**6**C and **7**, the fuel nozzle **240** disperses fuel through a plurality of tubes **250** extending radially from the end portion **244** of the fuel pipe **141**. Near the end portion **244**, the fuel pipe **141** defines a plurality of orifices **256** that place the interior portion **246** of the fuel pipe **141** in fluid communication with the hollow tubes **250**. The fuel nozzle **246** can include a first set of tubes **250** and a second set of tubes **254**. Each of the second set of tubes **254** can have a diameter that is different that the diameter of the first set of tubes **250**.

A shown in FIG. **8**, the slotted member **300** can be made from a plurality of elongated sheet metal blades **314**. In this embodiment, the front disk **310** defines a plurality of elongated slits in which each elongated slit is directed along a different non-diametrical chord of the front disk **310**. The front end of each elongated sheet metal blade **314** is engaged in a different one of the elongated slits defined by the front disk **310** so that each two adjacent ones of the sheet metal blades **314** define one of the slots **315** therebetween. A back wall **312** that is coupled to the back end of each one of the plurality of elongated sheet metal blades **314** and a mechanism **316**, such as a locking wire, maintains the plurality of elongated sheet metal blades **314** engaged with the front disk

310 and the back wall 312. This embodiment offers the advantage of being relatively inexpensive to manufacture since the front disk 310, the back wall 312 and the sheet metal blades 314 can all be cut from sheet metal (e.g., through stamping sheet metal, plasma cutting sheet metal or through other known methods of cutting sheet metal).

The above described embodiments, while including the preferred embodiment and the best mode of the invention known to the inventor at the time of filing, are given as illustrative examples only. It will be readily appreciated that many deviations may be made from the specific embodiments disclosed in this specification without departing from the spirit and scope of the invention. Accordingly, the scope of the invention is to be determined by the claims below rather than being limited to the specifically described embodiments above.

What is claimed is:

1. A burner for burning a fuel in a gaseous oxidizer stream, comprising:

(a) a tube, having an inner dimension, configured to allow passage therethrough of the gaseous stream, a selected end of the tube terminating in a burner discharge end;

(b) a front disk affixed to the burner discharge end of the tube, the front disk defining a hole therethrough;

(c) an oxidizer intake configured to deliver the oxidizer into the tube;

(d) a fuel nozzle configured to deliver the fuel into the tube, the fuel nozzle including a fuel pipe defining an interior space and terminating in an end portion, the fuel pipe defining a plurality of orifices adjacent the end portion and passing therethrough, a corresponding plurality of hollow tubes extending radially outwardly therefrom, each of the plurality of hollow tubes in fluid communication with the interior space defined by the fuel pipe and configured to deliver fuel from the interior space defined by the fuel pipe into the tube; and

(e) a slotted member, having an interrupted outer surface having an outer dimension and a length, disposed within a portion of the tube and affixed to the front disk, the slotted member defining an interior void therein that opens to the hole defined by the front disk, the outer dimension being less than the inner dimension of the tube thereby defining an passage therebetween, a plurality of elongated slots defined through the outer surface of the slotted member along the length of the slotted member, each slot directed along a different non-diametrical chord of the slotted member and fluidly coupling the interior void to the passage so that the plurality of elongated slots direct the gaseous stream from the tube into the interior void of the slotted member so as to impart both an inwardly-directed radial velocity component and a tangential velocity component to the gaseous stream.

2. The burner of claim 1, wherein the front disk defines a plurality of elongated slits, each elongated slit directed along a different non-diametrical chord of the front disk, and wherein the slotted member comprises:

(a) a plurality of elongated sheet metal blades, each of which having a front end and an opposite back end, the front end of each elongated sheet metal blade engaged in a different one of the elongated slits defined by the front disk so that each two adjacent ones of the sheet metal blades define one of the slots therebetween;

(b) a back wall that is coupled to the back end of each one of the plurality of elongated sheet metal blades; and

(c) a mechanism configured to maintain each of the plurality of elongated sheet metal blades engaged with the front disk and the back wall.

3. The burner of claim 1, further comprising a cylindrical sleeve, concentric with and disposed about the tube.

4. The burner of claim 1, wherein the end portion of the fuel pipe is disposed outside of the slotted member and inside the tube so that fuel and the oxidizer premix in the gaseous stream prior to the gaseous stream entering the slotted member.

5. The burner of claim 1, wherein the end portion is disposed inside of the interior void defined by slotted member and inside the tube so that fuel and the oxidizer mix in the gaseous stream inside the slotted member.

6. The burner of claim 5, wherein the fuel nozzle is configured to be adjustably moved axially with respect to the cylindrical slotted member.

7. The burner of claim 5, wherein the fuel nozzle further comprises a mechanism that injects fuel into the tube outside of the slotted member so that a portion of the fuel enters the gaseous stream outside of the slotted member and so that another portion of the fuel enters the gaseous stream inside of the slotted member.

8. The burner of claim 1, wherein the oxidizer comprises air.

9. The burner of claim 1, wherein the fuel comprises a burnable gas.

10. The burner of claim 1, wherein the tube is substantially cylindrical and wherein the slotted member is substantially cylindrical and is coaxial with the tube.

11. A burner for burning a fuel in a gaseous oxidizer stream, comprising:

(a) a tube, having an inner dimension, configured to allow passage therethrough of the gaseous stream, a selected end of the tube terminating in a burner discharge end;

(b) a front disk affixed to the burner discharge end of the tube, the front disk defining a hole therethrough, wherein the front disk defines a plurality of elongated slits, each elongated slit directed along a different non-diametrical chord of the front disk;

(c) an oxidizer intake configured to deliver the oxidizer into the tube;

(d) a fuel nozzle configured to deliver the fuel into the tube; and

(e) a slotted member, having an interrupted outer surface having an outer dimension and a length, disposed within a portion of the tube and affixed to the front disk, the slotted member defining an interior void therein that opens to the hole defined by the front disk, the outer dimension being less than the inner dimension of the tube thereby defining an passage therebetween, a plurality of elongated slots defined through the outer surface of the slotted member along the length of the slotted member, each slot directed along a different non-diametrical chord of the slotted member and fluidly coupling the interior void to the passage so that the plurality of elongated slots direct the gaseous stream from the tube into the interior void of the slotted member so as to impart both an inwardly-directed radial velocity component and a tangential velocity component to the gaseous stream, the slotted member including: a plurality of elongated sheet metal blades, each of which having a front end and an opposite back end, the front end of each elongated sheet metal blade engaged in a different one of the elongated slits defined by the front disk so that each two adjacent ones of the sheet metal blades define one of the slots therebetween; a back wall that is coupled to the back end of each one of the plurality of elongated sheet

metal blades; and a mechanism configured to maintain each of the plurality of elongated sheet metal blades engaged with the front disk and the back wall.

12. The burner of claim **11**, wherein the fuel nozzle includes a fuel pipe defining an interior space and terminating in an end portion, the fuel pipe defining a plurality of orifices adjacent the end portion and passing therethrough, a corresponding plurality of hollow tubes extending radially outwardly therefrom, each of the plurality of hollow tubes in fluid communication with the interior space defined by the fuel pipe and configured to deliver fuel from the interior space defined by the fuel pipe into the tube.

13. The burner of claim **12**, further comprising a cylindrical sleeve, concentric with and disposed about the tube.

14. The burner of claim **12**, wherein the end portion of the fuel pipe is disposed outside of the slotted member and inside the tube so that fuel and the oxidizer premix in the gaseous stream prior to the gaseous stream entering the slotted member.

15. The burner of claim **12**, wherein the end portion is disposed inside of the interior void defined by slotted member and inside the tube so that fuel and the oxidizer mix in the gaseous stream inside the slotted member.

16. The burner of claim **15**, wherein the fuel nozzle is configured to be adjustably moved axially with respect to the cylindrical slotted member.

17. The burner of claim **15**, wherein the fuel nozzle further comprises a mechanism that injects fuel into the tube outside of the slotted member so that a portion of the fuel enters the gaseous stream outside of the slotted member and so that another portion of the fuel enters the gaseous stream inside of the slotted member.

18. The burner of claim **12**, wherein the oxidizer comprises air.

19. The burner of claim **12**, wherein the fuel comprises a burnable gas.

20. The burner of claim **12**, wherein the tube is substantially cylindrical and wherein the slotted member is substantially cylindrical and is coaxial with the tube.

* * * * *