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

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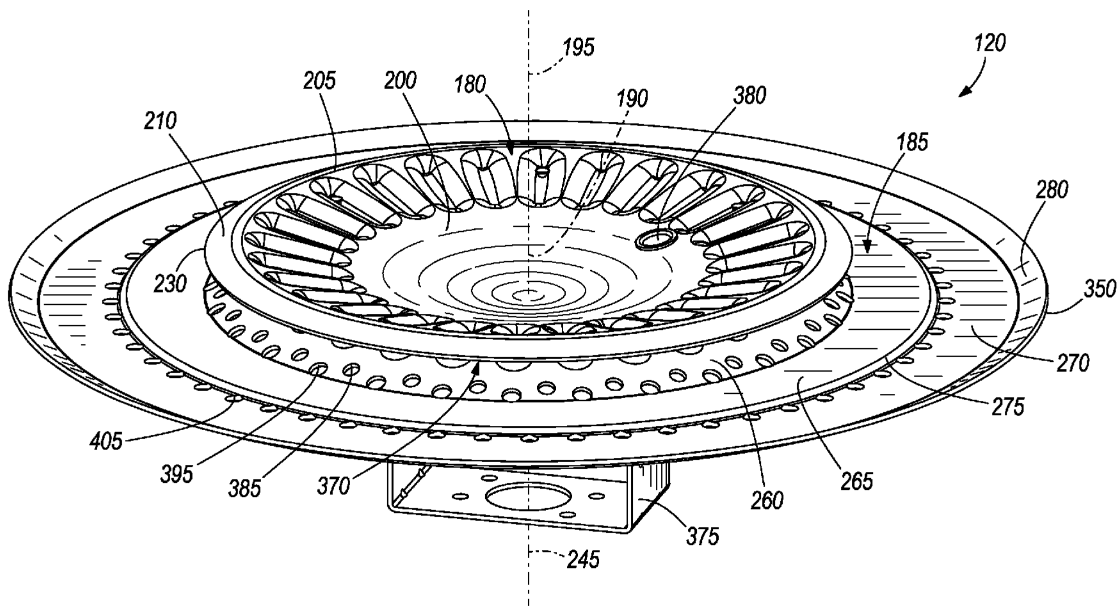
(52) **U.S. Cl.** **431/2**; 431/159

(57) **ABSTRACT**

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.



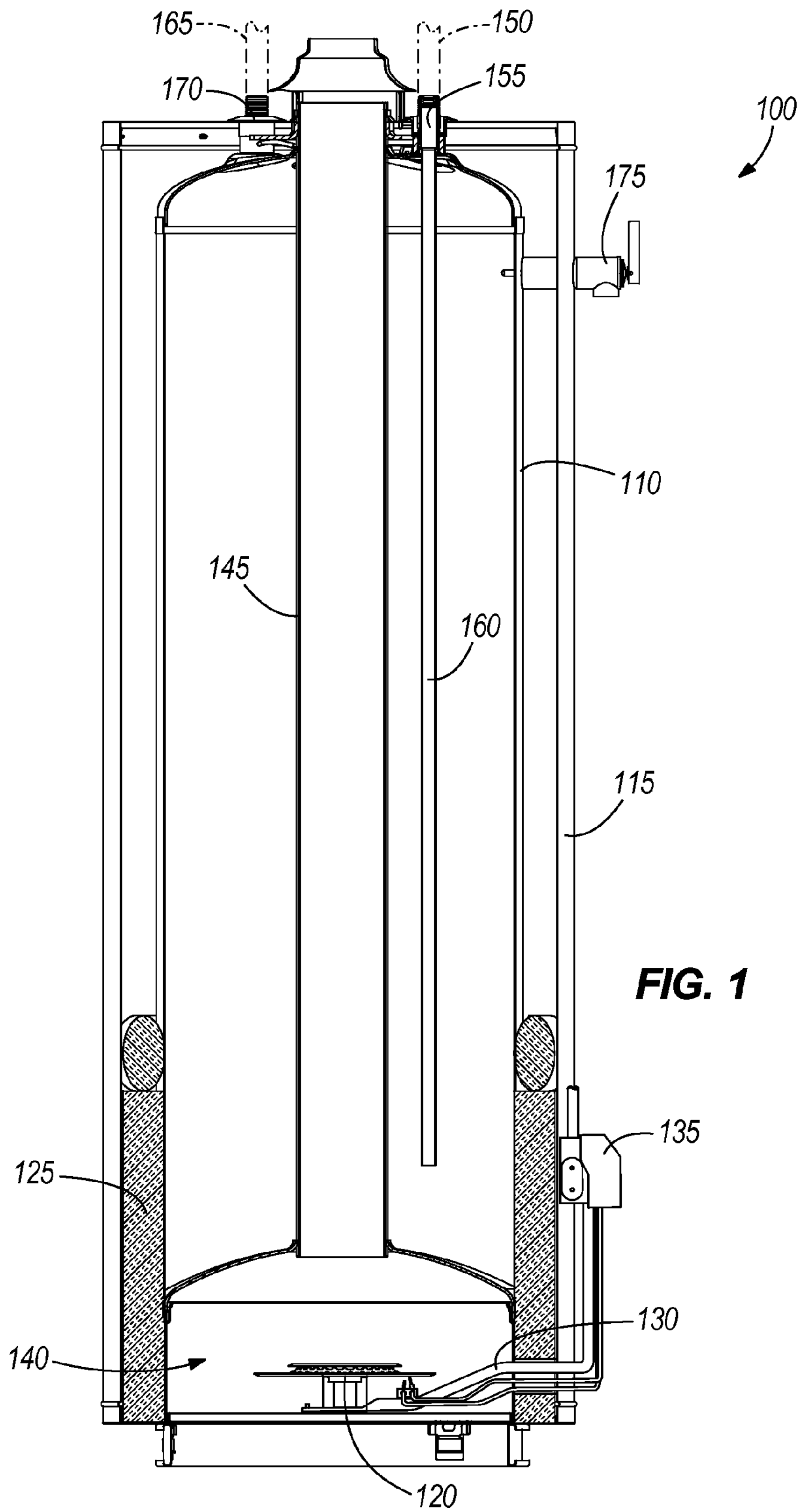
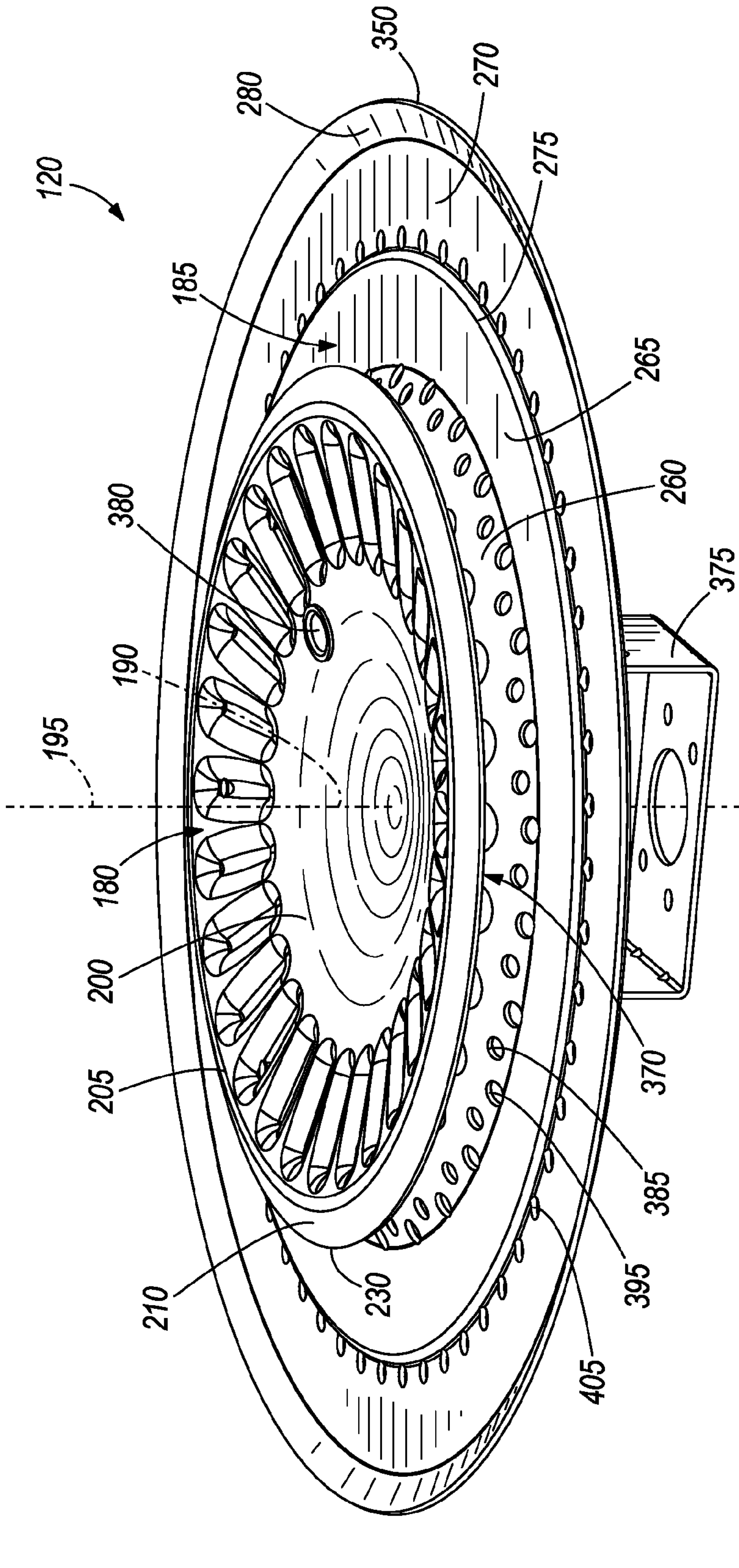


FIG. 1



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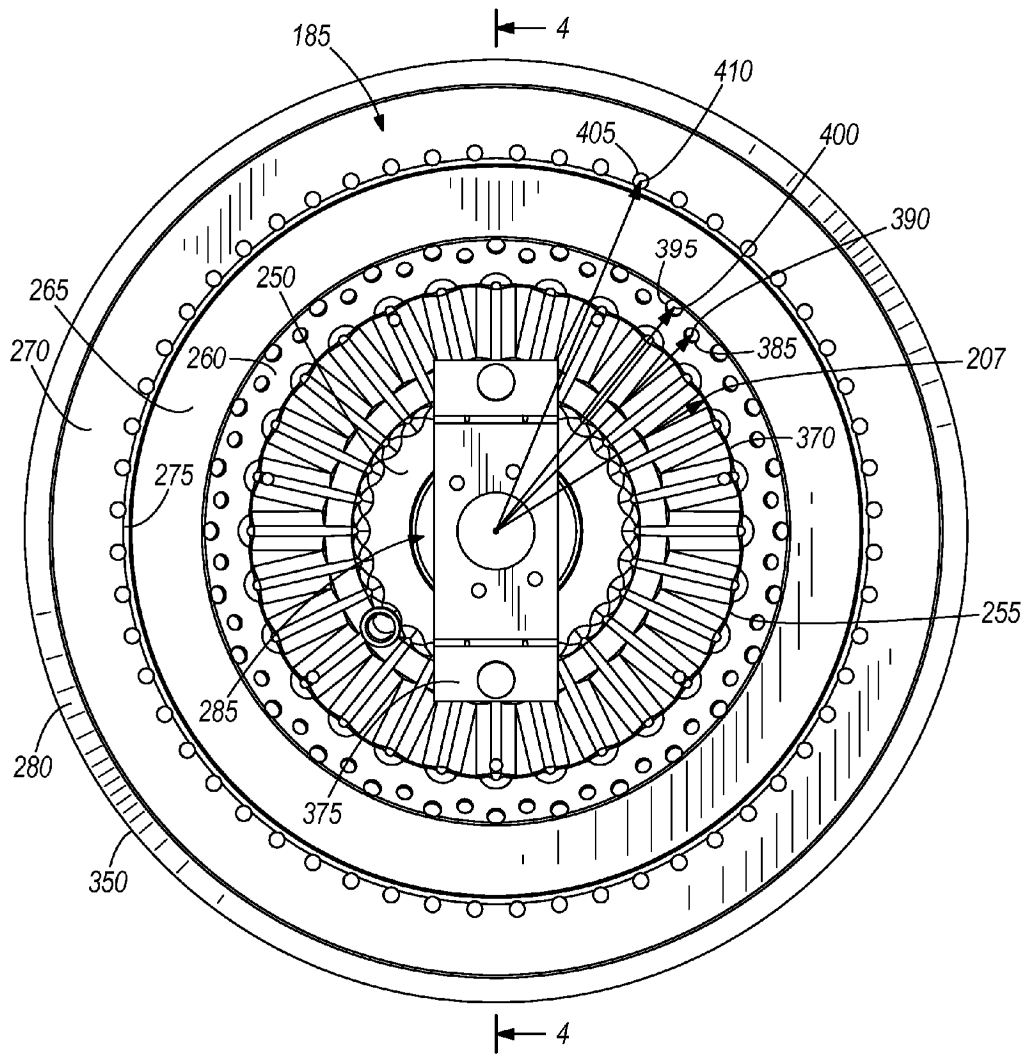
405

FIG. 2



4
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4

FIG. 3

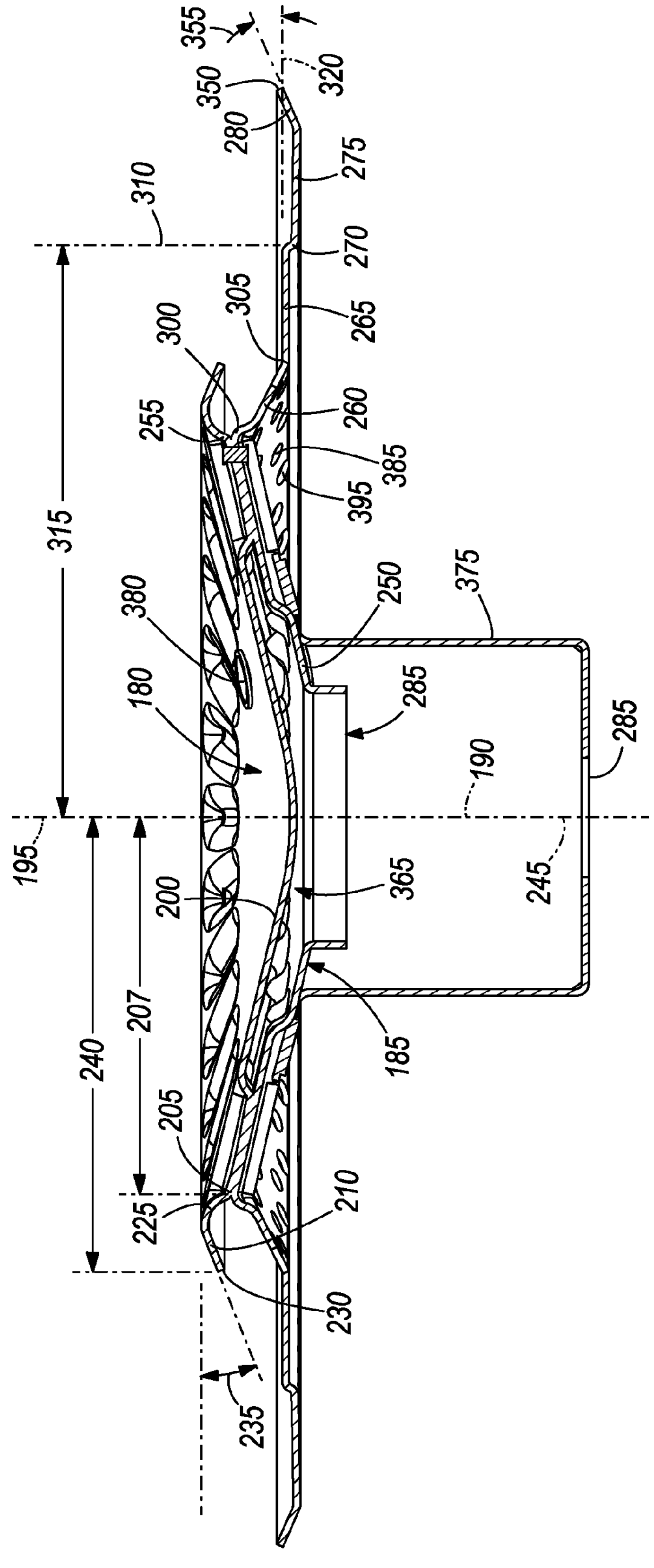
355
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FIG. 4

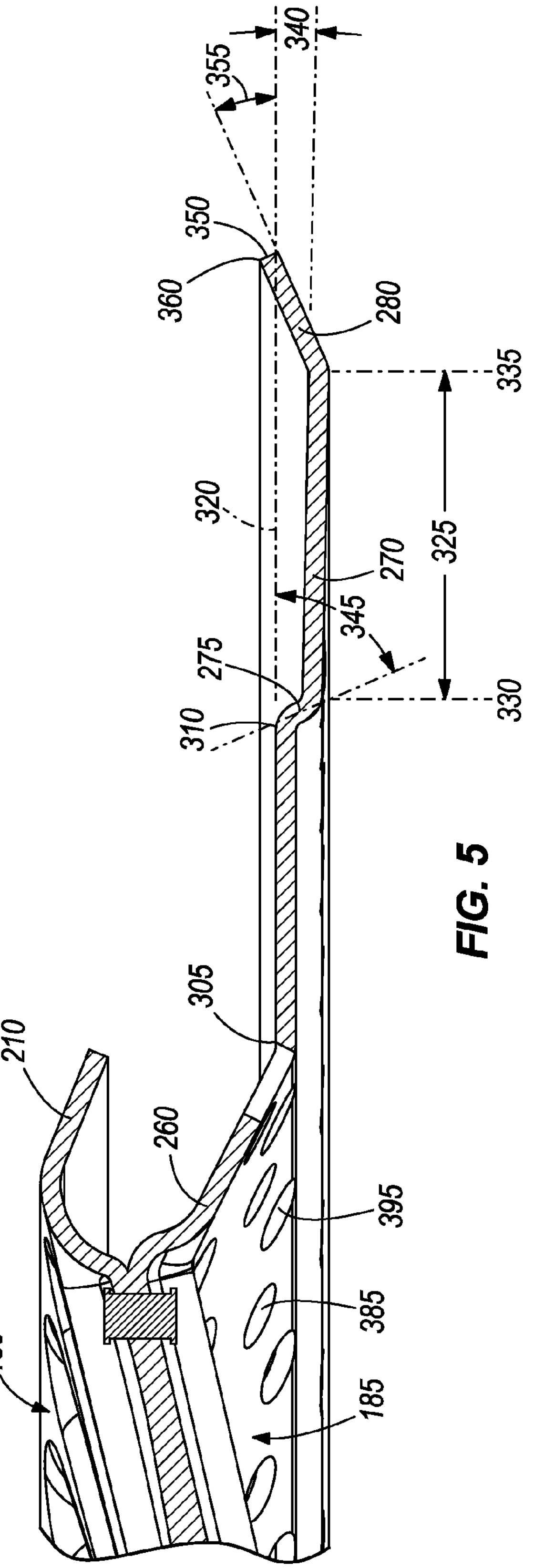
340
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FIG. 5

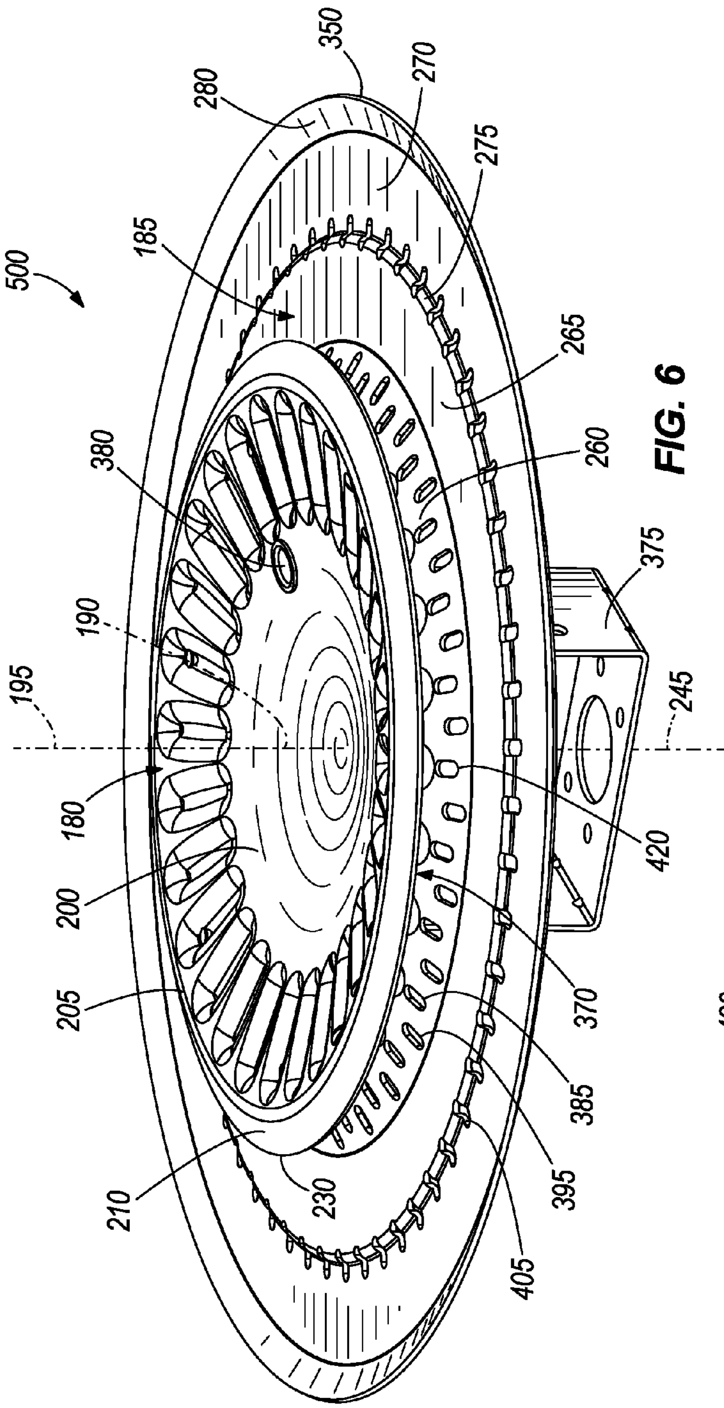
500
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FIG. 6

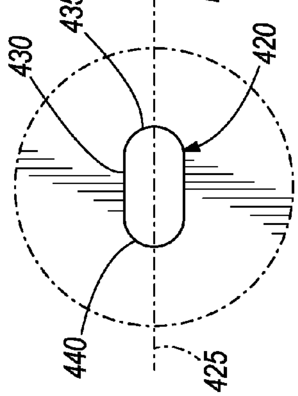
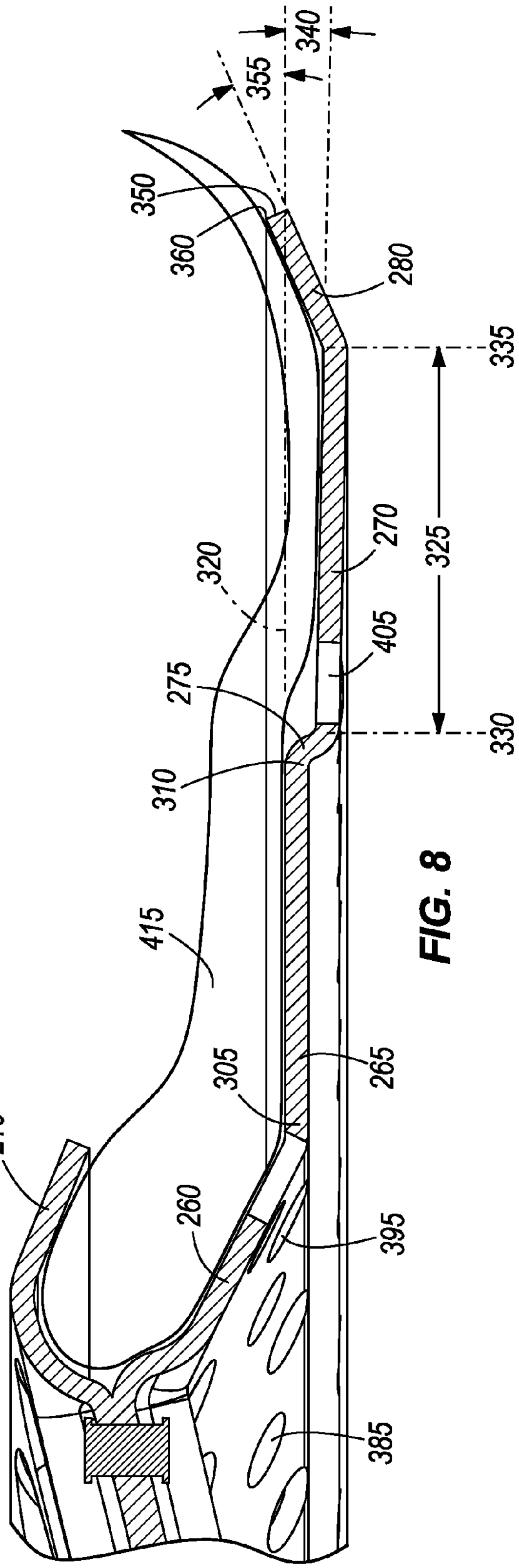

430
435
420
440
425

FIG. 7


340
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210
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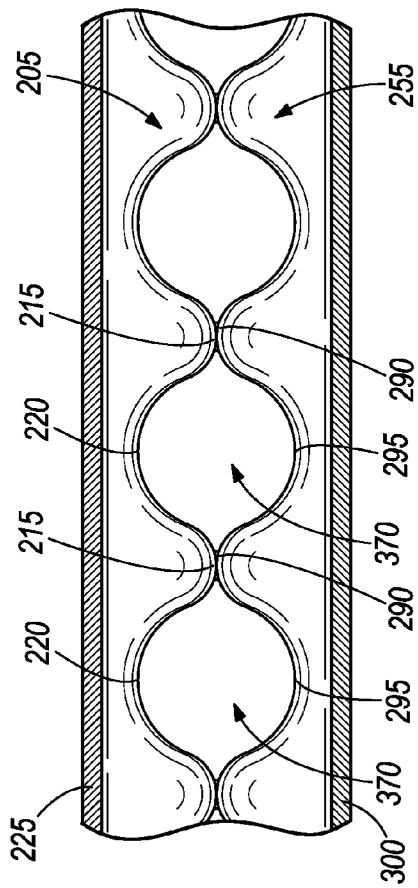
395
385

FIG. 8


205
255
215
290
220
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370
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290
220
295
370
225
300

FIG. 9

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 downwardly 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** though 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.

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