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(54) **DOUBLE FIRED U-TUBE FIRED HEATER**

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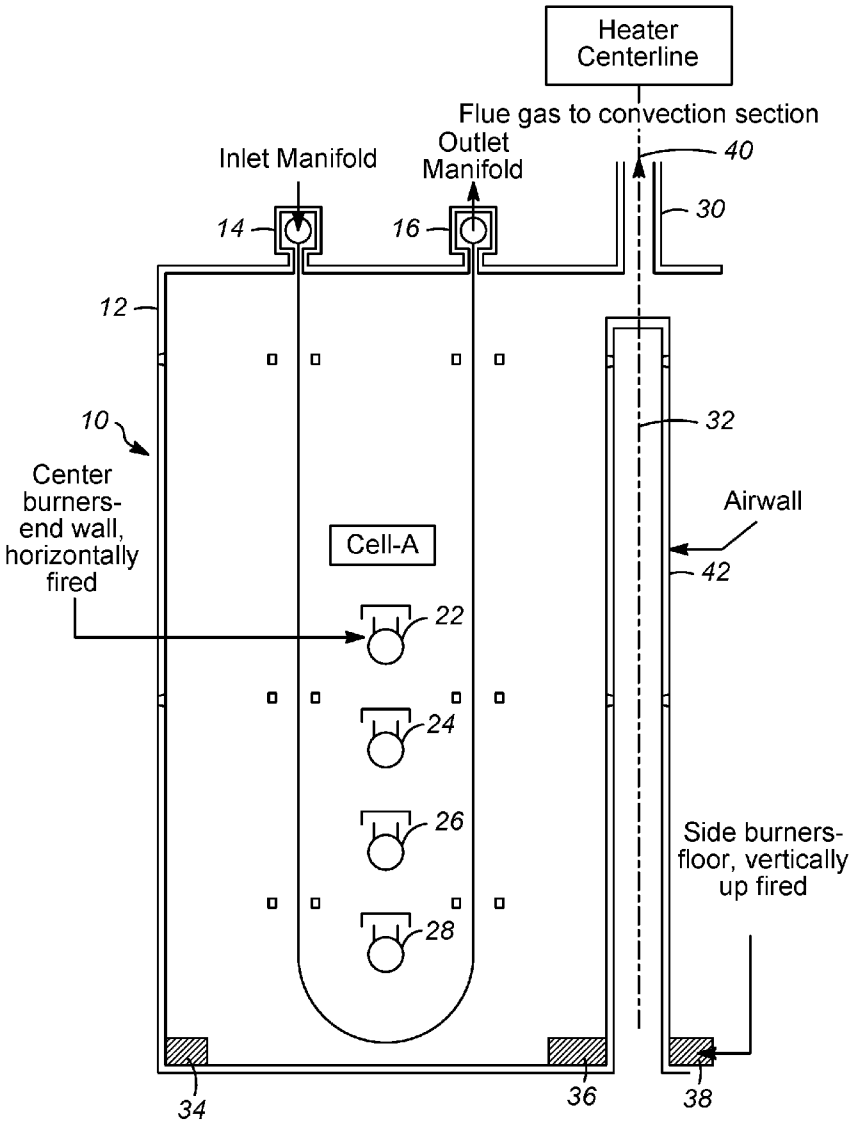
(52) **U.S. Cl.**
CPC ***F24H 1/43*** (2013.01)

(57) **ABSTRACT**

A fired heater is provided with u-shaped coils is provided. The coils have at least one inlet, at least one inlet section, at least one outlet and at least one outlet section. Burners are provided in both the center of the end wall of the fired heater and on the floor of the side wall. The fired heater is more compact and provides more even heat distribution compared to prior art heaters.



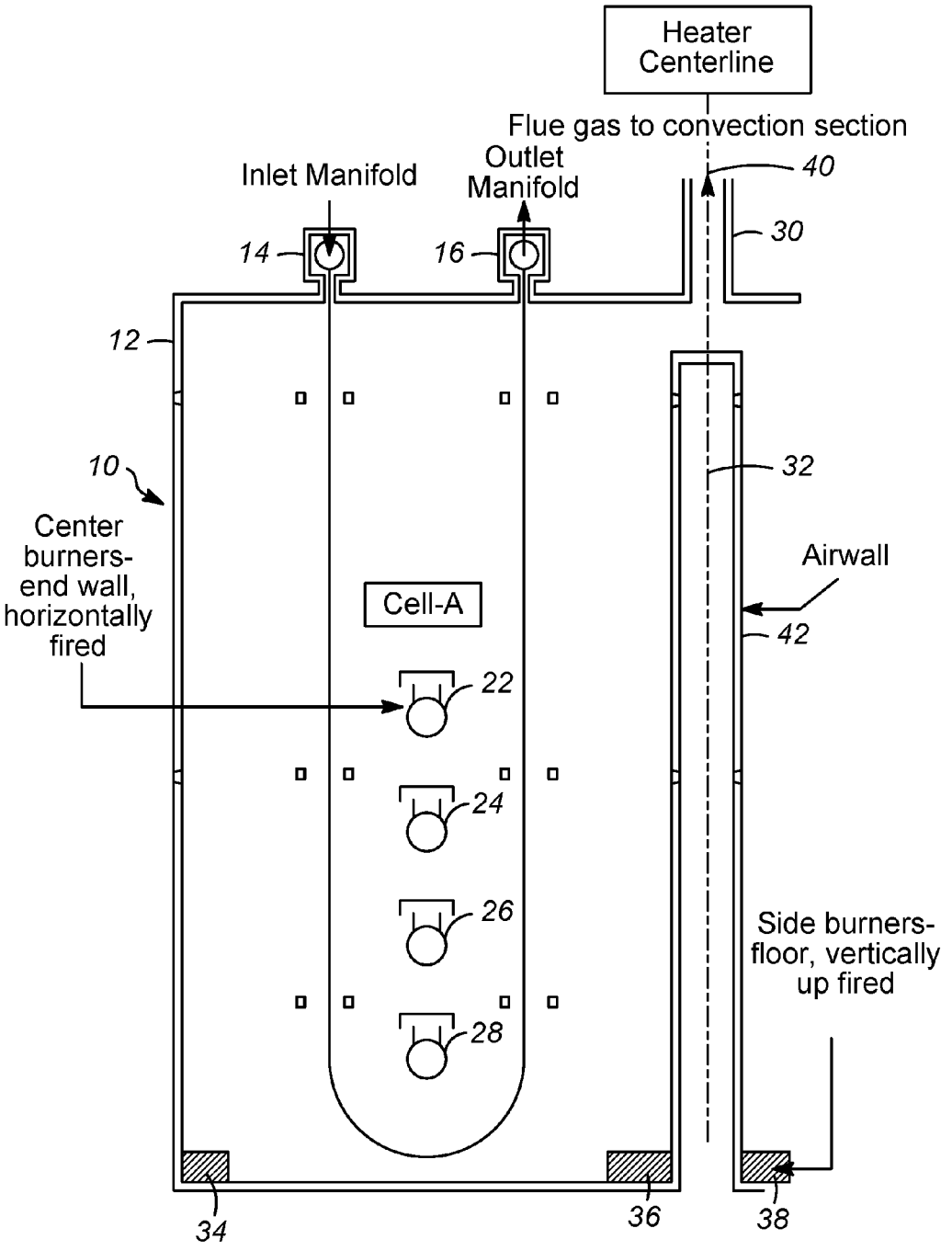

Heater Centerline
Flue gas to convection section
Inlet Manifold
Outlet Manifold
40
30
14
16
12
10
32
Center burners-end wall, horizontally fired
Airwall
Cell-A
42
22
24
26
28
Side burners-floor, vertically up fired
34
36
38

FIG. 1

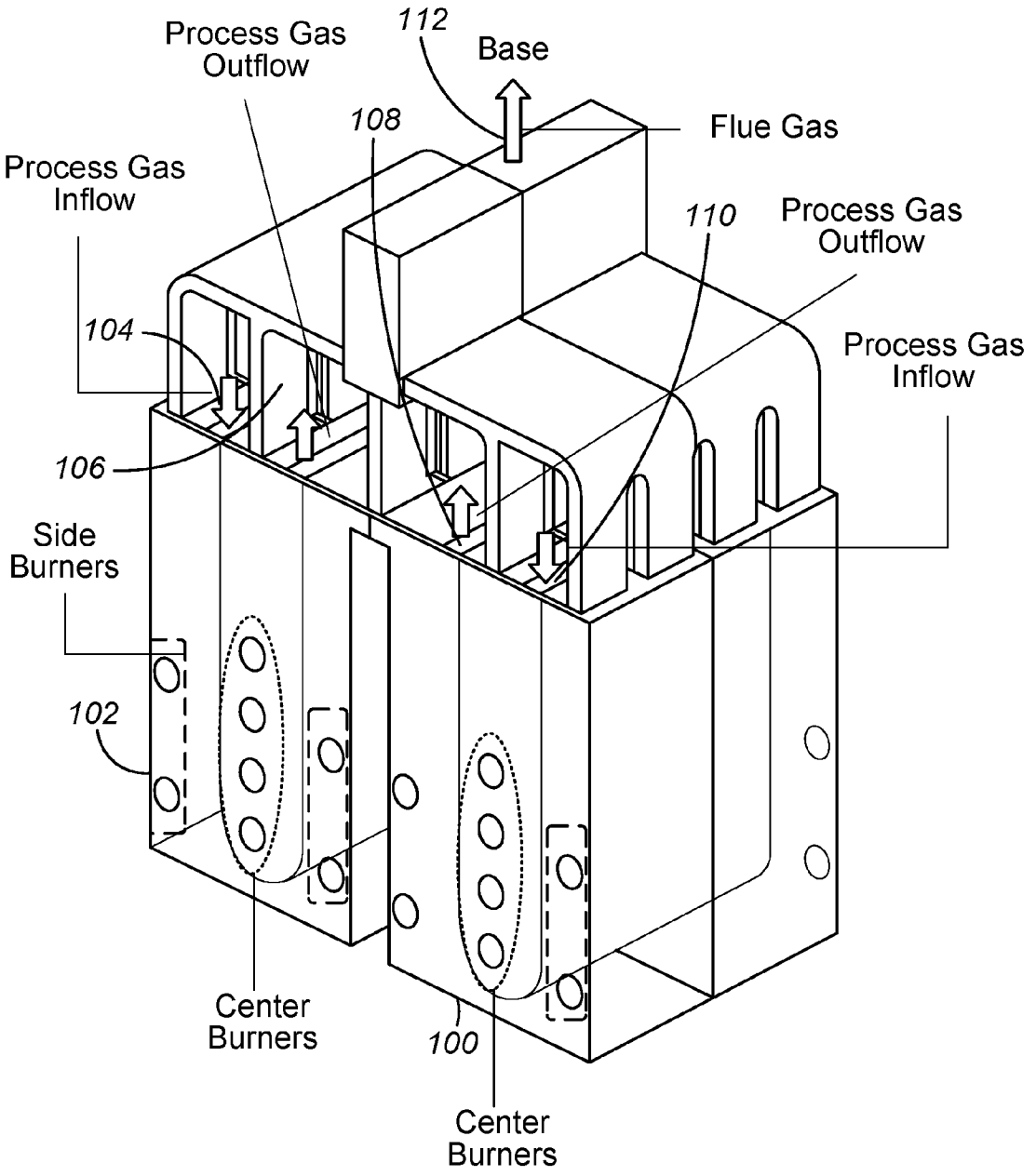
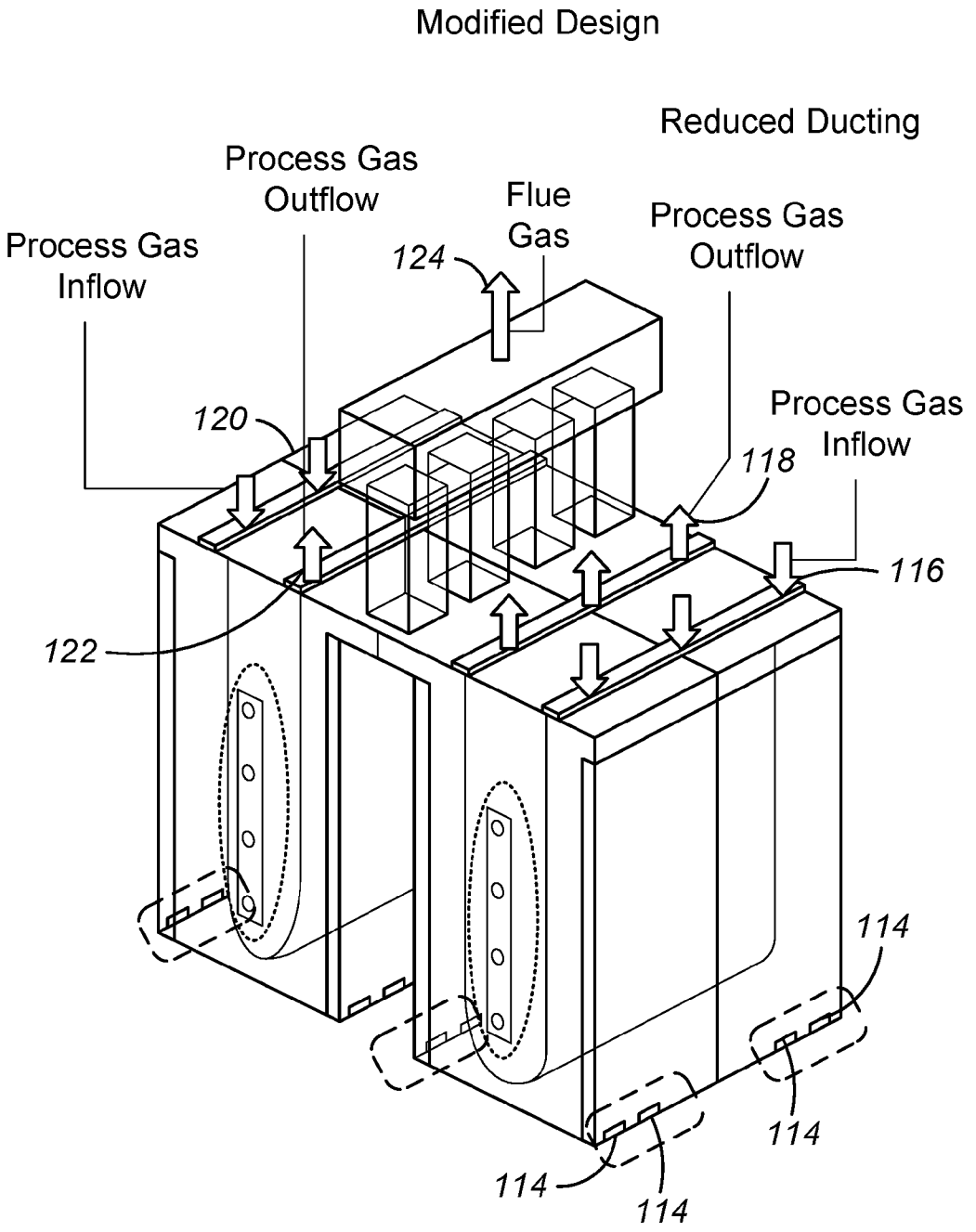


FIG. 2
(Prior art)



Flat-flame floor burners on the side

FIG. 3

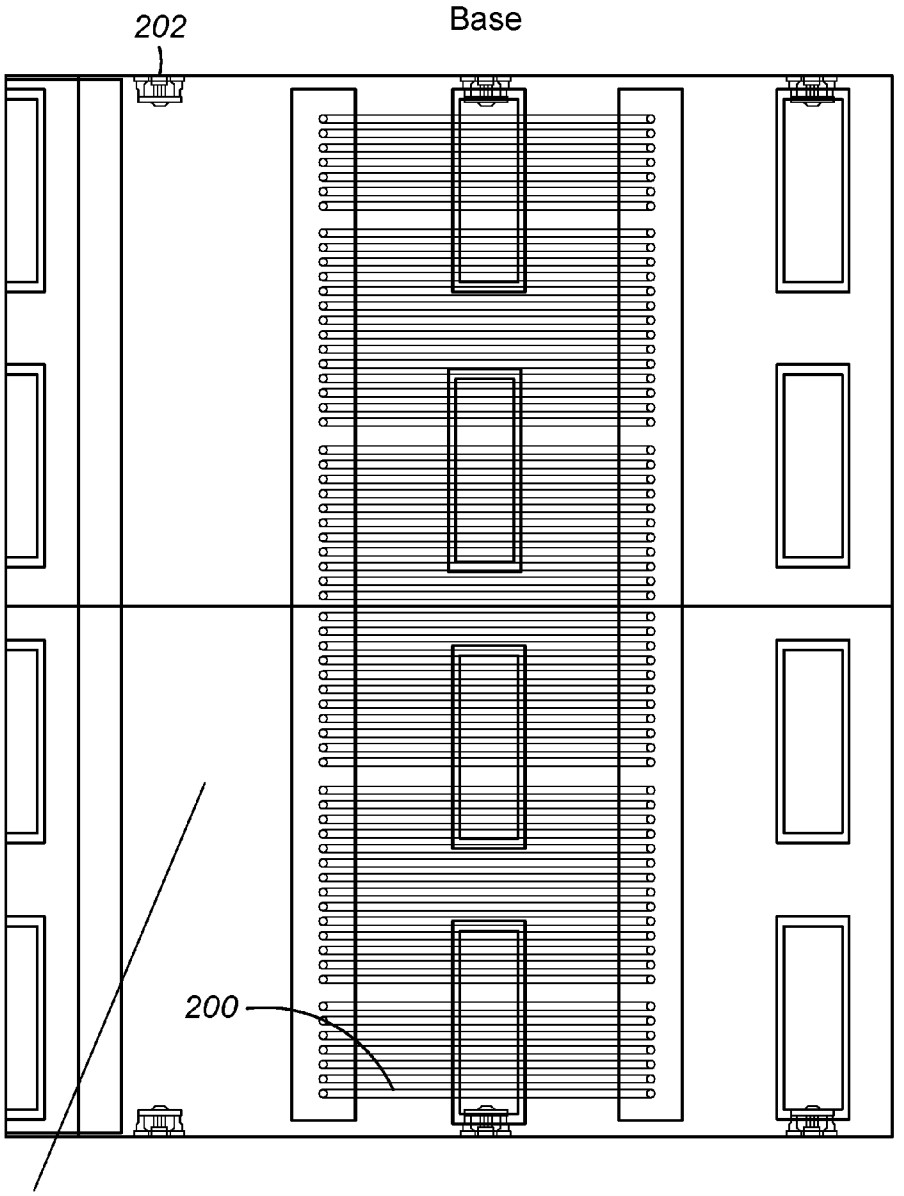
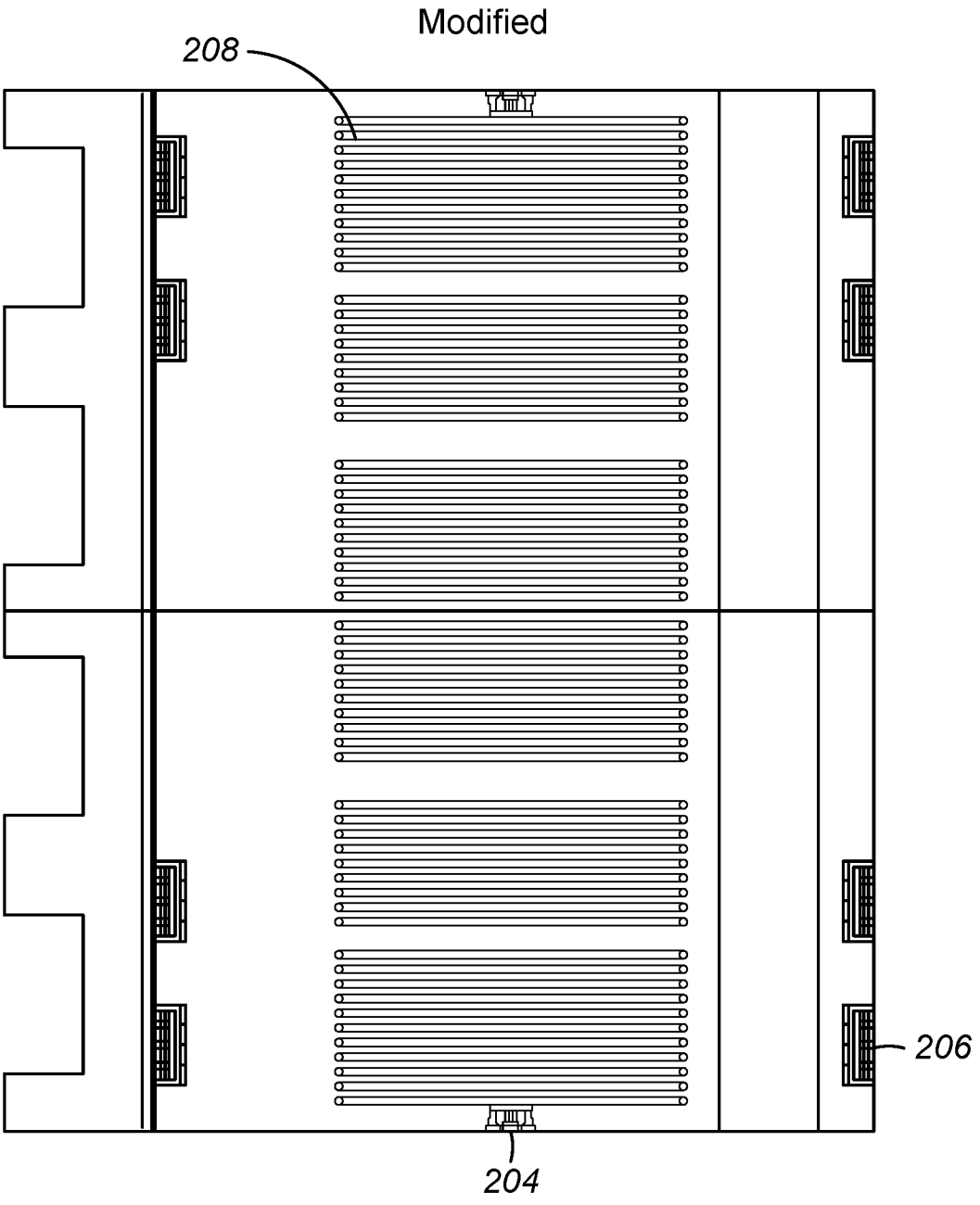


FIG. 4
(Prior art)



Improved uniformity in absorbed duty

FIG. 5

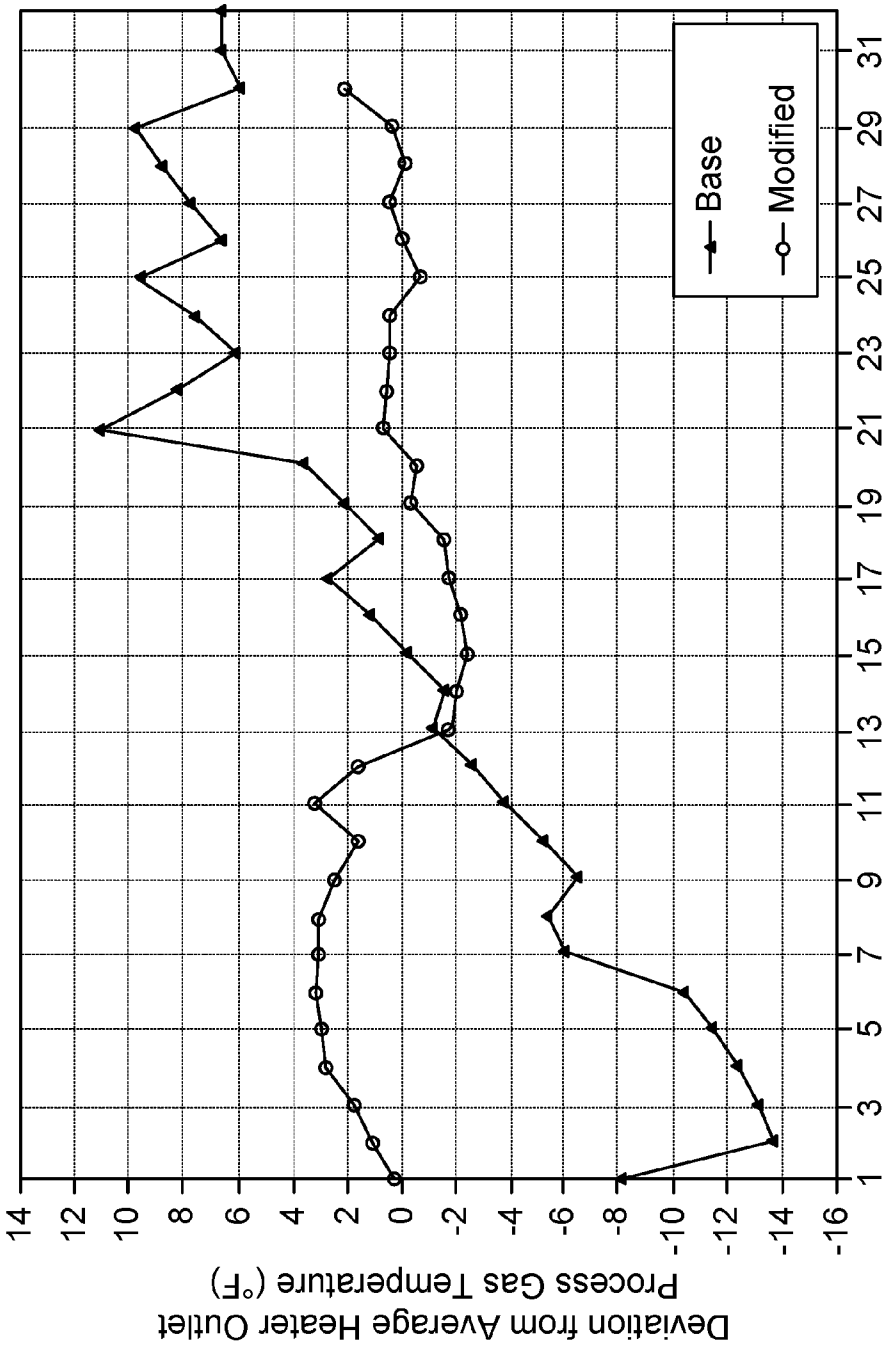

Deviation from Average Heater Outlet Process Gas Temperature (°F)
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Coil number from end-wall
Base
Modified
Modified design delivers more uniform distribution of absorbed duty

FIG. 6

DOUBLE FIRED U-TUBE FIRED HEATER

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority from Provisional Application No. 62/161,792 filed May 14, 2015, the contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] The invention relates to a fired heater for providing heat for a reactor for heating a hydrocarbon feed. More particularly, the invention relates to improved fired heaters for use in catalytic reforming units to produce desired products from feeds such as naphtha or in producing light olefins.

[0003] Catalytic reforming reactors that mostly consist of hydrocarbons with more than six carbon atoms are processed in a catalytic reformer and depending upon the conditions used can be converted to aromatic compounds or cracked to make paraffins. Fired heaters are used as necessary to heat the feed to a reaction temperature such as about 500° C.

[0004] Processes for converting hydrocarbons at higher temperature have been known for many decades. U.S. Pat. No. 2,182,586, describes a reactor and process for the pyrolytic conversion of a fluid hydrocarbon oil. Use is made of a horizontally arranged single reactor pipe (the publication refers to "tubes", but these are connected in a serial flow connection and thus form in fact a single tube), which results in relatively long residence times which are common in the process of thermal cracking of liquid hydrocarbon oils to improve motor fuel quality such as visbreaking. The use of the described heater for a process like steam cracking or for the cracking of a vaporous feed is not mentioned. Rather, excessive cracking and excessive gas formation are avoided.

[0005] U.S. Pat. No. 2,324,553, published in 1943, shows another heater for the pyrolytical conversion of hydrocarbons, wherein the reactor pipe is formed of serially connected "tubes", which are horizontally positioned in the heater. In the described process, oil is passed through the tube to a temperature below an active cracking temperature.

[0006] WO 97/28232 describes a cracking furnace for thermally cracking a liquid hydrocarbon feed in a spiral pipe. The furnace is said to have a reduced sensitivity for coke formation and an increased liquid residence time. It is not disclosed to use the installation for steam cracking.

[0007] Steam cracking is a specific form of thermal cracking of hydrocarbons in the presence of steam with specific process kinetics and other process characteristics. Herein, the hydrocarbon feed is thermally cracked in the vapor phase in the presence of steam. The cracking is carried out at much higher severity than applied in the moderate cracking of liquid hydrocarbon oils to improve fluid quality. Steam cracking furnaces comprise at least one firebox (also known as a radiant section) which comprises a number of burners for heating the interior. A number of reactor tubes (known as cracking tubes or cracking coils) through which the feed can pass are disposed through the firebox. The vapor feed in the tubes is heated to such a high temperature that rapid decomposition of molecules occurs, which yields desired light olefins such as ethylene and propylene. The mixture of hydrocarbon feed and steam typically enters the reactor tubes as a vapor at about 600° C. In the tubes, the mixture is usually heated to about 850° C. by the heat released by firing fuel in the burners. The hydrocarbons react in the heated tubes and are converted into a gaseous product, rich in primary olefins such as ethylene and propylene.

[0008] In cracking furnaces, the reactor tubes may be arranged vertically in one or more passes. In the art, the term cracking coil is also used. One or more of the cracking coils, which may be identical or not identical, may be present to form the total radiant reactor section of a firebox. Conventionally, ethylene cracking tubes are arranged in the firebox in one lane wherein the lane is heated from both sides by burners.

[0009] Such a lane may be in a so-called in-line arrangement whereby all the reactor tubes are arranged in essentially the same vertical plane. Alternatively, the tubes in such a lane may be in a so-called staggered arrangement whereby the tubes are arranged in two essential vertical parallel planes whereby the tubes are arranged in a triangular pitch towards each other. Such a triangular can be with equal sides (i.e. equilateral triangular pitch) or with unequal sides which is called an extended pitch.

SUMMARY OF THE INVENTION

[0010] The invention provides a fired heater comprising a firebox comprising: a plurality of coils comprising inlet sections and outlet sections, with outlet sections of the coils positioned in at least one lane and with inlet sections of the coils positioned in at least two lanes; and at least two sets of burners, wherein one set of burners is located in a center portion of an end wall of said fired heater and one set of burners is located on a floor next to a side wall of said fired heater.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** shows a schematic of one-half of a fired heater according to the invention.

[0012] FIG. **2** shows a prior art fired heater with side and center burners.

[0013] FIG. **3** shows a fired heater of the invention with side burners and floor burners.

[0014] FIG. **4** shows a schematic of heat distribution for a prior art fired heater.

[0015] FIG. **5** shows a schematic of heat distribution for a fired heater of the present invention.

[0016] FIG. **6** shows the deviation of heat within a prior art fired heater and a fired heater of the present invention.

DESCRIPTION OF THE INVENTION

[0017] The present invention decreases heater coil and manifold hot volume thereby improving selectivity and minimizing pass to pass bulk outlet temperature variation from heater average outlet conditions while decreasing cost and complexity of equipment and decreasing heat losses.

[0018] Compared to a prior art configuration there is an 18% reduction in coil heat transfer surface area/volume, 32% reduction in firebox volume, 42% reduction in casing area of firebox and flue gas ducts, outlet temperature variation reduced by a factor of 5 and equipment cost reduced by 10% plus. The invention provides significant reductions in capital and operating costs.

[0019] Double fired U-tube heaters use burners located on the end wall (wall perpendicular to radiant manifolds) inside and outside the U firing horizontally towards the middle of

the box. The opposing flames cause a hot spot in the middle of the box causing high outlet temperatures in that region while passes towards the end walls have lower outlet temperature. The tubes in the middle of the box set the surface area requirements for these film/tube wall temperature limited heaters. Prior art has utilized insulating tubes in the middle to somewhat decrease effect of hot spot but the hot volume/surface area requirements are unaffected by this approach.

[0020] This invention relocates the side burners (burners outside U-tube) to floor firing positions vertically upwards and biasing their placement towards the end walls. This eliminates their contributing to the hot spot in the middle of the box and their new placement adds heat to passes away from the middle (these passes pick up less heat in traditional design) thereby minimizing heat pickup variation amongst passes and permitting lower coil surface area and other savings identified above. A particular new feature is the combination of center (inside U) end wall horizontal fired burners with floor mounted, vertically upfired side burners biased towards the end wall. The floor mounted, vertically upfired side burners may be biased

[0021] FIG. **1** is a schematic of one-half of a two cell fired heater. The drawings is not to scale. Cell A is shown, while Cell B is not shown. This heater **10** is symmetrical about the centerline **32** as shown. Heater **10** has an outer wall **12**. Inlet manifold **14** and outlet manifold **16** are shown for the flow of air being heated as it passes through U-shaped coil **18**. While only one U-shaped coil is shown in FIG. **1**, inside a fired heater will be found many parallel U-shaped coils throughout the heater. Inside U-shaped coil **18** are shown four center burners **22**, **24**, **26** and **28** that are mounted on the end wall and are generally horizontally fired. Side burners **34**, **36** and **38** are shown mounted on the floor and are generally vertically up fired, although they may be either oriented to fire in the direction of the end wall or into the interior of the fired heater. Flue gas **34** is seen exiting at **30**. Access doors, platforms, manifold supports, instrument connections etc. are not shown in FIG. **1** for clarity. One column of center burners at each end wall with four levels of burners per column is shown. However, it would be possible to use two columns of burners at each end wall with a number of levels of burners as needed. A combination of two columns of burners at certain levels and one column at other levels is another configuration that would be feasible. As depicted, the side burners fire against side wall (i.e. burners are immediately next to side wall and the flames are laid against the wall). However, side burners could also be free-standing where the burners are further away from the side wall and the flame is not against the wall. The side burner placements may be biased towards each end wall to even out heat flux mal-distribution. The number of side burners and extent of bias is optimized as needed.

[0022] As depicted, inlet manifold **14** of U-tube coil **18** is located away from heater centerline **40** and outlet manifold **16** is closer to the heater centerline. However, the inlet and outlet manifold locations may be swapped as needed independently in each cell. As depicted, an airwall separates the two cells in the heater. Alternately, a firewall (such as a brick wall) may be used.

[0023] Two cells per heater are implied in the drawing. However, the configuration of the present invention can be used for one cell or for a multiple cell heater that has two or more cells.

[0024] FIG. **2** is a prior art fired heater that has center burners and side burners. Process gas inflow and outflow is shown as well as flue gas exiting from the top. In this fired heater, center burners **100** are shown on a front side with flames from the heaters directed to the interior of the fired heater. Side burners **102** are shown on either side of the two sets of center burners **100**. Process gas is shown flowing into burner at **104** and **110** and flowing out of the burner at **106** and **108**. Flue gas **112** exits from a top opening of the fired heater. There are a series of coils within the fired heater that are not shown in this view.

[0025] FIG. **3** shows a fired heater of the present invention that is more compact and differs from the prior art fired heater by having flat-flame floor burners shown on the floor by the side walls of the fired heater. There are center burners that are in the same position as center burners **100** from FIG. **2**. Instead of the side burners, there are now shown multiple sets of flat-flame floor burners **114** with pairs of burners on the bottom of each long side with a total of eight pairs of flat-flame floor burners. There are shown process gas inflow **116** and process gas outflow **118** and **122**. There is a central ducting shown that is reduced in comparison to FIG. **2**. Flue gas exits at **124**.

[0026] FIG. **4** shows a prior art fired heater, with a central section has an increased temperature while in FIG. **5** there is a significantly improved uniformity of heat within the fired heater. A series of coils **200** are shown in the center portion of the firebox for FIG. **4** with burners at both ends of the enclosure. In FIG. **5**, the burners **206** are on the sides as well as a single burner **204** shown at each end and adjacent to coils **200**.

[0027] FIG. **6** shows the deviation from average heat as measured at coils **1-32** from the end wall. The prior art fired heater configuration shows much greater variation with as much as a total of 26 F difference than the present invention which shows minimal variation with only about 4 F difference.

[0028] There are a variety of fired heaters that are designed for different uses including general refinery service. ANSI/API Standard 560, Fourth edition, August 2007 includes different configurations for fired heaters, especially for the lay-out of the coils and locations for the burners. Coils may be in a U-shape, a helical configuration, a series of horizontal tubes, or there may be vertical tubes. Burner arrangements are shown in this standard as up-fired, end-wall-fired, sidewall-fired and sidewall-fired multilevel.

[0029] Suitable cracking coils (also referred to as cracking tubes), are generally known. The coils may be formed of one or more cylindrical tubular conduits, preferably with a circular or oval cross-section. The conduits may be connected by connecting devices such as but not limited to connecting tubes and bends to provide a number of passes. A cracking coil may be formed of a plurality of tubular conduits joined together, for example having an "m-like shape" or "w-like shape" wherein the outer legs represent inlet sections which mount in a single outlet section, represented by the central leg of the w/m.

[0030] The coils generally each have at least one inlet and at least one outlet The inlet of the coil is a conduit via which, during use, the feed enters the cracking coil and usually thereby the firebox; the outlet is the conduit via which, during use, the product leaves the cracking coil, and thereby usually the firebox. The outlet may be connected with other

processing equipment such as but not limited to heat exchangers and/or quenchers.

[0031] The inlet section of a coil is the first part (in the longitudinal direction) of the coil that is inside the firebox, starting from the inlet of the coil into the firebox. It may extend up to the beginning of the outlet section. In particular, it is the part that is less thermally shielded than the outlet section. In a preferred embodiment, the inlet section is the part of the coil that thermally shields the outlet section of the coil, when operating the furnace.

[0032] The outlet section of a coil is the last part (in the longitudinal direction) of the coil that is inside the firebox, ending at the outlet of the coil going out of the firebox. In particular it is the part that is more thermally shielded than the inlet section. It may extend up to the end of the inlet section or to an intermediate section connecting inlet section and outlet section (such as return bends, as will be discussed below).

[0033] Usually, a plurality of the cracking tubes are connected to each other to form a parallel flow path for the feed. Thus, in contrast to a design wherein the "tubes" are connected in a serial manner and wherein the feed enters a first "tube", is partially converted and thereafter enters a subsequent "tube", the present design allows the composition of the stream at the inlet of each tube to be essentially the same for each tube. This allows short residence time and thereby high through put. If desired, during use, a plurality of the cracking tubes may thus be fed from a single container or conduit that is split into a number of feed streams, each fed to the inlet of a cracking tube and/or the product stream leaving the plurality of tubes via the outlet may be combined again into a single conduit or container.

[0034] The term that an entity (such as a coil section) is "thermally shielded" is defined herein as heat, being hindered to be transferred into the entity. This term is in particular used herein to indicate the extent to which heat generated by the burners during operation of the cracking furnace is hindered to be transferred into the shielded entity. With respect to the outlet sections of the coils being more thermally shielded than the inlet sections of the coils, this means in particular that the heat transfer into the cracking coils at the outlet section of the coil is shifted in favor of the heat transfer into the cracking coils at the inlet section of the coil, during operation of the burners compared to a coil configuration whereby such shielding is not or less occurring.

[0035] The term essentially vertically is used herein to indicate that an entity (such as a coil/tube or part thereof, a lane, a wall, etc) at least during use is at an angle of more than 45° with a horizontal surface (usually the floor of the firebox), in particular at an angle of more than 80°, preferably at an angle of about 90°.

[0036] The term essentially horizontal is used herein to indicate that an entity (such as a coil/tube or part thereof, a lane, a wall, etc.) at least during use, is at an angle of less than 45° with a horizontal surface (usually the floor of the firebox), in particular at an angle of less than 10°, preferably at an angle of about 0°.

[0037] The term essentially parallel (used in the geometrical sense) is used herein to indicate that an entity (such as a tube or part thereof, a lane, a wall, etc.) at least during use, is at an angle of less than 45° with another entity to which the entity is said to be essentially parallel, in particular at an angle of less than 10°, preferably at an angle of about 0°.

[0038] The term "about" and the like, as used herein, is in particular defined as including a deviation of up to 10%, more in particular up to 5%.

[0039] A process according to the invention respectively a furnace of the invention may offer several advantages.

[0040] The hydrocarbon feed to be heated may be any gaseous, vaporous, liquid hydrocarbon feed or a combination thereof. Examples of suitable feeds include ethane, propane, butanes, naphthas, kerosenes, atmospheric gas oils, vacuum gas oils, heavy distillates, hydrogenated gas oils, gas condensates and mixtures of any of these.

Specific Embodiments

[0041] While the following is described in conjunction with specific embodiments, it will be understood that this description is intended to illustrate and not limit the scope of the preceding description and the appended claims.

[0042] A first embodiment of the invention is a fired heater comprising a firebox comprising a plurality of coils comprising inlet sections and outlet sections, with outlet sections of the coils positioned in at least one lane and with inlet sections of the coils positioned in at least two lanes; and at least two sets of burners, wherein one set of burners is located in a center portion of an end wall of the fired heater and one set of burners is located on a floor next to a side wall of the fired heater. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, the lanes are about parallel to each other. In yet another embodiment, the outlet sections and the inlet sections are positioned about vertically, at least during use. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, the inlet sections in each lane of the at least two lanes and the outlet sections in the at least one lane are arranged in an inline arrangement or in a staggered arrangement, and the inlet sections in each lane of the at least two lanes are positioned in a staggered configuration with respect to outlet sections present in an adjacent parallel lane. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, the burners on the floor have a flame that is directed in a vertical direction. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, the burners on the floor have a flame that is directed in a horizontal direction. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein there are at least one set of burners above the burners on the floor. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the burners next to the side walls are immediately adjacent to the side walls.

[0043] A second embodiment of the invention is a method of improving heat distribution in a fired heater comprising providing a fired heater comprising a firebox comprising a plurality of coils comprising inlet sections and outlet sections, with outlet sections of the coils positioned in at least one lane and with inlet sections of the coils positioned in at least two lanes; and at least two sets of burners, wherein one set of burners is located in a center portion of an end wall of the fired heater and one set of burners is located on a floor next to a side wall of the fired heater.

1. A fired heater comprising a firebox comprising:

a plurality of coils comprising inlet sections and outlet sections, with outlet sections of the coils positioned in at least one lane and with inlet sections of the coils positioned in at least two lanes; and

at least two sets of burners,

wherein one set of burners is located in a center portion of an end wall of said fired heater and one set of burners is located on a floor next to a side wall of said fired heater.

2. The fired heater of claim **1** wherein the lanes are about parallel to each other.

3. The fired heater of claim **1** wherein the outlet sections and the inlet sections are positioned about vertically, at least during use.

4. The fired heater of claim **1** wherein the inlet sections in each lane of the at least two lanes and the outlet sections in the at least one lane are arranged in an inline arrangement or in a staggered arrangement, and the inlet sections in each lane of the at least two lanes are positioned in a staggered configuration with respect to outlet sections present in an adjacent parallel lane.

5. The fired heater of claim **1** wherein the burners on the floor have a flame that is directed in a vertical direction.

6. The fired heater of claim **1** wherein the burners on the floor have a flame that is directed in a horizontal direction.

7. The fired heater of claim **1** wherein there are at least one set of burners above said burners on the floor.

8. The fired heater of claim **1** wherein said burners next to said side walls are immediately adjacent to said side walls.

9. The fired heater of claim **1** wherein said burners next to said side walls are extended away from said side walls.

10. A method of improving heat distribution in a fired heater comprising providing a fired heater comprising a firebox comprising:

a plurality of coils comprising inlet sections and outlet sections, with outlet sections of the coils positioned in at least one lane and with inlet sections of the coils positioned in at least two lanes; and

at least two sets of burners,

wherein one set of burners is located in a center portion of an end wall of said fired heater and one set of burners is located on a floor next to a side wall of said fired heater.

* * * * *