RADIANT HEATER

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FIG. 1.

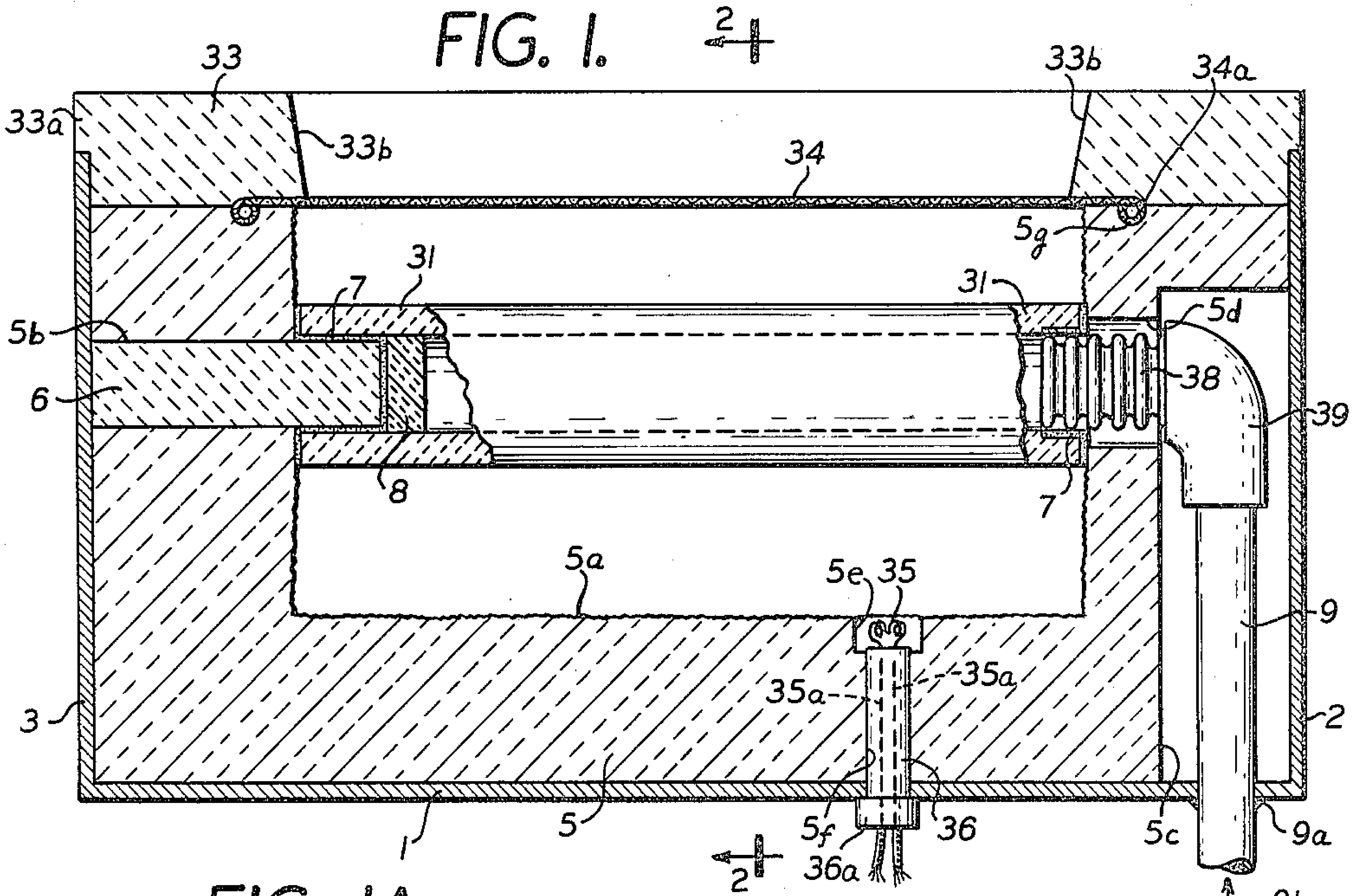


FIG. 1A.

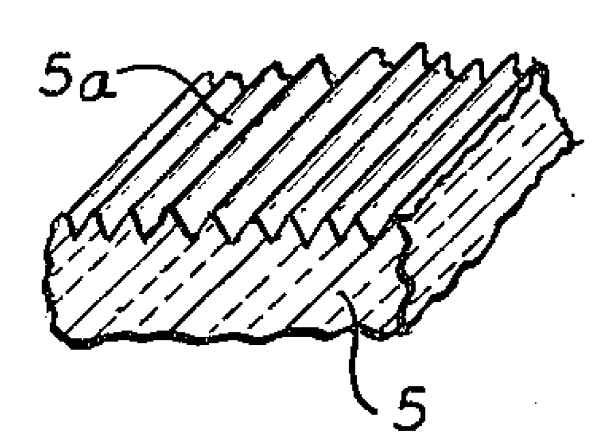


FIG. 2.

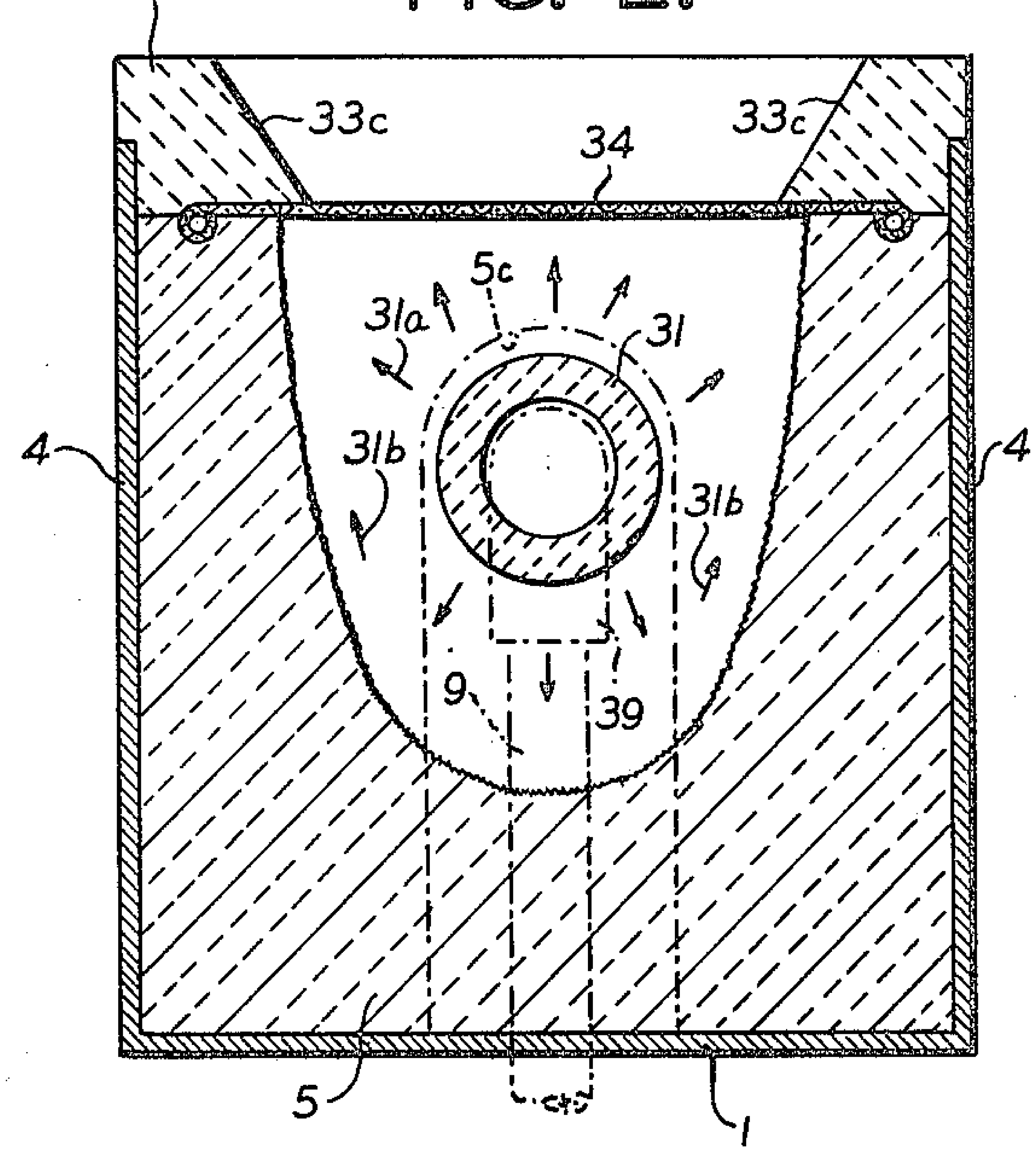
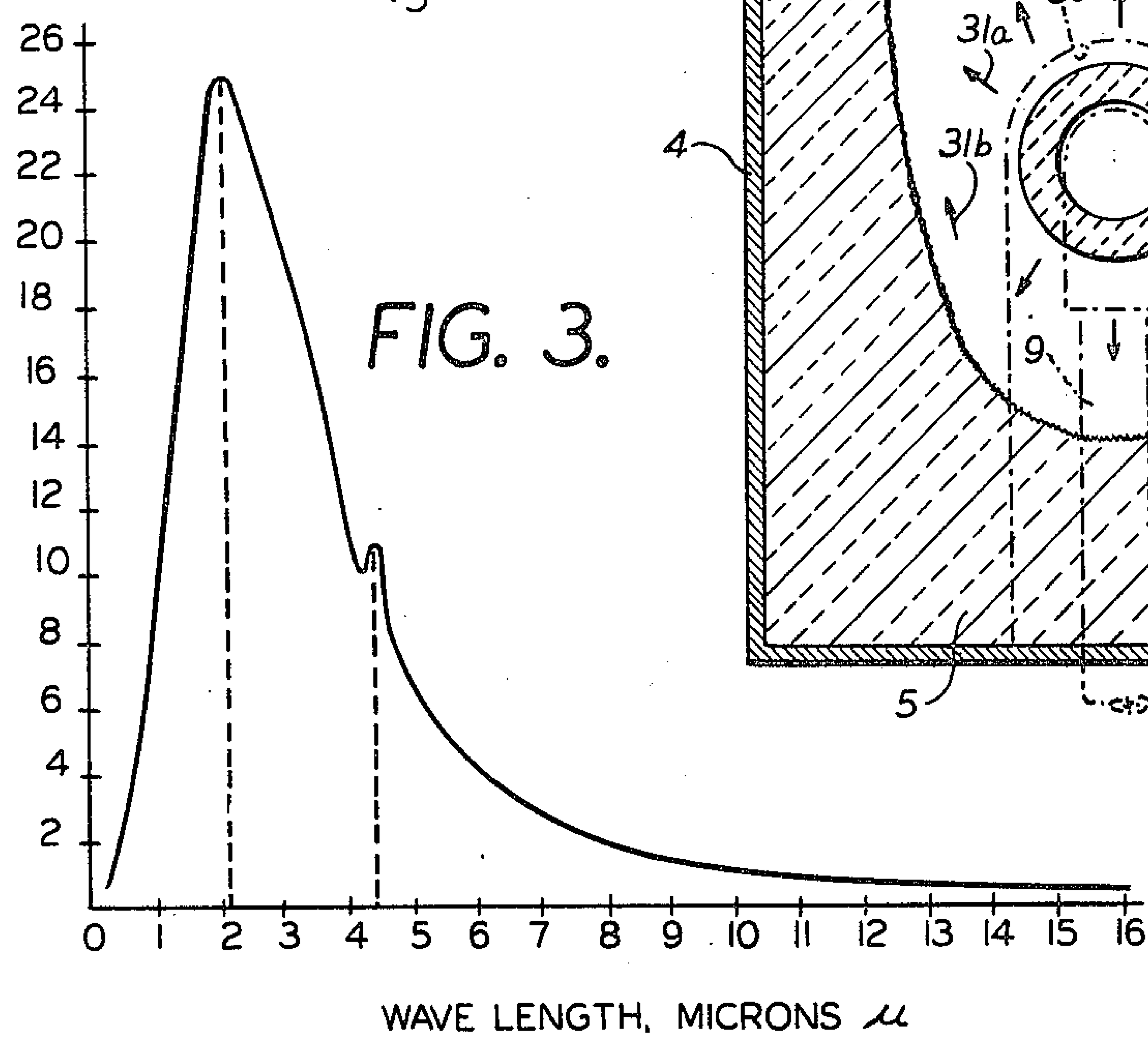


FIG. 3.



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Nov. 16, 1965 G. WEISS 3,217,701

RADIANT HEATER

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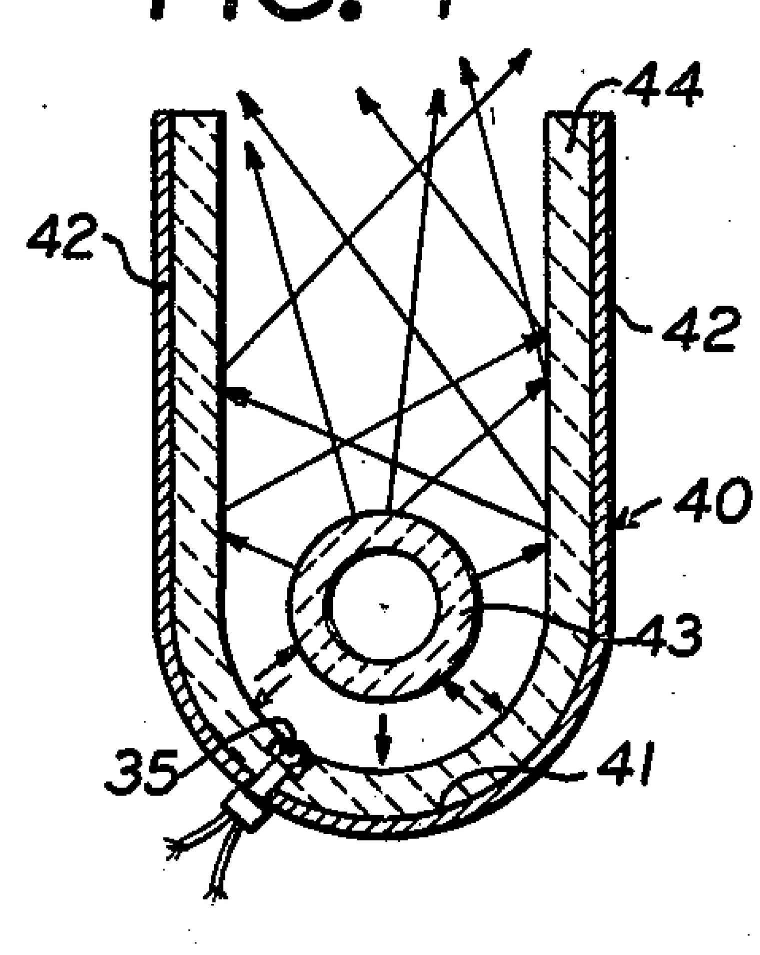
FIG. 4



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RADIANT HEATER

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3 Claims. (Cl. 126—92)

This invention is a continuation-in-part of my prior U.S. patent application Serial Number 726,720, for Improvement in or Relating to Methods of Manufacture and Operation of Thermocatalytic Elements and Products Derived Therefrom, filed April 7, 1958; Serial Number 726,758, filed April 7, 1958, for Thermocatalytic Reactions, now abandoned; Serial Number 840,765 for Arrangement of Thermocatalytic Heating Elements, filed Sept. 17, 1959, now Patent No. 3,063,493, issued November 13, 1962; and Serial Number 840,769 for Mounting of Thermocatalytic Elements, filed September 17, 1959, now Patent No. 3,119,439, issued January 28, 1964.

This invention relates to improvements in radiant heaters and the like, and in particular, relates to improvements in cavity radiators.

In said prior U.S. applications, I have disclosed a heating system comprising a hollow tube of porous fibrous refractory material, having a low coefficient of thermal conductivity or "K" factor, together with means for passing a mixture of air and a combustible gas through the wall of said tube, and also together with means for igniting the fuel-air mixture. The system as disclosed in said prior U.S. patent applications has been such that the reaction of the oxygen in the air and the combustible gas takes place on a surface of the tube wall, and also slightly within the surface, causing said surface to incandesce. The system in accordance with said prior U.S. applications has been a highly efficient source of heat. A considerable portion of the energy output of the system has been in the form of heat radiation from the incandescent tube surface, and another considerable portion of the energy output of the system has been in the form of convection heat given off by the exhaust gases of the system.

An important object of this invention is to provide an improved heating system, wherein a much higher proportion of the emitted energy will be in the form of radiant heat. In accordance with certain embodiments of the invention, I utilize in the system a tube of refractory material similar to the type discussed above, in conjunction with an improved wall structure adjacent to and in thermal communication with the tube in such a way as to transfer a considerable portion of the convection energy of the exhaust gases into radiant heat energy. In certain other embodiments of the invention, I form the refractory material into a wall structure other than tubular, the wall structure itself being of such shape and size and material as to cause maximum transfer of the convection energy of the exhaust gases into radiant energy.

In order to produce maximum conversion of the convection heat energy of the exhaust gases into radiant energy, it has been necessary to provide reflective surfaces for the exhaust gases which are non-metallic and refractory in nature. This is in contrast to the usual radiant electric heaters, in which, for greater efficiency, the heat radiated from a source is caused to impinge against a suitably designed and shaped metal reflecting surface which causes the heat energy to be emitted in selected direction. It has been found that the use of a metallic reflector to receive, reflect, and re-emit the energy emitted from the primary radiant incandescent surface is not satisfactory, to accomplish the purposes of this invention, because insufficient surface is thereby provided for impingement of the exhaust gases to insure maximum transfer of convection energy into radiant energy. Also, if a metallic reflector were used, it would radiate energy in both directions, which would require the use of insulation on the side of the reflector which is remote from the primary energy source.

It has also been found that the non-metallic reflector for the exhaust gases should have a low coefficient of thermal conductivty or "K" factor and should not absorb a relatively large amount of heat or have high thermal capacity. Accordingly, dense refractory materials such as ceramics are not satisfactory as reflectors.

In the embodiments of this invention, the radiant energy and the exhaust gases from the incandescent primary surface are directed against one or more secondary surfaces which are made of a refractory material which is optionally the same as or somewhat similar to the refractory material of the main wall surface. (The so-called primary surface may also act as a secondary surface in that it receives energy emitted from the original combustion reaction.) As a result, the secondary surfaces of the system are caused to incandesce and to become almost as hot as the main emitting wall surface. Since the exhaust gases emitted by the primary incandescent surface leave this surface at a temperature the same as that of this surface and then strike secondary surfaces and elevate these to nearly the same temperature, a maximum amount of convection heat energy of the exhaust gases is transferred into radiant energy. While much of the secondary surface temperature is due to radiation, nevertheless hot gas impingement is effectively transferred into radiant energy.

An important object of this invention is to achieve a maximum percentage of radiant heat output of the system, at the maximum output temperature consistent with long life of the materials of the system, and with minimum energy input. Accordingly, it is desirable to design the cavity in which the heat source is placed in such a way that the exhaust gases will reverberate therein, striking the incandescent secondary surfaces a maximum number of times before being finally emitted from the system, so as to insure maximum transfer of convection energy of the exhaust gases into radiant heat energy. From this standpoint, the ideal cavity would be infinitely small in cross section and infinitely great in depth, but such a cavity would only radiate at an infinitely small rate, by definition. Accordingly, the cavity dimensions are selected so as to permit some exhaust gas convection heat energy to be emitted therefrom. However, in many applications, it is possible to provide a large number of emitting cavities, so as to increase the total radiant energy output per unit area.

Other objects and advantages of this invention will become apparent from the following description, in conjunction with the annexed drawing, in which preferred embodiments of the invention are disclosed.

In the drawings:

FIG. 1 is a vertical section of a first embodiment of the invention.

FIG. 1A is a fragmentary perspective view of one optional wall structure of the cavity in which the heat source is placed.

FIG. 2 is a section on line **2—2** of FIG. 1.

FIG. 3 is a graph of the energy output of the device shown in FIGS. 1 and 2, measured against the wave length of the energy.

FIG. 4 is a vertical section of an alternate embodiment of the invention.

In the embodiment of FIGURES 1–3, a porous refractory tube **31**, which serves as the source of energy, is positioned within the cavity *5a* of generally rectangular block **5**. Cavity *5a* extends downwardly from the top of block

5. Block 5 is received within a rectangular metal casing having a bottom wall 1, front wall 2, rear wall 3, side walls 4 and an open top. Preferably, the top of block 5 is somewhat below the level of the top of walls 2, 3 and 4. The casing and block 5 are longitudinally elongated. Cavity *5a* is concave in cross section and longitudinally elongated. Optionally, cavity *5a* is generally parabolic in cross sectional shape. Optionally, the lower portion of the peripheral wall of cavity *5a* may be part-cylindrical in shape. Tube 31 is hollow and cylindrical and extends between the end faces of cavity *5a*. As shown in FIG. 2, the axis of tube 31 is generally centrally located with respect to the peripheral wall of the cavity.

Block 5 has a bore *5b* in the rear wall thereof, which is coaxial with tube 31. A ceramic rod 6 extends through a bore *5b* and into the bore of tube 31, fitting frictionally within said tube bore. A refractory cement 7 is interposed between the end of tube 31 and the rear face of cavity *5a*, and also between the peripheral wall of rod 6 and the bore of tube 31, and also around the front end of rod 6. An insulating disc 8, which may be made of asbestos or other suitable material, is positioned within the bore of tube 31 and is secured to the front end of tube 6 by means of the aforesaid refractory cement 7. Cement 7 is non-permeable to the flow of the fuel gas-air mixture in tube 31 and prevents any combustion reaction at the surfaces covered thereby.

In order to secure the front end of tube 31 in place, and also serve as a source of fuel thereto, a vertical hollow metal tube 9 is extended upwardly through an opening in casing bottom wall 1, at the front thereof, and is secured to wall 1 by means of brazing or welding *9a*. Said tube 9 extends above wall 1 into a rear recess or cut-out *5c* in block 5, this cut-out *5c* extending to the bottom and also to the front of block 5. Metal elbow 39 is fixed to the upper end of tube 9, and the upper opening of elbow 39 faces rearwardly and opposes a through bore *5d* in the front wall of block 5. This bore *5d* is axially aligned with the bore of tube 31, and also extends to the cut-out or recess *5c*. A flexible metal tube 38, of corrugated construction, extends axially through bore *5d*. The rear end of tube 38 extends into the bore of tube 31, and is cemented thereto by the refractory cement 7. The front end of tube 31 is also coated by cement 7. The front end of tube 38 extends into and is secured within the upper opening of elbow 39.

A gas-air mixture may be passed into tube 9, in the direction of arrow *9b*, for entry into tube 31.

Means are provided for ignition of fuel-air mixture passing through the wall of the porous refractory tube 31. These ignition means include a metal tube 36 which extends upwardly through a bottom opening in wall 1 and through a vertical bore *5f* in the bottom of block 5. A collar *36a* on tube 36 and integral therewith abuts the lower face of wall 1 and is secured thereto by any suitable means (not shown). Tube 36 extends to the upper end of bore *5f*. At its upper end, bore *5f* communicates with a bore *5e* of increased diameter which extends to the bottom of cavity *5a*. An igniter coil 35 is located within bore *5e*. The insulated leads *35a* of said igniter coil 35 extend through tube 36 and below the head *36a*, and are connected to any suitable source of electric power (not shown).

A metal screen 34 optionally and preferably overlies the top of cavity *5a* and extends beyond the periphery thereof. The peripheral edge of screen 34 is welded to a circumferentially extending wire frame *34a* which extends into a corresponding groove *5g* formed in the upper surface of block 5.

Frame 33, made of suitable refractory material, overlies and rests upon brick 5 and the outer portion of screen 34. Said frame 33 extends above the level of walls 2, 3 and 4 and has an outer circumferentially extending flange *33a* which overlies and rests upon said walls. Said frame 33 has a central opening which overlies and exposes and is of the same extent as the top opening of cavity *5a*, the front and rear surfaces of said inner opening of frame 33 being downwardly convergingly inclined as indicated by the reference numeral *33b*, and the side surfaces being downwardly inwardly inclined to a somewhat greater extent, as indicated by the reference numeral *33c*.

Tube 31 may be any suitable porous refractory tube having the property that upon passage of a suitable gas-air mixture through the tube and through the porous wall thereof, at selected pressure, and upon ignition of the mixture passing through the porous wall by means of igniter coil 35, the tube will sustain a combustion reaction at or adjacent the outer peripheral surface layer thereof, such as will cause said outer surface layer thereof to incandesce.

By way of illustration, tube 31 may be made of fine glass-type fibers, such as fibers of aluminum oxide and silicon dioxide. These fibers may be placed in an aqueous slurry, molded into the tubular form, dried and then heated at a temperature above normal operating temperature thereof, so as to partially sinter the fibers and cause them to adhere in a relatively rigid structure. Other suitable refractory fibers, such as quartz, may be employed. Optionally, a binder for the fibers in the form of an inorganic silicate metallic salt, or an organic silicate such as ethyl-orthosilicate which decomposes when heated to yield silicon dioxide, may be incorporated in the slurry before the fibers are molded and dried. The binder may be a colloidal alumina, or zirconium or aluminum oxide formed by the decomposition of a chloride or other suitable salt of zirconium or aluminum in aqueous aluminum. The binder may be zirconium phosphate formed in situ (deposited as a gel) by the interaction of phosphoric acid and zirconium oxychloride. Preferably, in the latter case, there is a surplus of phosphoric acid so as to attack the fibers and fuse them.

The wall of the refractory tube 31 has a relatively low coefficient of thermal conductivity or "K" factor and has a relatively high pore density. The walls separating the individual pores have high surface to mass ratio. The percentage by volume of the wall occupied by the fibers is relatively low.

By way of example, tube 31 may be twelve inches long and one and one quarter inch in diameter, having a bore of one half inch and a nominal heat output of 30,000 B.t.u. per hour. The fibers may have an average diameter of approximately two and one half microns and a density of 2.73 grams/per cm.^{3}. The wall as a whole consists of approximately 12.6% solids and 87.4% voids. The maximum operating temperature of tube 31 (temperature of the incandescing outer surface layer) is approximately 1100° C.

Block 5 is preferably molded or otherwise formed from refractory fibers or infusorial earth having a low coefficient of thermal conductivity or "K" factor. Preferably, block 5 is made of the same fibrous material as tube 31, which may be placed in an aqueous slurry, together with a binder, and molded into block form. The fibers do not have to be sintered. Optionally, as shown in FIG. 1A, the wall of cavity *5a* is corrugated so as to increase the surface area thereof. The surface area may be increased by other suitable means, such as by imparting some other shape thereto or by making it fuzzy.

The output of tube 31 is in the form of hot exhaust gases possessing suitable energy in the form of convection heat, and is also in the form of direct heat radiation radiating from the incandescent outer surface layer of tube 31. The arrows *31a* indicate diagrammatically the direction of the energy wave fronts emitted from tube 31. The radiant energy and the hot gases emitted from tube 31 either advance upwardly through the top opening of the cavity, or strike the wall of cavity *5a*. The arrows *31b* indicate highly diagrammatically that energy is reflected in the upward direction from the wall of cavity *5a*. It will be apparent that gases and radiant energy can be reflected back and forth several times between tube 31 and the wall of cavity **5a** before escaping from the cavity, through the top opening thereof.

The outer peripheral surface of tube **31** may be considered as a main or primary surface which is incandescent. The surface of cavity **5a** may be considered as a secondary surface. Since this secondary surface has a very low "K" factor, when the radiant heat energy and hot gases of tube **31** strike the secondary surface, it incandesces and becomes a secondary incandescent surface at almost the same temperature as the outer surface of tube **31**. It will be apparent that since some of the energy is reflected back to tube **31**, the outer surface serves as both a main or primary emitting surface and a secondary or reflective incandescent surface.

As the hot gases emitted by tube **31** strike the primary and secondary incandescent surfaces, a great deal of the convection heat energy of the hot gases is converted into radiant heat energy.

The design of the cavity is such that under the operating conditions, maximum output temperatures consistent with material limitation is achieved, with minimum input energy. The ideal cavity would be infinitely small in cross section and infinitely great in depth, but such a cavity could only radiate at an infinitely small rate, by definition. Accordingly, a ratio of depth to cross sectional area is selected which permits some convection energy to escape. However, as shown in FIG. 3, the convection energy output of the heater of FIGS. 1 and 2 is relatively small. FIG. 3 is a graph of the output radiant intensity of the heater verus the wavelength of the energy. FIG. 3 shows a resonance peak at slightly over 2 microns wavelength, this representing radiant energy. The much smaller peak at approximately 4.3 microns wavelength represents convection heat energy of the exhaust gases emitted from cavity **5a**. As shown by the graph, a very high proportion of the output of the heat device is in the form of radiant energy, and a very small proportion of the output is in the form of convection energy.

The embodiment illustrated in FIGURE 4 is similar to the first embodiment, the only difference being in the cross-sectional shape of housing **40**. Accordingly, except for this feature, reference is made to the first embodiment for the complete disclosure. Thus, refractory tube **43** corresponds to tube **31**, block **44** corresponds to block **5**, and igniter coil **35** is the same in both embodiments.

Housing **40** has a lower pheripheral portion **41** which is optionally generally part cylindrical in shape and has generally parallel and vertical upper side walls **42**.

The operation of this embodiment is much the same as the operation of the first embodiment, but the cavity shape of FIG. 4 is somewhat more effective for conversion of convection heat to radiant energy.

In either of the embodiments, it is possible to treat the fibers or refractory bodies used with catalytically active materials such as platinum, nickel, cobalt oxide, molybdenum oxide and combinations thereof, in order to obtain any desired control of the combustion reactions.

While I have disclosed preferred embodiments of my invention, it will be apparent that various changes, omissions and additions may be made in my invention without departing from the scope and spirit thereof.

It will be apparent that in each embodiment, the heating unit comprises first means forming a primary wall having a primary wall surface for emission of radiant energy from combustion of gases and also for emission of exhaust gases of said combustion containing convection heat energy. Thus, in FIGURE 1, the first means comprises the tube **31** forming the primary wall having an outer primary wall surface.

Also, in each embodiment, I provide second means forming a secondary wall having a secondary wall surface positioned for reception and reflection of said radiant energy and said exhaust gases, said secondary wall being shaped to form a cavity having an outlet. Illustratively, in the first embodiment, the second means forming the second wall includes the block **5**, the secondary wall surface being the inner surface **5a** of this block. In addition, the primary wall surface of tube **31** also serves as a secondary wall surface since it cooperates with the block to form the cavity and also receives reflected energy and gases.

Also, in each embodiment, the first and second means respectively comprise preferably amorphous, inorganic refractory fibers arranged in a porous wall structure. Also in each embodiment, I provide further means for supplying a combustible gas mixture through the first means to the primary wall surface, with the first means being adapted to support combustion of the gases at the primary surface layer. The fibers at the primary surface layer thereby incandesce. Also in each embodiment, the secondary wall surface layer incandesces upon impingement of the radiant energy and the hot exhaust gases thereon. In each embodiment, the cavity is seized and shaped for conversion of a substantial part of the convection heat energy of the exhaust gases into radiant energy by reason of the absorption of said convection energy by said wall surface of the cavity, and consequent conversion of the convection energy into radiant energy.

I claim:

1. A heating unit comprising: a primary wall having combustion reaction and emitted energy receiving wall surface means, said combustion reaction emitting radiant heat energy and exhaust gases containing convection heat energy, a secondary wall having wall surface means for receiving and reflecting said emitted energy from said primary wall surface means, said secondary wall comprising a block having a cavity formed therein which has a longitudinal axis, said cavity being formed about said primary wall and having an outlet therein, said primary wall comprising an elongated hollow tube extending between the ends of said cavity and along the longitudinal axis thereof, said combustion reaction and emitted energy receiving wall surface means being the outer peripheral surface of said tube, and said secondary wall surface means being the cavity surface of said block facing said peripheral surface of said elongated tube, each of said wall surface means comprising amorphous, inorganic refractory fibers arranged in a porous wall structure, and means for conducting a combustible gas mixture to said primary wall surface means whereby said combustion reaction occurs at said primary wall surface means, said fibers of said primary wall surface means thereby incandescing and said fibers of said secondary wall surface means also incandescing upon impingement thereof said emitted energy from said primary wall surface means.

2. A heating unit according to claim **1**, wherein said cavity surface is generally parabolic in cross-section.

3. A heating unit according to claim **1**, wherein the surface of said cavity includes a lower portion which is generally concave in cross-section and upper sides which are generally planar and parallel, said cavity having an open top.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,217,701 November 16, 1965

Gerhart Weiss

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 30, for "verus" read -- versus --; column 6, line 19, for "seized" read -- sized --.

Signed and sealed this 6th day of December 1966.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents