Oct. 22, 1968 L. C. HARDISON 3,407,025

SEMI-CATALYTIC INFRA-RED HEAT PRODUCING UNIT

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Figure 1

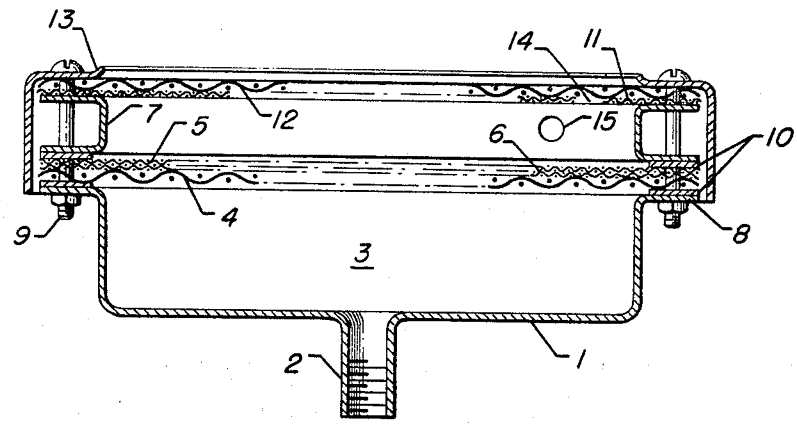
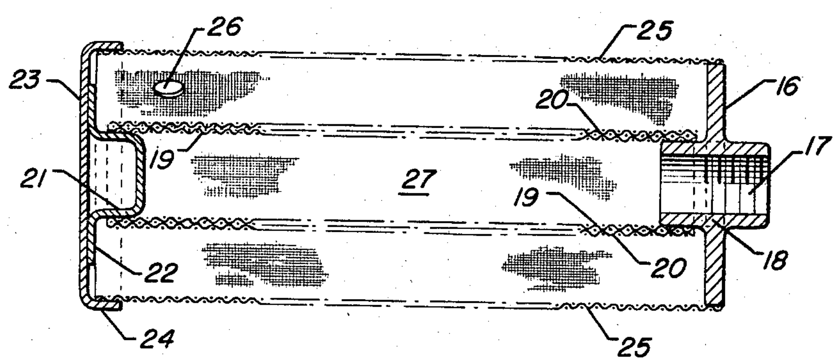


Figure 2



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SEMI-CATALYTIC INFRA-RED HEAT PRODUCING UNIT

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ABSTRACT OF THE DISCLOSURE

A semi-catalytic infra-red heater operating on gaseous fuel comprising a first stage non-catalytic alloy metal screen and a second stage catalyst coated alloy metal screen spaced a short distance downstream therefrom, said screens being supported by a housing having an air and fuel supply inlet thereto. The screeens may be flat and parallel, or tubular and concentric.

The present invention is directed to a semi-catalytic infra-red heat producing unit and more particularly to the design and construction of an all-metal infra-red heater unit providing both non-catalytic and catalytic combustion of a fuel-air mixture as the latter passes through two separate stages of special metal gauzes.

There have been many types of infra-red heat producing units devised to effect either a non-catalytic or a catalytic burning of fuel-air mixtures over or through a radiant surface. The earlier catalytic forms of infra-red heaters utilized activating agents impregnated onto asbestos fiber gauze to assist in the catalytic oxidation of a fuel-air mixture; however, such materials were fragile and limited to low temperature operations. In general, temperatures above about 900° F. would lead to charring and breakage. As a result, porous ceramics or metal alloy meshes have been preferred for non-catalytic and catalytic heat generating units.

Non-catalytic infra-red burners have been operated by flame impingement upon cup shaped ceramic members, or by fuel-air burning through porous ceramic plates. All of the ceramic infra-red burner units have been capable of very high temperature emissions but such devices are subject to breaking from handling and thermal shock and also have limitations in operating efficiency. For example, in a unit having flame impingement upon a ceramic cup type member, the source temperature of the radiant energy is normally extremely high, well above about 1700° F., such that there is no visible evidence of flame and a resulting white hot ceramic. However, since the source temperature is high, there is no possibility of easily controlling the actual wave length of the radiant energy reaching the material to be heated.

In connection with the use of electrically energized heaters, there are various disadvantages in that the surface of the heater itself must be at a relatively high temperature in order to produce radiant energy. As a result, it is sometimes difficult to provide the optimum wave length for the work being treated. Also, electrically energized heaters are not readily adaptable to proportional control since such heaters are either "On" or "Off" and it is difficult to secure intermediate ranges of radiant energy. Furthermore, the reflector means utilized in connection with energized infra-red heaters gradually become covered with dirt deposits so as to reduce their efficiency, i.e., as less energy is reflected there is a subsequent heat loss.

Various of the infra-red heat producing units incorporating catalytically coated alloy gauzes have been of particular advantage in providing controlled burning of fuel-air mixture in a flameless manner. Actually, opera-

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tions may provide temperature emissions over a wide range of temperature of from about 900° F. to about 1800° F. However, in studying gas emissions from the various types of catalytically coated, as well as from uncoated gauze units, there has been found that there is relatively high emissions of carbon monoxide. On the other hand, it has been found that by combining non-catalytic metal screens with catalytically coated alloy screens in a particular manner, and in accordnce with the present invention, there can be effected a greater efficiency and more complete combustion of the fuel-air stream, while at the same time obtaining the desired benefits of controllability of temperature and longer wave length infra-red radiant energy leaving the unit.

It is thus a principal object of the present invention to provide an infra-red heat producing unit which utilizes an interior or upstream non-catalytic all-metal gauze surface means to effect initial distribution and burner surface in combination with spaced exterior or downstream catalytically coated all-metal alloy gauze means that can effectively complete the oxidation of unburned gaseous components leaving the first surface.

It is also an object of the present invention to provide an all-metal unit that effects a first stage non-catalytic oxidation of the fuel-air mixture and a second stage catalytic oxidation that is carried out on the catalytically coated gauze surface spaced a short distance away from and downstream of the first stage layer.

It is still another object of the present invention to use an all-metal reflector screen or gauze that is adjacent to and in combination with the first stage non-catalytic infra-red burner screen so as to eliminate the use of mineral wool or other non-metallic diffuser materials.

It was found that certain of the earlier designed units had a problem of back-flashing of the fuel-air mixture into the manifold section or plenum of the housing, particularly after a gradual heat build-up in the diffusion packing or in connection with distributor screens that were spaced upstream from the infra-red heat emitting surface. Apparently, small cinder-like particles within a mineral wool distribution layer provided hot spots which in turn could initiate back-flashing into the fuel inlet zone. Also, in connection with the use of one or more metal alloy screens which were used as reflector or distributing members and were in spaced positions back of or up stream from the infra-red heat emitting screen, would serve to provide a stepwise back-flashing of the fuel-air mixture into the inlet zone. In other words, it appears that there was a stepwise temperature build up and heat absorption by the spaced upstream screens, particularly at low flow rates, such that there was sufficient heat carried back to cause combustion in the inlet zone. As a result, it is found that preferred designs utilize one or more heat reflector screens directly adjacent the first stage of fuel-air oxidation and infra-red heat generation.

In one embodiment, the present invention provides a catalytic radiant heating apparatus which comprises in combination, an internal gas pervious first stage combustion element of at least two adjacent uncoated metal alloy gauze members adapted to have a gaseous fuel stream pass therethrough, whereby at least one downstream member serves as a burner screen and at least one upstream member serves as a radiant heat shield on the fuel inlet side, a second stage combustion element of at least one gas pervious metal alloy gauze having a noble metal gas oxidizing catalytic surface that is spaced a short distance downstream from the face of the burner screen of said first stage element, and confined housing means having air and fuel supply inlet means thereto enclosing the upstream face of said radiant heat shield member of said first stage element and in addition encompassing the open spacing between said first and second stage combustion elements.

In another embodiment, the present invention provides an infra-red heat producing unit adapted to provide high temperature radiant heating above 900° F., and comprises in combination, a metal alloy gas combustion screen directly adjacent to and coextensive with at least one all-metal alloy gas distributing-reflective screen, a housing means having air and fuel supply inlet means thereto encompassing the upstream side of said adjacent screens, at least one alloy metal catalytic screen having a noble metal gas oxidizing surface that is spaced a short distance downstream from the outer surface of said gas combustion screen and providing an unobstructed free area over the surface of said combustion screen, whereby there may be the first stage non-catalytic oxidation of gases on said combustion screen and a second stage catalytic combustion on said catalytic screen of the gases leaving the former.

A preferred design utilizes fine mesh screen in each of the stages of fuel-air oxidation, as well as for the gas-distributing gas-reflective screen, with such screen being in the 20–70 mesh range having wire sizes from about 0.005 inch to about 0.02 inch diameter. In all cases, the alloy utilized shall be of chrome-nickel alloys, i.e., Nichrome, Chromel and the like, capable of withstanding high temperature ranges of the order of about 1600° F. or more.

A preferred burner unit also has provision for effecting a lighting of the fuel-air mixture at the surface of the interior non-catalytic heat producing screen. For example, a suitable small opening or "light-off hole" may be provided through the outer catalytically coated gauze or outer portion of the housing.

Additional constructional features and advantages of operation may be noted upon reference to the accompanying drawing and the following description thereof.

FIGURE 1 of the drawing is a sectional elevational view through one embodiment of an improved two-stage semi-catalytic infra-red heat producing unit.

FIGURE 2 of the drawing is a sectional elevational view of a cylindrical form of two-stage, semi-catalytic infra-red heat producing unit.

Referring now to FIGURE 1 of the drawing, there is indicated a housing **1** having a fuel-air inlet means **2** which leads to an interior plenum chamber or fuel distributing zone **3**. Extending interiorly across the housing **1**, as well as over the plenum zone **3**, is a relatively large mesh supporting screen **4**, an uncoated fine mesh reflector or radiation screen **6** and an uncoated burner screen **5**. In the present embodiment the edges of the screen traversing the housing are held by a spacer member **7** clamped against an outwardly projecting flange **8** by a cover ring **13** and suitable bolting means **9**. A pair of insulating gasket members **10**, which may be of asbestos, Fiberfrax or other suitable temperature resistant insulating material, are used each side of the screen members **4**, **5** and **6** to partially preclude the transfer of heat from the latter to the flame **8** and housing **1**.

The present embodiment shows the spacer member **7** as being of a channel shape and extending circumferentially around the edge of the housing above the upper burner screen **5** so as to provide an intermediate unobstructed spacing between the interior burner screen **5** and an external catalytically activated burner screen **11**. Where desired, a suitable heavier gauge wide mesh guard screen **12** is superimposed externally over the catalytic screen **11** and held in place along with the latter by the cover ring **13**. The spaced bolting means **9** also serve to clamp the cover ring **13** against the edges of the outer screens **11** and **12** as well as against the outer flange portion of spacer member **7** to provide a completed burner unit.

In accordance with the present improved infra-red burner design and construction, the catalytically coated outer screen **11** is provided of fine mesh chrome-nickel alloy, as noted hereinbefore in the 20–70 mesh range, but more preferably of about 40 mesh with 0.010 inch diameter wire, such that there may be uniform distribution of the partially oxidized fuel-air mixture leaving the inner burner screen **5** over the entire cross sectional area of burner unit. The catalytic coating may comprise platinum, palladium or a combination thereof either alone or in combination with one or more of the other members of the platinum group of metals such as ruthenium, iridium, rhodium, etc. Also some percentages of other activating components, such as thorium, tungsten, cesium and the like may be applied in combination with the one or more platinum group metals. Deposition of the coating may be carried out in the manner similar to that set forth in the Suter et al. U.S. Patent No. 2,720,494, issued Oct. 11, 1955, where alloy metal wire or ribbon is catalytically activated to provide a desirable form of gas oxidizing or incinerating element. It is believed unnecessary to provide detail herein as to the means for applying and activating the coating in connection with the infra-red heat generating member of this invention, since reference may be made to such patent for preparation and coating methods.

In the operation of the unit of FIGURE 1, the fuel-air mixture enters the plenum chamber **3** by way of inlet **2** and is distributed from the latter by way of support screen **4** and reflector screen **6** to the burner screen **5**. By providing flame or spark ignition of the fuel-air mixture on the outer surface of the burner screen **5** there will be flame and heating of the screen **5** to in turn provide infra-red radiant heat therefrom. Initially, there may be a small amount of visible flame extending over the surface of burner screen **5**; however, generally under high temperature radiant conditions, when screen **5** has become heated to above a cherry red temperature, there will be little or no visibility to the flame carrying outwardly from the surface of the screen. The hot combustion gases leaving the surface of burner screen **5** is passed through the internal open space being provided by the height of channel spacer member **7** so as to contact the surface of the catalytically coated burner screen **11**. The latter will effect the catalytic oxidation of the unburned fuel-air components as well as oxidation of carbon monoxide being entrained with the gaseous product stream leaving the first stage burner screen **5**. In other words, the activated or catalytically coated burner screen **11** will serve to act as a second stage of oxidation or a "clean-up" stage for the gaseous mixture leaving the burner unit. After a short period of operation, the outer screen **11** will provide a glowing infra-red heat generating surface to emit heat along with the inner screen **5** so that the total infra-red heat generation from both burner stages is effective to radiate outwardly to a work material that is to receive heat from the burner unit.

It is not intended to limit the construction to any one means for effecting the lighting of the fuel-air mixture on the surface of the first stage burner screen **5**; however, for illustrative purposes, FIGURE 1 of the drawing indicates that a lighting hole **14** may be provided through a small portion of the outer catalytically coated screen **11** as well as through guard screen **12**, where such screen is being used as an outer protection over the face of the unit. In an alternative arrangement, a lighting hole such as **15** may be provided through the wall of the channel shaped spacer member **7** as well as through an opposing portion at **15'** in the cover ring **13**.

It may be noted that the present embodiment indicates a screen **11** to provide the second stage of combustion for the infra-red heat producing unit, although in some instances, it may be desirable to provide a plurality of catalytically coated screens over the outer surface of the heat producing unit such that there is adequate complete combustion of all of the gases leaving the unit and substantial elimination of any CO fumes therefrom. It should also be noted that it is a particular feature of the present two-stage construction to utilize a definite spaced distance as provided by spacer member 7 which will maintain an unobstructed spacing on the downstream face of the burner screen 5. This space provides for the redistribution of unburned gases as well as combustion gases to the surface of the catalytically coated screen member 11. The actual amount of spacing may, for example, be from about 1/8 inch to about 1 inch, but will vary in accordance with the size of the burner unit, gas flow rates and mesh sizes, which may be utilized for both the first and second stage burner screens.

It is a still further feature of the improved construction to utilize at least two adjacent screens at the first stage of fuel-air oxidation. In other words, by having two or more uncoated screens at this zone, it is possible to have at least one of the internal screen members to serve as a distributor or radiation screen causing heat generated on the outer surface of screen 5 to be reflected outwardly from the heater unit. In any case, there should not be any spacing between the burner screen member, such as 5, and an upstream reflector or radiant member, such as 6, that would permit a stage-wise absorption of heat backwardly into the plenum or fuel distribution zone, which would in turn lead to the problems of back-flashing described hereinbefore.

Referring now more particularly to FIGURE 2 of the drawing, there is indicated a cylindrical or tubular form of infra-red heat producing unit having a circularly shaped end closure member 16 having a central fuel inlet opening 17. Opposing the latter and projecting inwardly from the circular portion of the closure member 16 is a hub portion 18 adapted to support cylindrically formed screen members 19 and 20. The latter are uncoated alloy screen members which may be in the 20 to 70 mesh range, but preferably of the order of about 40 to 50 mesh so as to provide an initial stage of burning and resulting heat radiation for a fuel-air mixture introduced by way of the inlet 17. The downstream end of the members 19 and 20 are supported on a suitable shoulder portion 21 of a circular support member 22 which in turn is held internally within a circular end closure member 23. The latter has a small flange section 24 which is of a diameter approximately equivalent to the external diameter of the closure member 16 at the inlet end of the unit whereby there may be end supporting surfaces for an outer second stage catalytically coated oxidizing screen 25. The outer oxidizing screen 25 is covered with a suitable metallic deposition or coating of an oxidation catalyst, preferably a platinum group metal, such as described hereinbefore in connection with the teachings of the Suter et al. Patent No. 2,720,494. For assembly purposes, screen 25 may be tack-welded or otherwise attached to the outer periphery of closure member 16 and to flange 25 on closure 23. In addition, for lighting purposes, there may be a suitable lighting hole 26 through a small portion of the surface of the outer catalytic screen 25.

The operation of the embodiment of FIGURE 2 is similar to that described in connection with FIGURE 1 except that radiant heat is emitted radially outwardly from a tubular unit which may be cylindrical or of polygon shape. A fuel-air mixture entering inlet 17 carries to an inner plenum zone 27 within the interior of screen 19, which serves as a heat radiation shield, as well as distributor member, such that following a light-off through hole 26 there is a burning of fuel over the entire outer surface of burner screen 20. Following the initial oxidation stage, the entire outer surface of the latter screen becomes glowing and has an almost invisible high temperature flame that is capable of producing high temperature infra-red heat therefrom. The color of the burner screen 20 and the temperature therefrom will, of course, depend upon the rate of gas flow through the unit and the rate of oxidation across the surface of the screen 20. At the second stage of combustion, being provided by the outer catalytically activated screen 25, there will be a substantial completion of the oxidation of unburned portions of the fuel-air mixture as well as oxidation of carbon monoxide to carbon dioxide that is entrained with the combustion products. Here again, after a period of initial operation, the outer catalytically coated screen 25 will provide a high temperature infra-red heat producing glow which will carry outwardly to material that is to be heated.

It should also be noted in connection with the embodiment of FIGURE 2 that space provided between the inner burner screen 20 and the second stage burner screen 25 so as to permit adequate oxidation to take place across the outer surface of the first stage burner screen 20 without hinderance from an adjacent outer screen. In addition, there is suitable space for the redistribution of combustion gases and unburned fuel to uniformly pass to the surface of the outer second stage screen 25 for a completion of oxidation of unburned components in the gas flow. Generally, a single outer activated screen such as 25 will suffice to effect the second stage of burning; however, in some instances of high flow rates, it may be desirable to have more than one coated and circumscribing screen. Also, it may be necessary to provide a suitable guard screen around the catalytically coated screen to preclude the latter from being deformed or scraped during installation procedures.

Further, it may be noted that at least two uncoated screens, 19 and 20, are used adjacent one another at the first stage of combustion whereby there is at least one inner distributor and reflector screen to assist in precluding excessive backward radiation of heat into the plenum or fuel inlet portions of the unit.

Small cylindrical heater units may be used singly or in groups to provide specialized heating operations. Optional arrangements of units, such as rows, multiple rows, and other geometric patterns thereof, may be used with or without reflector means to provide for the directing of infra-red heat to a particular heat absorbing area. Also, fuel gas and air may be supplied from header means or from individual supply pipes and air aspirator means, since it is not intended to limit the present invention to any one form of fuel distribution system.

In connection with a series of test operations on an improved infra-red heat generating panel having the spaced combination of non-catalytic and catalytic surfaces, it was found that readings showing the hydrocarbon content in the effluent gases directly above an open light-off hole averaged several points higher than readings above portions of the outer catalytically activated screen. In other words, the tests showed a significantly greater advantage for the use of the second stage catalytic oxidation in effecting the completion of fuel burning.

Specifically, in a series of test operations, a unit was used which was similar to FIGURE 1 having an internal uncoated 30 mesh screen with 0.01 inch diameter wire of Chromel C as a radiation shield; an adjacent uncoated 40 mesh screen of the same type wire and a 1/2-inch spacing to an outer catalytically coated 30 mesh screen of 0.010-inch Chromel C wire. A primarily platinum metal catalytic coating was deposited on this outer screen in accordance with the teachings of the above referred to United States Patent No. 2,720,494.

For one test run, air flow of 150 cubic feet per hour (s.c.f.h.) and an air to methane ratio of 10 was used through the unit to provide a resulting hydrocarbon content reading of 8.0 above the open light-off hole in the outer catalytically activated screen and an average reading of 2.4 over the rest of the outer catalytic radiant screen. The test readings were taken with a Mine Safety Appliance Meter, Model #40. The temperature at the outside of the outer (catalytic) screen was 840° F. at the time of taking the test readings.

In another test run with the same unit, where air flow rate was 350 s.c.f.h. and the air-fuel ratio 10 to 1, the resulting hydrocarbon content reading was 2.8 above the open light-off hole and an average of 0.6 over the surface of the catalytic screen. At this fuel rate, the temperature at the surface of the outer screen was 1170° F.

In still another test run with the same unit, where the air flow rate was 240 s.c.f.h. and the air fuel ratio was 12 to 1, the resulting hydrocarbon content reading was 8.4 at the open light-off hole and an average of 1.7 over the surface of the catalytic screen. At this fuel rate, the temperature at the surface of the outer screen was 950° F.

From the foregoing examples, as well as from other accompanying test operations, it is found that the second stage catalytic screen is of particular advantage in effecting more complete burning of the fuel stream through the heat generating unit; and, that combustion efficiencies range from about 91% to 98.8% above the light-off opening for a 850° F. to 1200° F. temperature range at the surface of the outer screen; while, in comparison, the efficiencies range from about 98.5% to 99.7% for the same temperature range where the gaseous stream carries through the second stage catalytic surface.

I claim as my invention:

1. A catalytic radiant heating apparatus which comprises in combination, an internal gas pervious non-catalytic first stage combustion element of at least two directly adjacent substantially unspaced apart uncoated alloy metal gauze mambers adapted to have a gaseous fuel stream pass therethrough, whereby at least one downstream member serves as a burner screen and at least one upstream member serves as a radiant heat shield on the fuel inlet side, a second stage combustion element of at least one gas pervious alloy metal gauze with a mesh size in the 20 to 70 mesh range having a noble metal gas oxidizing catalytic surface that is spaced a short distance downstream from the face of the burner screen of said first stage element, and confined housing means having air and fuel supply inlet means thereto enclosing the upstream face of said radiant heat shield member of said first stage element and in addition encompassing the open spacing between said first and second stage combustion elements.

2. A semi-catalytic radiant heating apparatus adapted to produce heat in the infra-red range above 900° F. from a gaseous fuel stream, which comprises in combination, an uncoated non-catalytic first stage fuel gas combustion element having at least one alloy metal burner screen and at least one directly adjacent alloy metal gas diffusing and heat shielding screen, the latter being upstream and substantially unspaced from and coextensive with said burner screen, a catalytically active second stage combustion element of at least one gas pervious alloy metal screen with a mesh size in the 20 to 70 mesh range coated with a noble metal gas oxidizing deposition, said second stage element being spaced a short distance downstream from said first stage element whereby to provide an unobstructed combustion area therebetween, and confined housing means having air and fuel supply inlet means thereto enclosing the upstream face of said first stage combustion element and in addition encompassing said area between said first and second stage combustion elements.

3. A infra-red heat producing unit adapted to provide high temperature radiant heating above 900° F. which comprises in combination, a non-catalytic alloy metal gas combustion screen directly adjacent to and substantially unspaced from and coextensive with at least one non-catalytic alloy metal gas distributing-heat shielding screen, a housing means having air and fuel supply inlet means thereto enclosing the upstream side of said adjacent screens, at least one alloy metal catalytic screen with a mesh size in the 20 to 70 mesh range having a noble metal gas oxidizing surface that is spaced a short distance downstream from the outer surface of said gas combustion screen and providing an unobstructed free area over the surface of said combustion screen, whereby there may be first stage non-catalytic oxidation of gases on said combustion screen and a second stage catalytic combustion on said catalytic screen for the gas flow through the unit, and closure means around the periphery of said unobstructed area between said first and second stage combustion elements.

4. The unit of claim 3 further characterized in that said allow metal gauze members for said combustion elements are of chrome-nickel alloy with mesh sizes in the 20 to 70 mesh range.

5. The unit of claim 3 further characterized in that lighting hole means is provided therethrough downstream from said first stage combustion element.

6. A semi-catalytic radiant heating unit for producing high temperature infra-red heat above 900° F. from a gaseous fuel stream, which comprises in combination, a substantially flat uncoated non-catalytic first stage fuel gas combustion element having at least one alloy metal burner screen and at least one alloy metal gas diffusing and heat shielding screen, the latter being positioned directly adjacent the upstream face and substantially unspaced from and coextensive with said burner screen, confined housing means having air and fuel supply inlet means thereto encompassing the upstream face of said first stage combustion element and providing a gas manifold section to the latter, removable means attaching the periphery of said first stage combustion element to exterior wall portions of said housing, a catalytically active second stage combustion element having at least one gas pervious alloy metal screen with a mesh size in the 20 to 70 mesh range coated with a noble metal gas oxidizing deposition that is removably spaced a short distance from the downstream face of said first stage combustion element, and peripheral spacer means around the edges of said first and second stage combustion elements and said housing providing said short spaced distance between said elements and a resulting unobstructed area over the downstream face of said burner screen of said first stage combustion element.

7. The heating unit of claim 6 further characterized in that both the first stage and second stage combustion elements are formed of alloy metal gauze members having mesh sizes in the 20 to 70 mesh range and said first stage combustion element is transversely supported by a heavier gauge and wider mesh alloy metal supporting member that traverses the interior of said confined housing.

8. The heating unit of claim 6 further characterized in that said second stage combustion element is coated with a platinum group metal deposition and lighting hole means is provided through said unit to said unobstructed area downstream for said first stage combustion element.

9. A semi-catalytic radiant heating unit adapted to produce heat in the infra-red range above 900° F. from a gaseous fuel stream, which comprises, in combination, a tubular form internal non-catalytic first stage combustion element having at least one uncoated alloy metal burner screen and at least one alloy metal gas diffusing and heat shielding screen, the latter extending directly adjacent to and substantially unspaced from and coextensive with the upstream face of said burner screen, end closure means between the end portions of said tubular first stage combustion element with fuel-air inlet means through at least a portion of said end closure means whereby a fuel-air mixture may be uniformly distributed radially outwardly through said tubular combustion element, a catalytically active second stage combustion element of at least one gas pervious alloy metal screen with a mesh size in the 20 to 70 mesh range coated with a platinum group metal that is spaced from said first stage combustion element, said second stage element being of a larger but similar tubular configuration to said first stage element whereby there is an unobstructed area of substantially uniform depth between said tubular elements permitting non-catalytic flame combustion over the downstream face of said burner screen of said first stage ele-

ment and a second stage combustion of gases passing radially outwardly through said second stage catalytic element, and a resulting substantially uniform infra-red heat emitted radially from said unit.

10. The heating unit of claim **9** further characterized in that said second stage tubular combustion element is provided with a small lighting hole permitting ignition of gases on said interior first stage combustion element.

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