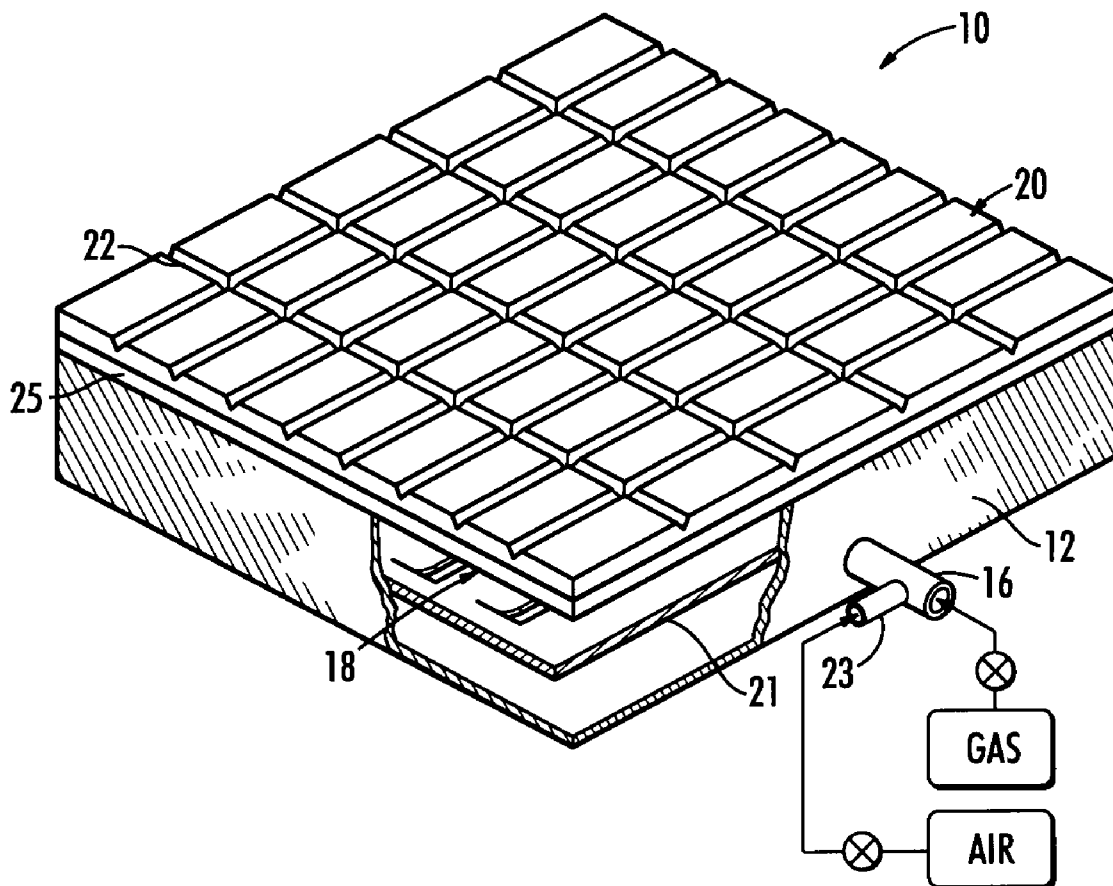


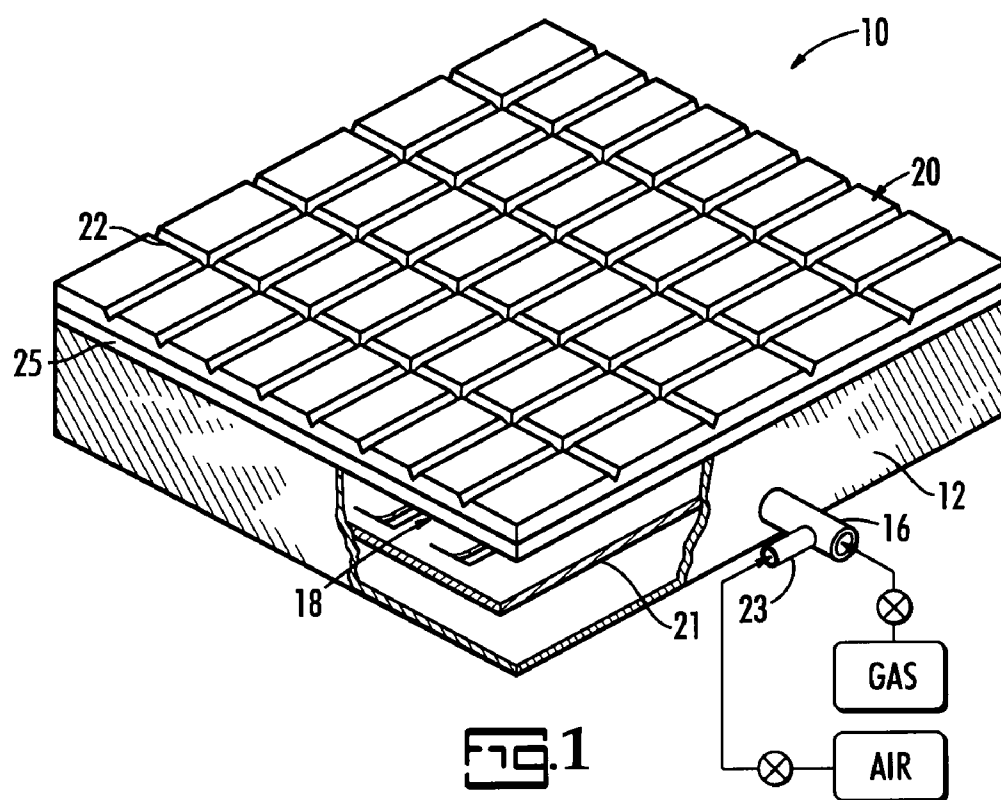


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Cookson et al.(10) **Pub. No.: US 2008/0227044 A1**(43) **Pub. Date: Sep. 18, 2008**(54) **METAL FOAM RADIANT BURNER****Publication Classification**(76) Inventors: **Edward J. Cookson**, Flat Rock,
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12, 2007.(57) **ABSTRACT**

An improved radiant burner which is particularly useful at low flow rates. The radiant burner has a reticulated metal foam with a first face and a second face and a density sufficient for combustion fuel to pass there through. The first face is adapted to be the initial contact for the combustion fuel passing through the reticulated metal foam. The second face is adapted to radiate after the combustion fuel has been ignited. The second face has a plurality of grooves





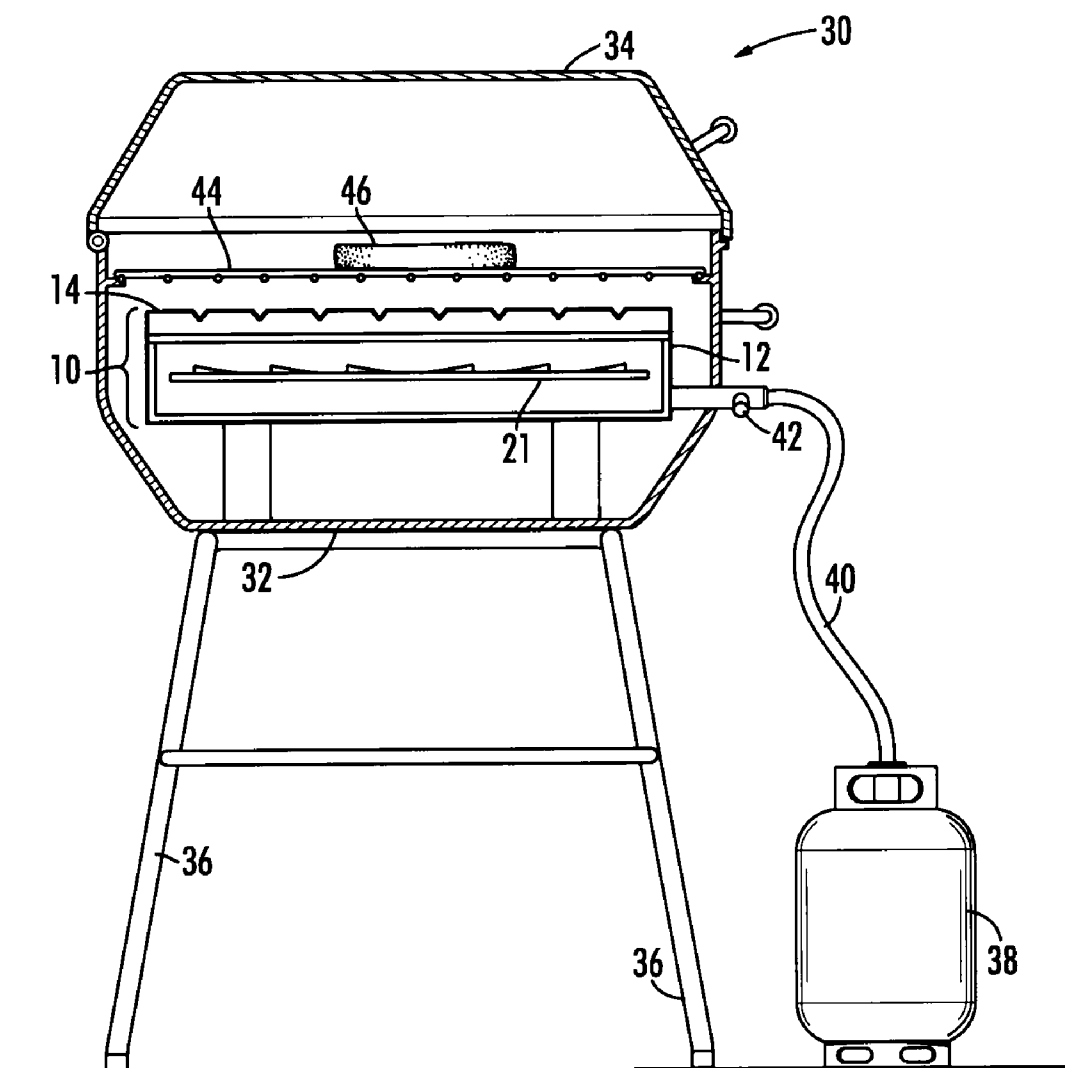


FIG. 2

METAL FOAM RADIANT BURNER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to pending U.S. Provisional Patent Application No. 60/906,348 filed Mar. 12, 2007 which is incorporated herein by reference.

BACKGROUND

[0002] The present invention is related to radiant burners made of metal foam. More specifically, the present invention is related to metal foam radiant burners comprising grooves wherein the burner is capable of low gas input rates thereby allowing the burners to be used at lower temperatures

[0003] Radiant burners utilizing reticulated foam structures have been used in various applications. In general, there are two predominant classes of reticulated foam radiant burners. One type is ceramic foam and the other type, and the focus of this invention, is a metal foam.

[0004] Ceramic foams have been utilized in the burner art for some period of time. Ceramic foams are typically made by impregnating polyurethane foam with a ceramic precursor. The impregnated foam is then heated to vaporize the foam and then to sinter the ceramic. A reticulated ceramic is formed wherein the ceramic is in regions previously represented by voids in the foam and those area which were occupied by foam represent voids in the ceramic. Ceramic foam radiant burners are exemplified in U.S. Pat. No. 5,409,375 to Butcher which is incorporated herein by reference.

[0005] Ceramic foams are marginally suitable as the combustion surface in a radiant heater yet they are also known to be somewhat deficient. Ceramic foams do not heat evenly and zones which are significantly colder than average are routinely observed. Grooves in the surface mitigate the uneven heating to a certain extent, however, this exasperates problems associated with physical robustness. Yet another deficiency is the brittle nature of the ceramic. Ceramic foams are susceptible to flash back induced damage which has greatly minimized their wide spread acceptance as a suitable combustion surface. Yet another problem, particularly with reference to their use in gas grills, is that drippings from the food clog the pores of the ceramic thereby exasperating the uneven heating.

[0006] Metal foams alleviate some of the deficiencies of ceramic foams. They are more physically robust and less susceptible to damage from blow back. Part of the robustness is considered to be due to the high thermal shock resistance of metal foams as compared to ceramic foams. Metal foams can also be formed at lower relative densities than ceramic foam materials which is advantageous for gas flow through the porous structure and for weight reduction.

[0007] A particular advantage with metal foam is that they exhibit a more consistent thermal profile. The metal foam exhibits a resistance to flame penetration into the porosity of the material which greatly decreases flame flash-back. This also mitigates the appearance of the cool zones which are a prevalent problem in ceramic foams.

[0008] Food drippings are also less of a problem with metal foams since the drippings are typically wicked away from the surface and are therefore less likely to plug the pores.

[0009] For many of the reasons discussed above, metal foams have been considered a viable alternative to ceramic foam based radiant heaters. While metal foams do offer some advantages they are deficient in other ways. One limit to their wide spread use is the problem referred to as turn down characteristics. Metal foams perform poorly under low gas

flow conditions and are therefore not suitable for low heat applications including cooking lighter meats, such as chicken or fish. Therefore, even though metal foam may be adequate for cooking a large steak they are limited in their ability to impact the market if they can not be used for other meats or items which require less heat. Dual burners have been used, however, this greatly increases the price since the grill must be manufactured with a high burner and a low burner in the same physical space. This is an unacceptable solution.

[0010] The use of reticulate foam as a combustion surface has never reached the anticipated potential. Ceramic foams are brittle and do not burn evenly whereas metal foams are inadequate for use in lower temperature applications with a low gas flow. Therefore, the art has long been suffering for a reticulated foam combustion surface which is physically robust, burns evenly, is less susceptible to clogging and which burns efficiently. The present invention provides such a material.

SUMMARY OF THE INVENTION

[0011] It is an object of the present invention to provide a reticulated foam radiant burner particularly suitable for use in low gas flow, or low heat, applications.

[0012] It is another object of the present invention to provide a radiant burner which is physically robust and which resist flame blow back.

[0013] A particular feature of the present invention is that it can be used as a natural draft burner thereby eliminating the necessity for forced air.

[0014] These and other advantages, as will be realized, are provided in a radiant burner. The radiant burner has a reticulated metal foam with a first face and a second face and a density sufficient for combustion fuel to pass there through. The first face is adapted to be the initial contact for the combustion fuel passing through the reticulated metal foam. The second face is adapted to radiate after the combustion fuel has been ignited. The second face has a plurality of grooves.

[0015] Yet another embodiment is provided in a heating system. The heating system has an apparatus for providing combustible gas. A mixer is provided which is capable of mixing the combustible gas with air to form a combustible fuel mixture. A reticulated metal foam burner is provided with a first face and a second face wherein the first face is capable of receiving the combustible fuel mixture and the combustible fuel mixture passes through the reticulated metal foam burner for combustion on a second surface. The second surface has a plurality of grooves. A plenum chamber is provided which is adapted to distribute the combustible fuel mixture over the first surface.

BRIEF DESCRIPTION OF FIGURES

[0016] FIG. 1 is a partial cutaway perspective view of an embodiment of the present invention.

[0017] FIG. 2 is a cross-sectional view of an embodiment of the present invention.

DETAILED DESCRIPTION OF INVENTION

[0018] The present invention is directed to a reticulated metal foam burner. More specifically, the present invention is directed to a reticulated metal foam burner comprising grooves to improve the combustion efficiency and to facilitate operation at low gas flow or low temperatures.

[0019] An embodiment of the invention is illustrated in FIG. 1. In FIG. 1, a heating element, 10, is illustrated comprising a plenum, 12, and metal foam burner, 14, attached

thereto. The metal foam burner is sealed to the plenum such that a combustible mixture of fuel, entering through an inlet, 16, must pass through the metal foam. A diffuser, 21, is preferably within the plenum to diffuse the gas such that the gas has a relatively consistent density at the interior face of the metal foam burner. An air inlet, 23, allows the gas to mix with air thereby forming a combustible mixture. It is most preferred that the combustible mixture have an air to gas ratio from about 5-1 to about 15-1 with about 10-1 being preferred. A seal, 25, between the plenum and metal foam burner, allows the metal foam burner and plenum to expand at different amounts without loss of gas except through the metal foam burner.

[0020] The metal foam burner, 14, has a first face, 18, facing the interior of the plenum. The fuel contacts the metal foam burner at the first face and passes through the metal foam burner in a tortuous path. The fuel is caused to ignite thereby generating a flame front near the surface of the metal foam burner. The flame front may be slightly internal to the surface or it may be at the surface. It is preferable that the flame front not be above the surface since this is inefficient, particularly, with regards to generation of infrared or radiant heat which is most desired.

[0021] A second face of the metal foam burner, 20, also referred to as the surface, comprises a multiplicity of grooves, 22, extending into the metal foam. The grooves may be "V"-shaped, "U"-shaped, rectangular, oval, half-round, triangular or multifaceted. The grooves are preferable "V"-shaped. The groove depth is preferably at least about 0.125 to no more than about 0.5 inches. The groove preferable has an included angle of about 10 to about 60 degrees. Below about 10 degrees the volume within the groove is insufficient and above about 60 degrees the angle of the groove relative to the surface is insufficiently small resulting in a loss of advantages offered by the grooves. The grooves are preferably spaced at least about 1/8 inch to no more than 2 inches apart at the center. The grooves may be parallel to one or more sides, perpendicular to one or more sides, or form serpentine or tortuous paths with, or without, intersections. For the purposes of manufacturing linear grooves are preferred. Curves forming a logo or design may be desired wherein the logo or design is indicative of an entity or product.

[0022] The heating element can be placed in a housing and utilized as a heat source in any application wherein radiant heaters are employed.

[0023] Yet another embodiment is illustrated in cross-sectional view in FIG. 2. In FIG. 2 a gas grill, 30, comprising a heating element of the instant invention is illustrated. Gas grills typically comprise a base, 32, and a closable lid, 34, in a clam-shell configuration. It is readily apparent that the top can be opened to access contents and closed to contain heat within the confines of the clam-shell configuration. Legs, 36, are preferred.

[0024] A gas source, 38, such as a propane bottle or natural gas connection, provides fuel through a hose, 40, to the plenum, 12. An air inlet, 42, allows the fuel to mix with air, preferably by aspiration, thereby providing a combustible mixture, into the plenum. The combustible mixture is distributed throughout the plenum by a diffuser, 21, and it then passes through the metal foam burner, 14, generating heat. A grill, 44, provides a support for an item, 46, being cooked.

[0025] The metal foam has open cells with a density of 10-25% of theoretical density. For the purposes of the present invention density refers to the percentage of density relative to the density of a solid block of the same material. A related measure is the porosity reported in pores per inch (ppi) which is the inverse of the average pore diameter. An average pore

diameter of 0.10 inches would be reported as 10 ppi, for example. The preferred metal foam burner has a porosity of 2-150 pores per inch.

[0026] The metal foam is selected from a metal material which is unaltered by heating above 900° C. in an oxidizing atmosphere. Particularly preferred materials include FeCrAlY, stainless steel, alloys of nickel such as Inconel, combinations and alloys thereof.

[0027] The manufacture of metal foams is known throughout the industry. For the purposes of the present invention a volatile foam, such as polyurethane, can be impregnated and preferably saturated with metal foam precursors, fired, and cut to form grooves. This is preferred for groove consistency. Alternatively, a volatile foam with grooves therein can be impregnated and preferably saturated with metal foam precursors and fired thereby forming a material with grooves therein. It is preferable that the grooves be cut in a monolith since this provides more systematic grooves.

[0028] Open cell metal foam is typically formed by bonding metal particles together through a thermal treating process which is typically referred to as sintering. In practice polymer foam is coated with a metal composition. It is preferable that the metal composition comprise some form of a solvent to aid in transporting the metal particles into the interior of the polymer foam. Surfactants, sintering aids, binding agents, thickening agents and other adjuvants are typically added, as understood in the art, to insure adequate wetting of the polymer. It is most preferable to saturate the polymeric foam to insure adequate coverage of the internal struts. After a sufficient amount of metal composition is incorporated into the polymer foam the volatile components are vaporized and the metal particles fused together by heat thereby forming a metal foam which is a replica of the interstitial spaces in the polymeric foam.

EXAMPLES

[0029] Equivalent burners were prepared and compared for emissions and efficiency. The burners comprised (METAL COMPOSITION), at a density of (DENSITY HERE), were identically prepared. Samples of (SIZE OF TILE) without grooves and with (SIZE, SHAPE, SEPARATION, ETC.) grooves were compared at various pressures. The results are presented in Table 1. Each tile was tested in the same burner body to insure consistency of plenum configuration and gas flow parameters. The tiles were tested as a function of gas pressures in inches of water column (i.w.c) at a constant air to gas ratio of about 10 to 1. The combustion data included carbon monoxide (CO) in ppm, carbon dioxide (CO₂) in ppm, oxides of nitrogen (NO_x) in ppm, and temperature as indicated from a radiometer reading in mW.

TABLE 1

Comparison of slotted versus unslotted burners							
Sample	Grooves	Pressure	CO	CO ₂	O ₂	NO _x	mW
1 Inv.	y	3	183	1.019	18.62	1.213	7.09
2 Comp.	N	3	314	1.299	19.27	1.303	5.84
3 Inv.	Y	4	650	1.517	18.06	1.745	8.40
4 Comp.	N	4	360	1.161	18.94	1.748	6.92
5 Inv.	Y	5	317	1.402	18.48	1.85	5.27
6 Comp.	N	5	344	1.096	18.78	2.219	7.57
7 Inv.	Y	6	616	1.614	18.08	2.11	5.90
8 Comp.	N	6	525	1.53	18.34	2.45	8.32
9 Inv.	Y	7	435	1.658	18.09	1.998	6.25
10 Comp.	N	7	732	1.963	17.81	2.67	9.48

TABLE 1-continued

<u>Comparison of slotted versus unslotted burners</u>							
Sample	Grooves	Pressure	CO	CO ₂	O ₂	NO _x	mW
11 Inv.	Y	8	298	1.940	17.79	1.983	7.02
12 Comp.	N	8	774	2.080	17.62	2.759	9.87

[0030] To confirm that the grooves were providing the advantages, as opposed to an unrecognized and unintentional manufacturing or compositional alteration, the burners which lacked grooves were modified by cutting grooves therein. These newly grooved, but pretested, burners were retested as above. The results are presented in Table 2. In Table 2 the results of Table 1 with the ungrooved burners are repeated to facilitate comparison.

TABLE 2

<u>Comparison of slotted versus unslotted burners</u>							
Sample	Grooves	Pressure	CO	CO ₂	O ₂	NO _x	mW
2 Inv.	Y	3	191	1.152	19.12	1.800	5.79
2 Comp.	N	3	314	1.299	19.27	1.303	5.84
4 Inv.	Y	4	271	1.248	18.91	1.857	7.00
4 Comp.	N	4	360	1.161	18.94	1.748	6.92
6 Inv.	Y	5	351	1.532	18.57	2.133	8.01
6 Comp.	N	5	344	1.096	18.78	2.219	7.57
8 Inv.	Y	6	324	1.264	18.61	2.201	8.62
8 Comp.	N	6	525	1.53	18.34	2.45	8.32
10 Inv.	Y	7	453	1.824	18.05	2.556	9.61
10 Comp.	N	7	732	1.963	17.81	2.67	9.48
12 Inv.	Y	8	354	1.833	18.13	2.440	10.23
12 Comp.	N	8	774	2.080	17.62	2.759	9.87

[0031] As indicated in the preceding data the inventive samples clearly indicate an improvement in combustion as realized from the reduction in CO emissions. This improvement is generally realized across all input rates. As observed during the testing that the inventive samples appeared to be hotter especially at lower input rates. As realized there are anomalous examples, at least partly, due to the difficulty in obtaining the measurements. Visual observations of the glow characteristics followed the measured trend.

[0032] As realized from the data a metal foam burner is provided wherein with a porosity of (XXX—POROSITY OF EXAMPLES) and supply pressure of about 3 i.w.c. using air and natural gas in a 10:1 ratio a flame can be obtained with a sufficient combustion to exhibit less than 300 ppm CO, and more preferably less than 200 ppm CO. This represents a significant advantage over the art. (CHECK THIS)

[0033] The present invention has been described with particular reference to the preferred embodiments without limit thereto. Those of skill in the art will realize additional embodiments

Claimed is:

1. A radiant burner comprising:

a reticulated metal foam comprising a first face and a second face with a density sufficient for combustion fuel to pass there through;

said first face adapted to contact said combustion fuel for passing through said reticulated metal foam;

said second face adapted to radiate after said combustion fuel has been ignited wherein said second face comprises a plurality of grooves.

2. The radiant burner of claim 1 wherein said reticulated metal foam has a density of 2-25% relative to a theoretical density.

3. The radiant burner of claim 1 wherein said reticulated metal foam has 2-150 pores per inch.

4. The radiant burner of claim 1 wherein said reticulated metal foam comprises a material selected from the group consisting of FeCrAlY alloy, stainless steel and nickel alloy.

5. The radiant burner of claim 1 wherein said grooves have an included angle of 10-60°.

6. The radiant burner of claim 1 wherein said grooves have a depth of at least 0.125 to no more than 0.5 inches.

7. The radiant burner of claim 1 wherein said grooves are separated by at least 0.125 to no more than 2 inches.

8. The radiant burner of claim 1 wherein said grooves are linear.

9. The radiant burner of claim 1 wherein at least two grooves intersect.

10. The radiant burner of claim 1 wherein at least one groove of said grooves is curved.

11. The radiant burner of claim 1 further comprising a plenum attached to said reticulated metal foam wherein said plenum comprises said combustion fuel.

12. The radiant burner of claim 1 wherein said reticulated metal foam with a porosity of (XXX—POROSITY OF EXAMPLES) and supply pressure of about 3 i.w.c. using air and natural gas in a 10:1 ratio a flame can be obtained with a sufficient combustion to exhibit less than 300 ppm CO.

13. The radiant burner of claim 12 wherein said flame can be obtained with a sufficient combustion to exhibit less than 200 ppm CO.

14. A heating system comprising:

an apparatus for providing combustible gas;

a mixer capable of mixing said combustible gas with air to form a combustible fuel mixture;

a reticulated metal foam burner comprising a first face and a second face wherein said first face is capable of receiving said combustible fuel mixture and wherein said combustible fuel mixture passes through said reticulated metal foam burner for combustion on a second surface wherein said second surface comprises a plurality of grooves; and

a plenum chamber adapted to distribute said combustible fuel mixture over said first surface.

15. The heating system of claim 14 wherein said reticulated metal foam burner has a density of 2-25% relative to a theoretical density.

16. The heating system of claim 14 wherein said reticulated metal foam burner has 2-150 pores per inch.

17. The heating system of claim 14 wherein said reticulated metal foam burner comprises a material selected from the group consisting of FeCrAlY alloy, stainless steel and nickel alloy.

18. The heating system of claim 14 wherein said grooves have an included angle of 10-60°.

19. The heating system of claim 14 wherein said grooves have a depth of at least 0.125 to no more than 0.5 inches.

20. The heating system of claim 14 wherein said grooves are separated by at least 0.125 to no more than 2 inches.

21. The heating system of claim 14 wherein said grooves are linear.

22. The heating system of claim 14 wherein at least two grooves intersect.

23. The heating system of claim **14** wherein said reticulated metal foam with a porosity of (XXX—POROSITY OF EXAMPLES) and supply pressure of about 3 i.w.c. using air and natural gas in a 10:1 ratio a flame can be obtained with a sufficient combustion to exhibit less than 300 ppm CO.

24. The heating system of claim **23** wherein said flame can be obtained with a sufficient combustion to exhibit less than 200 ppm CO.

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