



(19) **United States**

(12) **Patent Application Publication**  
**Hucsko et al.**

(10) **Pub. No.: US 2011/0244405 A1**

(43) **Pub. Date: Oct. 6, 2011**

(54) **LOW NOX BURNER FOR A WATER HEATER**

(52) **U.S. Cl. .... 431/2; 431/159**

(76) **Inventors: John Hucsko, Cambridge (CA);  
Brad Willett, Fergus (CA)**

(57) **ABSTRACT**

(21) **Appl. No.: 13/078,785**

(22) **Filed: Apr. 1, 2011**

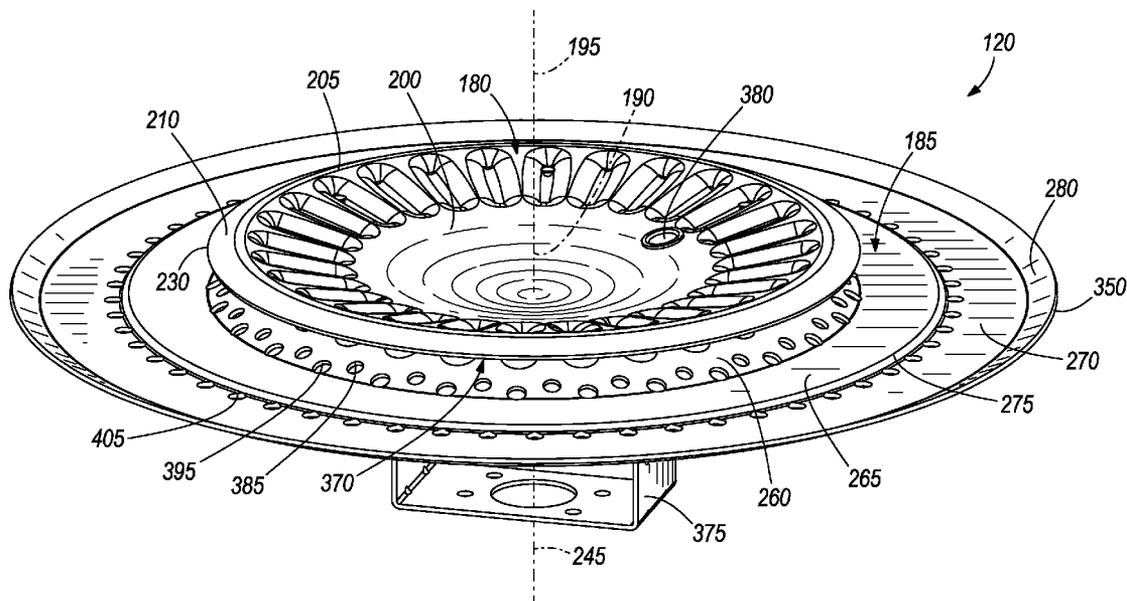
A low NOx burner includes an upper plate and a lower plate joined together. A chamber is defined between an upper inner portion and a lower inner portion. The peaks of upper and lower scalloped ridges are in contact such that multiple ports are defined. The ports extend radially outward from the chamber. The chamber is adapted to receive a fuel/air mixture through a fuel/air intake opening. The ports permit a flow of the fuel/air mixture from the chamber for combustion to create a diffuse flame. An intermediate portion is positioned such that the flame attaches to the intermediate portion. The intermediate portion and a trough are arranged such that flame is directed downwards to the trough from the intermediate portion and attaches to the trough. An outer rim is positioned and angled to attach the flame to the trough and to direct the flame upwards from the trough.

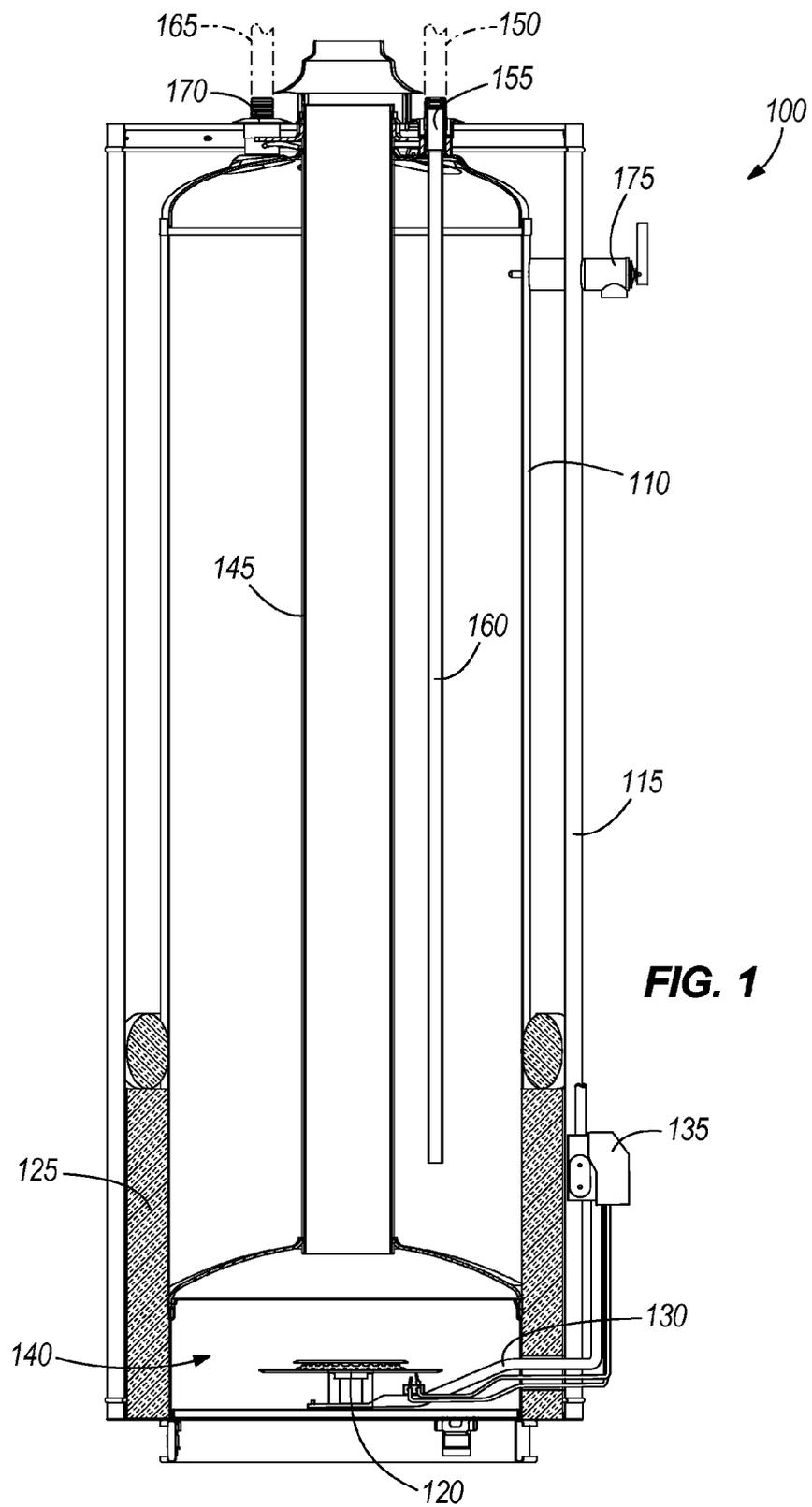
**Related U.S. Application Data**

(60) **Provisional application No. 61/320,131, filed on Apr. 1, 2010.**

**Publication Classification**

(51) **Int. Cl. F23D 99/00 (2010.01)**





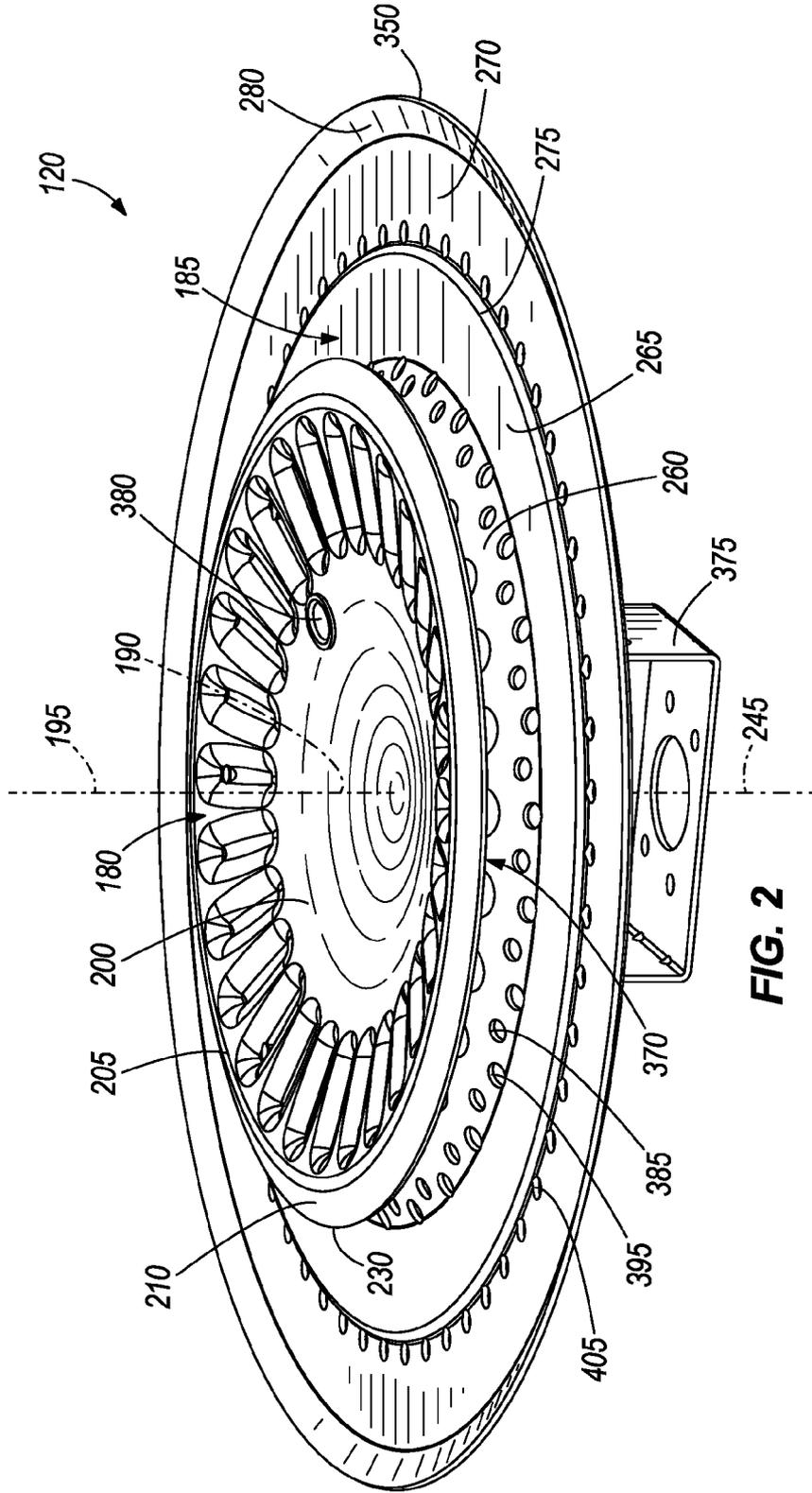
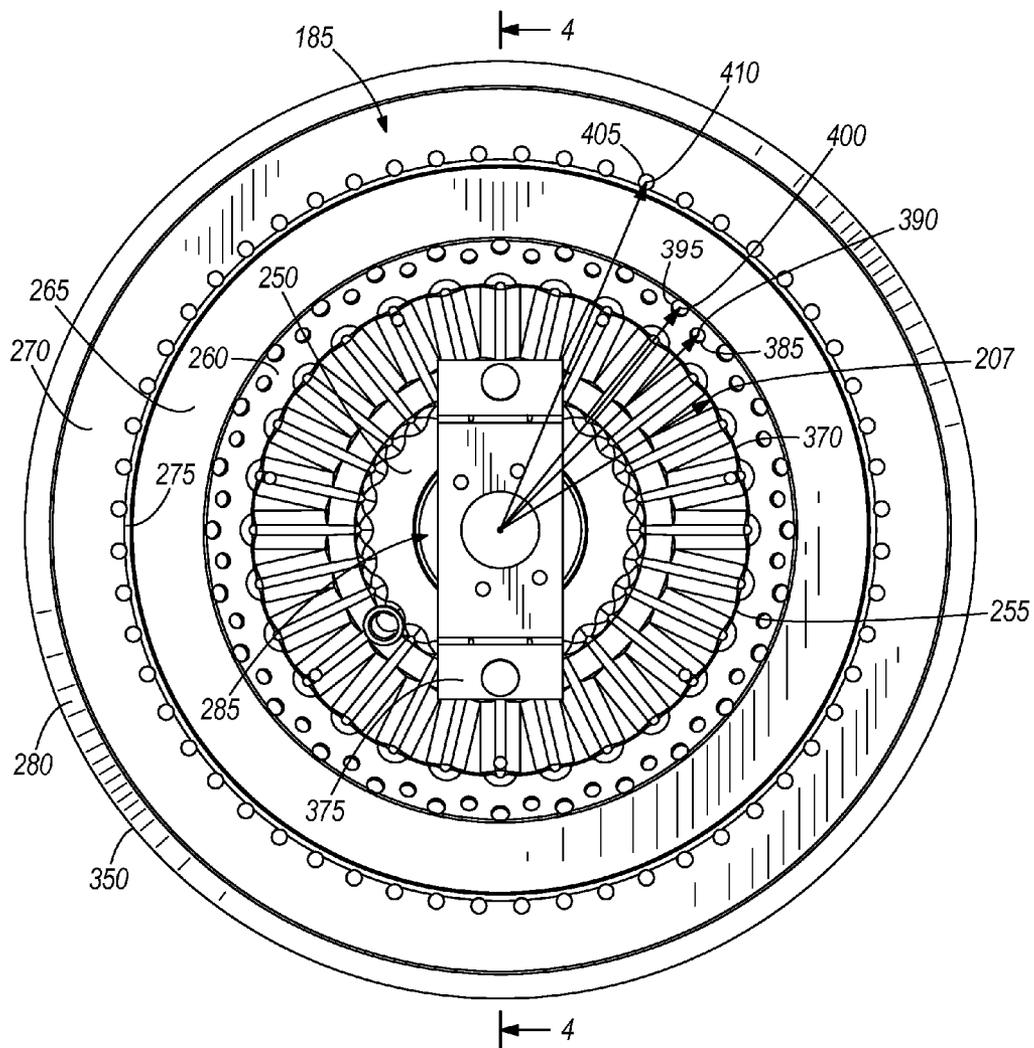


FIG. 2



**FIG. 3**

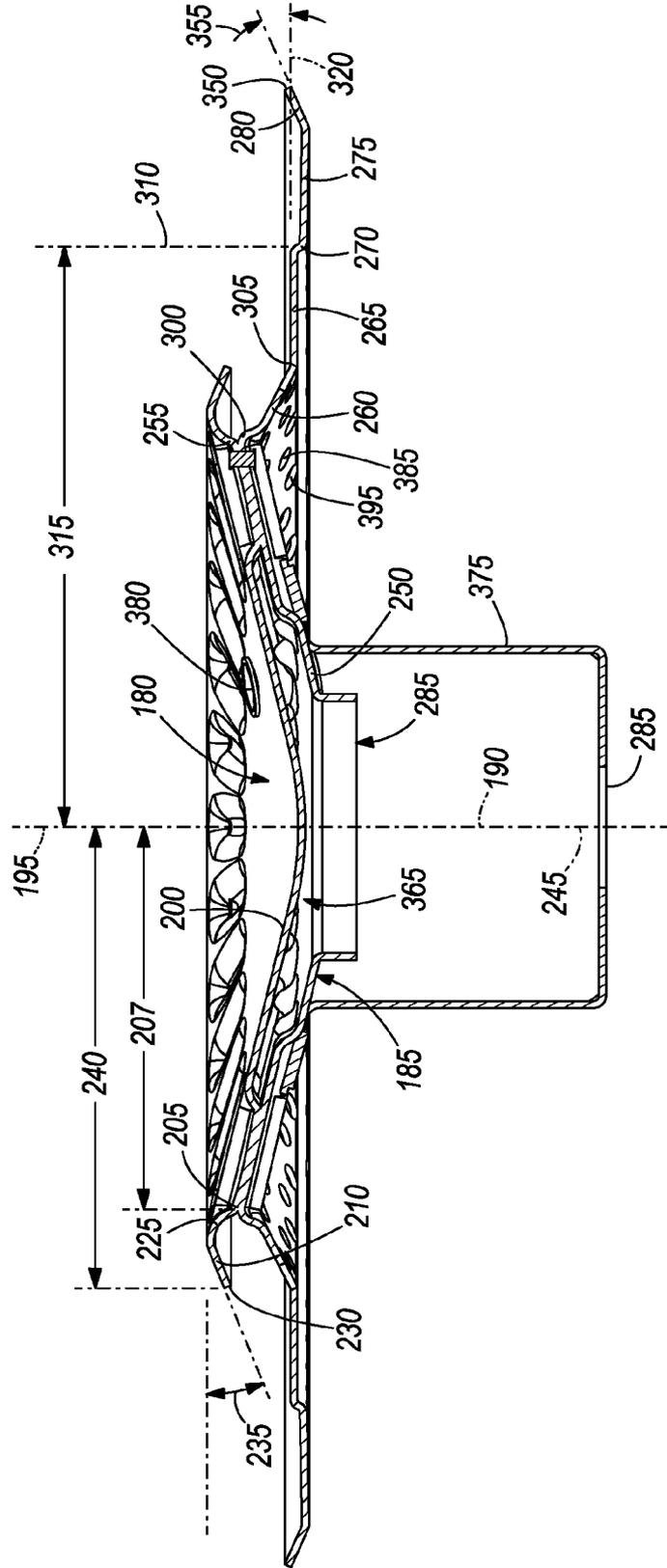


FIG. 4

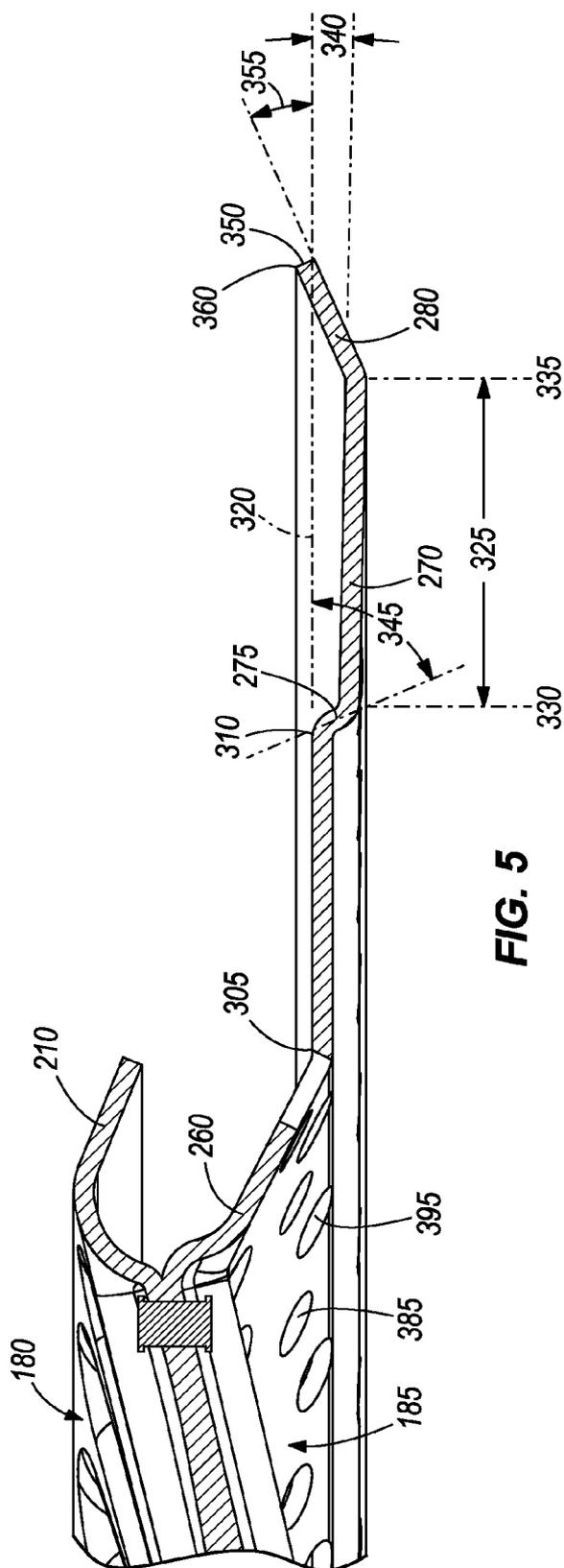
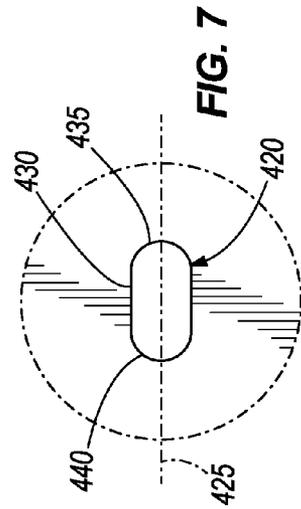
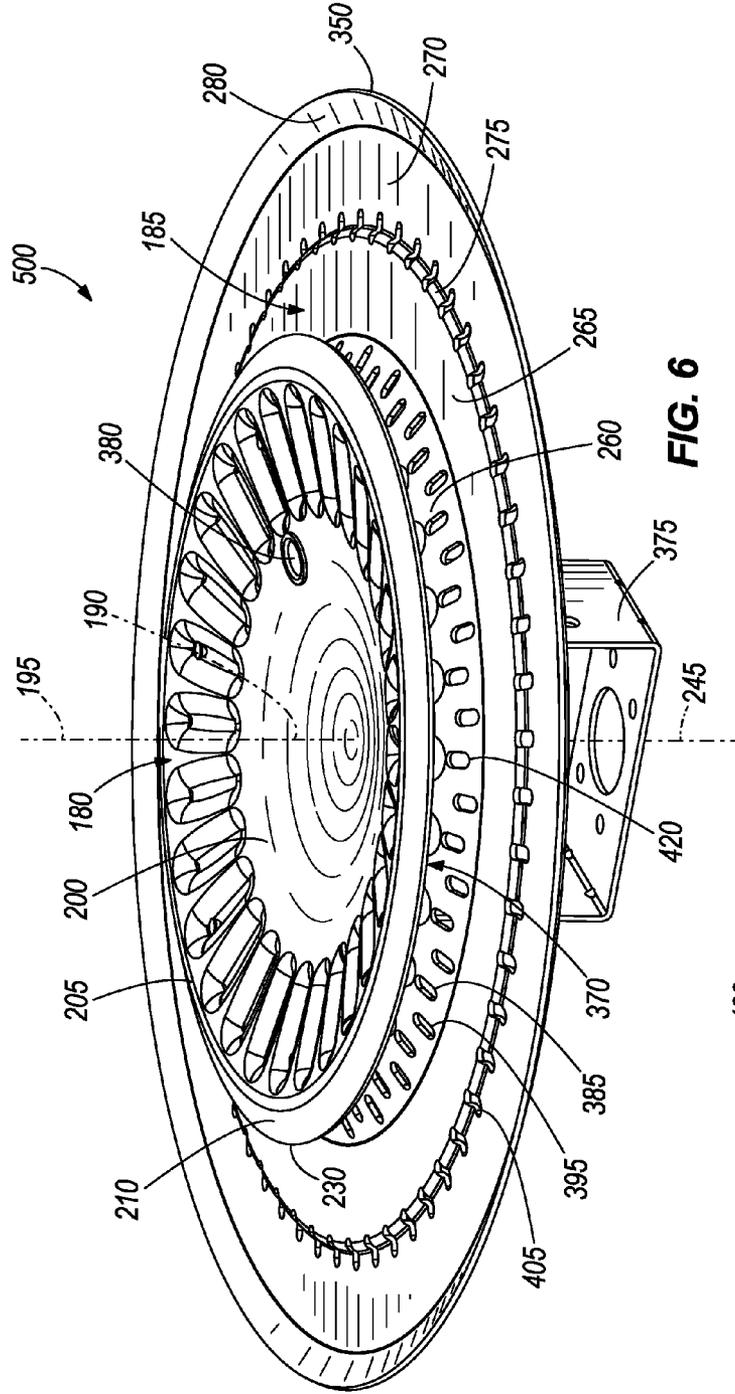


FIG. 5





**LOW NOX BURNER FOR A WATER HEATER**

**RELATED APPLICATIONS**

**[0001]** This application claims priority to co-pending U.S. Provisional Patent Application No. 61/320,131 filed on Apr. 1, 2010, the entire content of which is incorporated herein by reference.

**BACKGROUND**

**[0002]** The present invention relates to low NOx burners, and more particularly to low NOx burners for water heaters.

**[0003]** Nitrogen oxides (NOx) are generated by high temperature flames during combustion. A low NOx burner reduces the amount of NOx formed during combustion. A low NOx burner for a water heater is typically defined as burner producing NOx in amounts no greater than 40 Ng/J.

**SUMMARY**

**[0004]** In one embodiment, the invention provides a low NOx burner including an upper plate and a lower plate. The upper plate defines an upper plate axis and includes an inner upper portion, an upper scalloped ridge surrounding the upper inner portion, and a lip surrounding the upper scalloped ridge. The upper inner portion extends radially outward a first radial distance from the upper plate axis to the upper scalloped ridge. The upper scalloped ridge defines peaks and valleys and has an upper portion. The lip angles radially outward and downward from the upper portion of the upper scalloped ridge and defines an outer circumferential edge of the upper plate. The lower plate defines a lower plate axis and includes a lower inner portion, a lower scalloped ridge surrounding the lower inner portion, an exit portion surrounding the lower scalloped ridge, an intermediate portion surrounding the exit portion, a trough surrounding the intermediate portion, and an outer rim surrounding the trough. The inner portion has a fuel/air intake opening and extends radially outward the first radial distance from the lower plate axis to the lower scalloped ridge. The lower scalloped ridge defines peaks and valleys and has a lower portion. The exit portion angles radially outward and downward from the lower portion of the lower scalloped ridge. The intermediate portion extends from the exit portion to a distal end at a second radial distance. The second radial distance is greater than the first radial distance. The trough is below and radially outward of the intermediate portion. The outer rim includes an outer circumferential edge of the lower plate. The upper scalloped ridge and the lower scalloped ridge are joined together so that the upper plate axis and the lower plate axis are collinear. A chamber is defined between the upper inner portion and the lower inner portion. The peaks of the upper and lower scalloped ridges are in contact such that multiple ports are defined between the valleys of the upper and lower scalloped ridges. The ports extend radially outward from the chamber through the scalloped ridges. The chamber is adapted to receive a fuel/air mixture through the fuel/air intake opening. The ports are adapted to permit a flow of the fuel/air mixture from the chamber for combustion to create a diffuse flame. The intermediate portion is positioned such that the flame attaches to the intermediate portion. The intermediate portion and trough are arranged such that flame is directed downwards to the trough from the intermediate portion and attaches to the trough. The outer rim is positioned and angled to attach the flame to the trough and to direct the flame upwards from the trough.

**[0005]** In another embodiment, the invention provides a low NOx burner including an upper plate and a lower plate. The upper plate defines an upper plate axis and includes an inner upper portion, an upper scalloped ridge surrounding the upper inner portion, and a lip surrounding the upper scalloped ridge. The upper inner portion extends radially outward a first radial distance from the upper plate axis to the upper scalloped ridge. The upper scalloped ridge defines peaks and valleys and has an upper portion. The lip angles radially outward and downward from the upper portion of the upper scalloped ridge and defines an outer circumferential edge of the upper plate. The lower plate defines a lower plate axis and includes a lower inner portion, a lower scalloped ridge surrounding the lower inner portion, an exit portion surrounding the lower scalloped ridge, an intermediate portion surrounding the exit portion, and an outer rim surrounding the intermediate portion. The inner portion has a fuel/air intake opening and extends radially outward the first radial distance from the lower plate axis to the lower scalloped ridge. The lower scalloped ridge defines peaks and valleys and has a lower portion. The exit portion angles radially outward and downward from the lower portion of the lower scalloped ridge. The intermediate portion extends from the exit portion to a distal end at a second radial distance. The second radial distance is greater than the first radial distance. The outer rim includes an outer circumferential edge of the lower plate. The upper scalloped ridge and the lower scalloped ridge are joined together so that the upper plate axis and the lower plate axis are collinear. A chamber is defined between the upper inner portion and the lower inner portion. The peaks of the upper and lower scalloped ridges are in contact such that multiple ports are defined between the valleys of the upper and lower scalloped ridges. The ports extend radially outward from the chamber through the scalloped ridges. The chamber is adapted to receive a fuel/air mixture through the fuel/air intake opening. The ports are adapted to permit a flow of the fuel/air mixture from the chamber for combustion to create a diffuse flame. The intermediate portion is positioned such that the flame attaches to the intermediate portion. The outer rim is positioned and angled to attach the flame to the lower plate and to direct the flame upwards from the lower plate.

**[0006]** In another embodiment, the invention provides a method of operating a low NOx burner. The method includes the step of providing a low NOx burner including an upper plate having an outer diameter and a lower plate having an outer rim and an outer diameter, the plates joined together to define a chamber and multiple ports formed between the plates, the ports extending radially outward from the chamber, and the outer diameter of the upper plate being less than the outer diameter of the lower plate. The method also including the steps of providing a fuel/air mixture to the chamber, directing the fuel/air mixture through the ports, combusting the fuel/air mixture to create a flame, and directing the flame upwards at the outer rim to attach the flame to the lower plate.

**[0007]** Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

**BRIEF DESCRIPTION OF THE DRAWINGS**

**[0008]** FIG. 1 is a sectional view of a conventional gas-fired water heater.

**[0009]** FIG. 2 is a perspective view of a low NOx burner.

**[0010]** FIG. 3 is a bottom view of the burner of FIG. 2.

[0011] FIG. 4 is a cross-section view of the burner taken along line 4-4 in FIG. 3.

[0012] FIG. 5 is an enlarged sectional view of a portion of the burner of FIG. 4.

[0013] FIG. 6 is a perspective view of an alternative embodiment of a low NOx burner.

[0014] FIG. 7 is an enlarged view of a slot of the burner of FIG. 6.

[0015] FIG. 8 is an enlarged section view of a portion of the burner of FIG. 4.

[0016] FIG. 9 is a detail view of a portion of the burner of FIG. 2.

#### DETAILED DESCRIPTION

[0017] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways.

[0018] FIG. 1 illustrates a water heater 100 including a tank 110 containing water, a jacket 115 surrounding the tank 110, and a burner 120. Insulation 125 is provided between the tank 110 and the jacket 115. A flammable fuel is provided to the burner 120 by a fuel line inlet 130 connected to a fuel valve 135. The burner 120 is positioned in a combustion chamber 140 beneath the tank 110. The fuel valve 135 is connected to a fuel supply. The fuel can be, for example, natural gas or propane. The combustion chamber 140 is connected to an air supply, for example, the atmosphere around the water heater 100. A flue tube 145 extends from the combustion chamber 140 through the tank 110. The products of combustion or exhaust gases created by the burner 120 flow through the flue tube 145 to heat the water stored in the tank 110. A baffle (not shown) can be positioned in the flue tube 145 to increase the heat transfer between the products of combustion and the water stored in the tank 110. A cold water inlet pipe 150 is connected by a spud 155 to a dip tube 160 to supply cold water to the tank 110. A hot water supply pipe 165 connected to a spud 170 supplies hot water to an end-use location, for example, a faucet. A temperature and pressure (T&P) valve 175 permits water to be released from the tank 110 in the event of high pressure or high temperature within the tank 110. Other than the burner 120 to be described in detail below, the water heater 100 as described above is a conventional gas-fired water heater 100.

[0019] FIG. 2 illustrates a low NOx pan burner 120 for use in a water heater 100. The burner 120 includes an upper plate 180 and a lower plate 185 joined together. The burner 120 defines a central axis or axis of symmetry 190. Upper, lower, above, below, inward, outward, and other directional terms are relative to the central axis when the burner 120 is in a normal operating position as shown in FIG. 1.

[0020] As shown in FIGS. 2 and 4, the upper plate 180 defines an upper plate axis 195 that is collinear with the central axis 190 when the upper plate 180 is joined to the lower plate 185. The upper plate 180 includes an inner portion 200, a scalloped ridge 205, and a lip 210. The inner portion 200 extends radially outward from the upper plate axis 195 to the scalloped ridge 205. As shown in FIG. 4, the scalloped ridge 205 is located at a radial distance 207 from the upper plate axis 195. The scalloped ridge 205 surrounds the inner portion 200 and defines alternating peaks 215 and valleys 220

(shown in FIG. 9) that are spaced equiangularly around the upper plate axis 195. As shown in FIG. 4, the lip 210 surrounds the inner portion 200. The lip 210 extends radially outward from an upper portion 225 of the scalloped ridge 205 to an outer circumferential edge 230 of the upper plate 180. The lip 210 is angled downwards from horizontal towards the lower plate 185. A lip angle 235 is defined between the lip 210 and horizontal. The lip angle 235 can vary and is preferably twenty degrees or twenty-two degrees. The outer circumferential edge 230 is positioned at a radial distance 240 from the upper plate axis 195. The outer diameter of the upper plate 180 is less than the outer diameter of the lower plate 185.

[0021] As shown in FIGS. 2-4, the lower plate 185 defines a lower plate axis 245 that is collinear with the central axis 190 when the lower plate 185 is joined to the upper plate 180. The lower plate 185 includes an inner portion 250, a scalloped ridge 255, an exit portion 260, an intermediate portion 265, a trough 270, a transition 275, and an outer rim 280. As shown in FIG. 3, the inner portion 250 includes a fuel/air intake opening 285 and extends radially outward from the lower plate axis 245 to the scalloped ridge 255. The scalloped ridge 255 is located at the radial distance 207 from the lower plate axis 245. The scalloped ridge 255 surrounds the inner portion 250 and defines alternating peaks 290 and valleys 295 (shown in FIG. 9) that are spaced equiangularly around the lower plate axis 245. As shown in FIG. 3, the exit portion 260 surrounds the inner portion 250. The exit portion 260 extends radially outward from a lower portion 300 of the scalloped ridge 205 to a distal end 305. As shown in FIGS. 2 and 4, the exit portion 260 is angled downward from the lower portion 300 of the scalloped ridge 205.

[0022] As shown in FIG. 4, the intermediate portion 265 surrounds the exit portion 260. The intermediate portion 265 extends from the distal end 305 of the exit portion 260 to a distal end 310. The distal end 310 of the intermediate portion 265 is located at a radial distance 315 from the central axis 190. The radial distance 315 is greater than the radial distance 240 so that the distal end 310 of the intermediate portion 265 is radially outward from the outer circumferential edge 230 of the upper plate 180. The intermediate portion 265 defines a horizontal plane 320.

[0023] As shown in FIG. 5, the trough 270 surrounds the intermediate portion 265 and is located below the intermediate portion 265. The trough 270 is planar and has a radial width 325. The width 325 extends from a proximal end 330 of the trough 270 to a distal end 335 of the trough 270. The width 325 can vary. The trough 270 is angled downwards from horizontal. The trough 270 is positioned at a trough angle 340 defined between the trough 270 and the horizontal plane 320. The trough angle 340 can vary and is preferably is 1.2 degrees. Alternatively, the trough 270 is positioned parallel to the horizontal plane 320. The entire trough 270 is located below the horizontal plane 320. The transition 275 connects the intermediate portion 265 and the trough 270. The transition 275 is positioned at an angle 345 from horizontal. The angle 345 can vary and can be ninety degrees.

[0024] As shown in FIG. 5, the outer rim 280 surrounds the trough 270 and extends radially outward and upwards from the distal end 335 of the trough 270 to an outer circumferential edge 350 of the lower plate 185. A rim angle 355 is defined between the outer rim 280 and the horizontal plane 320. The rim angle 355 can vary. Preferably, the rim angle 355 is greater than the trough angle 340. An uppermost portion 360 of the outer circumferential edge 350 is positioned above the

intermediate portion 265. In one alternative, the uppermost portion 360 is even with the intermediate portion 265. In another alternative, the uppermost portion 360 is below the intermediate portion 265. Alternatively, the burner 120 does not include the trough 270 and the transition 275 so that the outer rim 280 extends radially outward and upward from the intermediate portion 265.

[0025] As shown in FIG. 4, the upper scalloped ridge 205 and the lower scalloped ridge 255 are joined together such that a chamber 365 is defined between the upper inner portion 200 and the lower inner portion 250. As shown in FIG. 9, the peaks 215 of the upper scalloped ridge 205 contact the peaks 290 of the lower scalloped ridge 255 to define a plurality of ports 370 between the valleys 220 of the upper scalloped ridge 205 and the valleys 295 of the lower scalloped ridge 255. As shown in FIG. 3, the ports 370 extend radially outward from the chamber 365 through the scalloped ridges 205, 255. As shown in FIG. 2, a bracket 375 is coupled to the lower plate 185 for mounting the burner 120 in the combustion chamber 140. A drain tube 380 extends through both plates 180, 185.

[0026] As shown in FIG. 3, a plurality of first air apertures 385 are formed through the exit portion 260 radially outward from the ports 370 at a distance 390 from the central axis 190. A plurality of second air apertures 395 are formed through the exit portion 260 radially outward from the first air apertures 385 at a distance 400 from the central axis 190. The distance 400 is greater than the distance 390. Each first air aperture 385 is positioned in line with a port 370. Each second air aperture 395 is positioned between two adjacent ports 370 so each port 370 is flanked by two adjacent second air apertures 395. The relative positioning between the first air apertures 385 and the second air apertures 395 can vary. For example, in one alternative, each first air aperture 385 is positioned between two adjacent ports 370 and each second air aperture 395 is positioned in line with a port 370. The size and shape of the first air apertures 385 and the second air apertures 395 can vary. As illustrated, the first air apertures 385 and the second air apertures 395 are circular holes.

[0027] As shown in FIG. 3, a plurality of third air apertures 405 are formed through the trough 270 at a distance 410 from the central axis 190. The third air apertures 405 are located radially outward from the second air apertures 395 and the distance 410 is greater than the distance 400. Each third air aperture 405 is positioned between a first air aperture 385 and the adjacent second air aperture 395. The relative positioning between the first air apertures 385, the second air apertures 395, and the third air apertures 405 can vary. The third air apertures 405 are positioned near the transition 275. In one alternative, a portion of each third air aperture 405 extends into the transition 275. In a second alternative, the third air apertures 405 are formed in the transition 275. In a third alternative, the third air apertures 405 are formed in the intermediate portion 265 near the trough 270. The size and shape of the third air apertures 405 can vary. As illustrated, the third air apertures 405 are circular holes.

[0028] In use, a fuel/air mixture is introduced to the chamber 365 through the fuel/air intake opening 285. As shown in FIG. 8, the fuel/air mixture flows uniformly out of the chamber 365 through the ports 370 and is combusted to create a diffuse flame 415. Secondary air is introduced to the flame 415 through the first air apertures 385 and the second air apertures 395 to help complete combustion of the fuel/air mixture near the ports 370. The flame 415 is directed down-

wardly to a first elevation at the intermediate portion 265 by the lip 210 of the upper plate 180 so that the flame 415 attaches to the intermediate portion 265. The flame 415 is then directed downwards to a second elevation at the trough 270 and attaches to the trough 270. The downward angle 345 of the trough 270 helps to attach the flame 415 to the trough 270. Secondary air is introduced to the flame 415 through the third air apertures 405 to assist in completing combustion of the fuel/air mixture near the trough 270. The flame 415 is directed upwards out of the trough 270 by the outer rim 280. The change in the flame 415 direction at the outer rim 280 also helps to attach the flame 415 to the trough 270.

[0029] The flame 415 attaches better to the lower plate 185 of the burner 120 than a similar burner 120 with a lower plate that terminates at the distal end of the intermediate portion. It is believed that this improved attachment of the flame 415 may be due to the changes in direction that the flame 415 undergoes as it moves from the intermediate portion 265 to the trough 270 and then to the outer rim 280. Alternatively, the improved attachment of the flame 415 may be due to an area of low pressure in the trough 270 near the transition 275 that helps to pull the flame 415 down into attachment with the trough 270. This area of low pressure would also help to draw secondary air through the third air apertures 405. Alternatively, the improved attachment of the flame 415 may be due to a change from laminar flow along the intermediate portion 265 to turbulent flow in the trough 270 near the transition 275 and a change back to laminar flow further along the trough 270 towards the outer rim 280. The outer rim 280 directs the flame 415 upward, unlike other similar burners that let the flame fall off of the outer circumferential edge of a planar lower plate. This helps to secure the flame 415 to the lower plate 185, directs the flame 415 upwards towards the flue tube 145, and prevents heat damage to the combustion chamber 140 and components attached to or near the combustion chamber 140.

[0030] The burner 120 is suited for uses of up to and including 50,000 BTU per hour. The burner 120 is especially suited for high-efficiency water heaters that may include a near-condensing or less-than-fully-condensing heat transfer relationship between the products of combustion and the water stored in the tank 110 and/or restricted air flow through the flue tube 145 due to baffling. Restricted air flow through the flue tube 145 can make it difficult to sustain combustion at the burner 120. The second air apertures 395 and the third air apertures 405 allow the burner 120 to sustain combustion even with restricted air flow. The second air apertures 395 provide for higher entrainment of secondary air into the flame at the port exit area. The third air apertures 405 provide secondary air to support the flame in the trough 270.

[0031] The increased surface area of and amount of flame attachment to the lower plate 185 of the burner 120 as compared to a similar burner 120 with a lower plate that terminates at the distal end of the intermediate portion allows for increased time for flame attachment to the lower plate 185 and increased volume of the lower plate 185, which improves the ability of the lower plate 185 to function as a heat sink to lower the flame temperature. Lowering the flame temperature reduces the production of NOx. Therefore, the greater the width 385 of the trough 270, the better performance of the burner 120 in terms of NOx production. Typically, the width 385 of the trough 270 is limited by the size of the access opening to the combustion chamber 140 through which the burner 120 is installed. The trough 270 also improves the

rigidity or stiffness of the lower plate 185. Alternatively, the lower plate 185 can include a series of radial corrugations instead of or in addition to the trough 270. The corrugations increase the surface area of the lower plate 185 while also helping to improve the rigidity or stiffness of the lower plate 185.

[0032] FIG. 6 illustrates a burner 500 that is an alternative embodiment of the burner 120. The burner 500 is identical to the burner 120 except that the air apertures 385, 395, 405 are formed as elongated slots 420 rather than circular holes. As shown in FIG. 7, each slot 420 includes a major axis 425, an elongated portion 430, a leading end 435, and a trailing end 440. Each slot 420 extends along the major axis 425 from the leading end 435 to the trailing end 440. Each major axis 425 extends radially from the central axis 190. In use, the slots 420 present secondary air to a radially longer portion of the flame than a circular hole. This helps to stretch out the introduction of the secondary air to the flame to increase the entrainment of the secondary air to the flame.

[0033] Various features and advantages of the invention are set forth in the following claims.

What is claimed is:

1. A low NOx burner comprising:

an upper plate defining an upper plate axis and including an inner upper portion, an upper scalloped ridge surrounding the upper inner portion, and a lip surrounding the upper scalloped ridge, the upper inner portion extending radially outward a first radial distance from the upper plate axis to the upper scalloped ridge, the upper scalloped ridge defining peaks and valleys and having an upper portion, and the lip angling radially outward and downward from the upper portion of the upper scalloped ridge and defining an outer circumferential edge of the upper plate; and

a lower plate defining a lower plate axis and including a lower inner portion, a lower scalloped ridge surrounding the lower inner portion, an exit portion surrounding the lower scalloped ridge, an intermediate portion surrounding the exit portion, a trough surrounding the intermediate portion, and an outer rim surrounding the trough, the inner portion having a fuel/air intake opening and extending radially outward the first radial distance from the lower plate axis to the lower scalloped ridge, the lower scalloped ridge defining peaks and valleys and having a lower portion, the exit portion angling radially outward and downward from the lower portion of the lower scalloped ridge, the intermediate portion extending from the exit portion to a distal end at a second radial distance, the second radial distance greater than the first radial distance, the trough being below and radially outward of the intermediate portion, the outer rim including an outer circumferential edge of the lower plate;

wherein the upper scalloped ridge and the lower scalloped ridge are joined together so that the upper plate axis and the lower plate axis are collinear, such that a chamber is defined between the upper inner portion and the lower inner portion, such that the peaks of the upper and lower scalloped ridges are in contact, and such that a plurality of ports are defined between the valleys of the upper and lower scalloped ridges, the ports extending radially outward from the chamber through the scalloped ridges;

wherein the chamber is adapted to receive a fuel/air mixture through the fuel/air intake opening;

wherein the ports are adapted to permit a flow of the fuel/air mixture from the chamber for combustion to create a diffuse flame;

wherein the intermediate portion is positioned such that the flame attaches to the intermediate portion;

wherein the intermediate portion and trough are arranged such that flame is directed downwards to the trough from the intermediate portion and attaches to the trough; and

wherein the outer rim is positioned and angled to attach the flame to the trough and to direct the flame upwards from the trough.

2. The low NOx burner of claim 1, wherein the intermediate portion defines a horizontal plane;

wherein the entire trough is located below the horizontal plane;

wherein the trough is angled downwards with respect to the horizontal plane; and

wherein a trough angle is defined between the horizontal plane and the trough.

3. The low NOx burner of claim 2, wherein a rim angle is defined between the outer rim and the horizontal plane; and wherein the rim angle is greater than the trough angle.

4. The low NOx burner of claim 2 further comprising:

a plurality of first air apertures in the lower plate, the first air apertures located radially outward from the ports; and

a plurality of second air apertures in the lower plate, the second air apertures located radially outward from the first air apertures;

wherein the first air apertures and the second air apertures are positioned near the ports to introduce secondary air to help to complete combustion of the fuel/air mixture.

5. The low NOx burner of claim 4 further comprising:

a plurality of third air apertures in the lower plate, the third air apertures located radially outward from the second air apertures;

wherein the third air apertures are positioned to introduce secondary air near the trough to help complete combustion of the fuel/air mixture.

6. The low NOx burner of claim 5, wherein the third air apertures are in the trough.

7. The low NOx burner of claim 6, wherein the first air apertures are formed as slots, the second air apertures are formed as slots, and the third air apertures are formed as slots.

8. The low NOx burner of claim 6, wherein the first air apertures are formed as circular holes, the second air apertures are formed as circular holes, and the third air apertures are formed as circular holes.

9. The low NOx burner of claim 2 further comprising:

a plurality of air apertures in the trough;

wherein the air apertures are positioned to introduce secondary air near the trough to help to complete combustion of the fuel/air mixture.

10. The low NOx burner of claim 1 further comprising:

a plurality of first air apertures in the lower plate, the first air apertures located radially outward from the ports; and

a plurality of second air apertures in the lower plate, the second air apertures located radially outward from the first air apertures;

wherein the first air apertures and the second air apertures are positioned near the ports to introduce secondary air to help to complete combustion of the fuel/air mixture.

**11.** The low NOx burner of claim **10** further comprising:  
 a plurality of third air apertures in the lower plate, the third air apertures located radially outward from the second air apertures;  
 wherein the third air apertures are positioned to introduce secondary air near the trough to help complete combustion of the fuel/air mixture.

**12.** The low NOx burner of claim **11**, wherein the third air apertures are in the trough.

**13.** The low NOx burner of claim **1** further comprising:  
 a plurality of air apertures in the trough;  
 wherein the air apertures are positioned to introduce secondary air near the trough to help complete combustion of the fuel/air mixture.

**14.** A low NOx burner comprising:  
 an upper plate defining an upper plate axis and including an inner upper portion, an upper scalloped ridge surrounding the upper inner portion, and a lip surrounding the upper scalloped ridge, the upper inner portion extending radially outward a first radial distance from the upper plate axis to the upper scalloped ridge, the upper scalloped ridge defining peaks and valleys and having an upper portion, and the lip angling radially outward and downward from the upper portion of the upper scalloped ridge and defining an outer circumferential edge of the upper plate; and  
 a lower plate defining a lower plate axis and including a lower inner portion, a lower scalloped ridge surrounding the lower inner portion, an exit portion surrounding the lower scalloped ridge, an intermediate portion surrounding the exit portion and an outer rim surrounding the intermediate portion, the inner portion having a fuel/air intake opening and extending radially outward the first radial distance from the lower plate axis to the lower scalloped ridge, the lower scalloped ridge defining peaks and valleys and having a lower portion, the exit portion angling radially outward and downward from the lower portion of the lower scalloped ridge, the intermediate portion extending from the exit portion to a distal end at a second radial distance, the second radial distance greater than the first radial distance, the outer rim including the an outer circumferential edge of the lower plate;  
 wherein the upper scalloped ridge and the lower scalloped ridge are joined together so that the upper plate axis and the lower plate axis are collinear, such that a chamber is defined between the upper inner portion and the lower inner portion, such that the peaks of the upper and lower scalloped ridges are in contact, and such that a plurality of ports are defined between the valleys of the upper and lower scalloped ridges, the ports extending radially outward from the chamber through the scalloped ridges;  
 wherein the chamber is adapted to receive a fuel/air mixture through the fuel/air intake opening;  
 wherein the ports are adapted to permit a flow of the fuel/air mixture from the chamber for combustion to create a diffuse flame;

wherein the intermediate portion is positioned such that the flame attaches to the intermediate portion; and  
 wherein the outer rim is positioned and angled to attach the flame to the lower plate and to direct the flame upwards from the lower plate.

**15.** The low NOx burner of claim **14** further comprising:  
 a plurality of first air apertures in the lower plate, the first air apertures located radially outward from the ports; and  
 a plurality of second air apertures in the lower plate, the second air apertures located radially outward from the first air apertures;  
 wherein the first air apertures and the second air apertures are positioned near the ports to introduce secondary air to help to complete combustion of the fuel/air mixture.

**16.** A method of operating a low NOx burner, the method comprising the steps of:  
 providing a low NOx burner including an upper plate having an outer diameter and a lower plate having an outer rim and an outer diameter, the plates joined together to define a chamber and a plurality of ports formed between the plates, the ports extending radially outward from the chamber, and the outer diameter of the upper plate being less than the outer diameter of the lower plate;  
 providing a fuel/air mixture to the chamber;  
 directing the fuel/air mixture through the ports;  
 combusting the fuel/air mixture to create a flame; and  
 directing the flame upwards at the outer rim to attach the flame to the lower plate.

**17.** The method of claim **16**, further comprising:  
 directing the flame from the ports to a first elevation on the lower plate below the ports to attach the flame to the lower plate at the first elevation; and  
 directing the flame from the first elevation to a second elevation on the lower plate below the first elevation to attach the flame to the lower plate at the second elevation.

**18.** The method of claim **17**, the method further comprising:  
 providing a first portion of secondary air to the flame at a first distance radially outward from the ports; and  
 providing a second portion of secondary air to the flame at a second distance radially outward from the ports, the second distance greater than the first distance.

**19.** The method of claim **18**, the method further comprising:  
 providing a third portion of secondary air to the flame at a third distance radially outward from the ports, the third distance greater than the second distance;  
 providing the third portion of secondary air at the second elevation.

**20.** The method of claim **17**, the method further comprising:  
 providing secondary air to the flame radially outward from the ports at the second elevation.

\* \* \* \* \*