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Dufour

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[54] **HEAT EXCHANGE APPARATUS**

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[73] Assignee: **Institute of Gas Technology,** Chicago, Ill.

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[52] **U.S. Cl.**..... **126/110 R;** 431/347; 126/92 C; 126/116 B

[51] **Int. Cl.²**..... **F24H 3/02**

[58] **Field of Search**.... 126/110 R, 19, 92 C, 116 B, 126/116 R; 431/347, 350, 353; 432/72

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Assistant Examiner—Henry C. Yuen
Attorney, Agent, or Firm—Dominik, Knechtel, Godula & Demeur

[57] **ABSTRACT**

A heat exchange apparatus including at least one catalytic combustion cell formed of two closely spaced parallel plates having facing surfaces coated with a catalyst and with a gas orifice arranged so as to discharge a jet of gas into the space between the plates.

7 Claims, 6 Drawing Figures

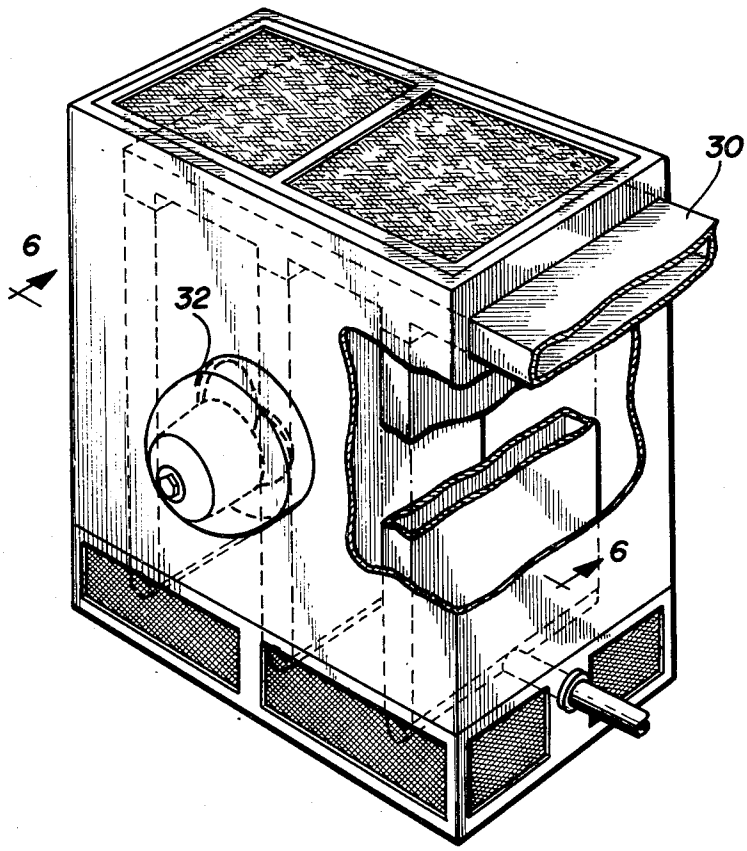


FIG. 1

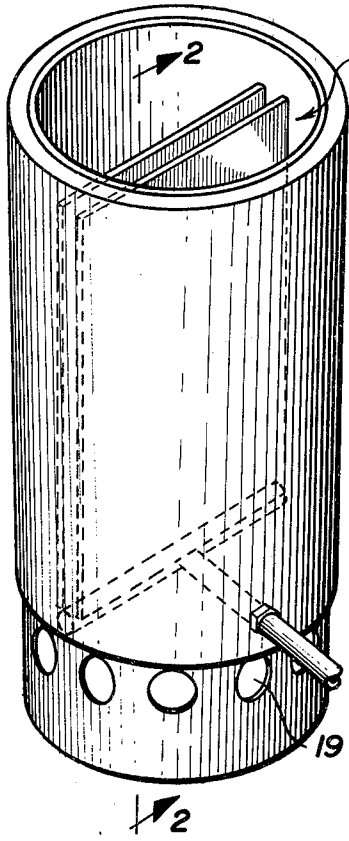
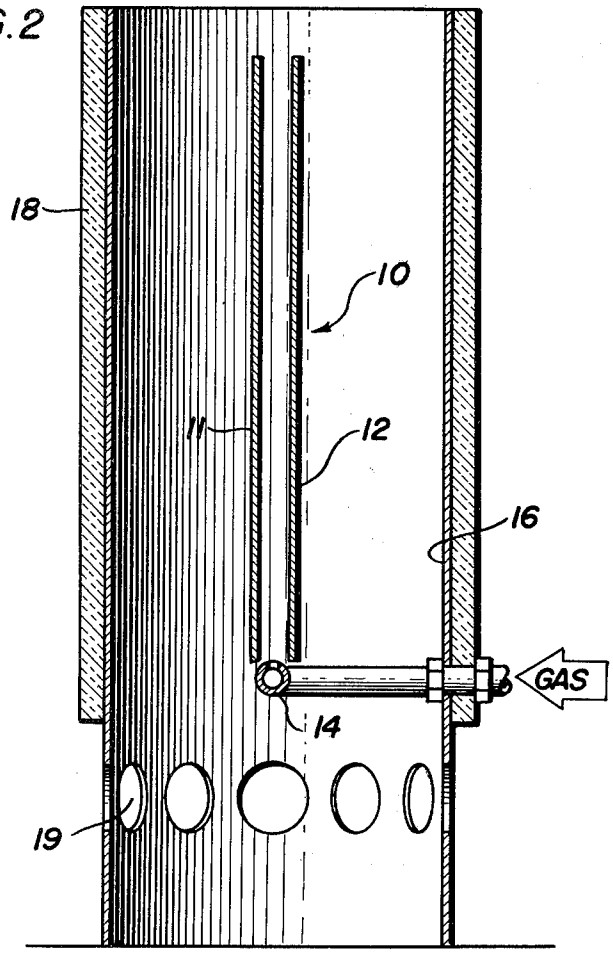


FIG. 2



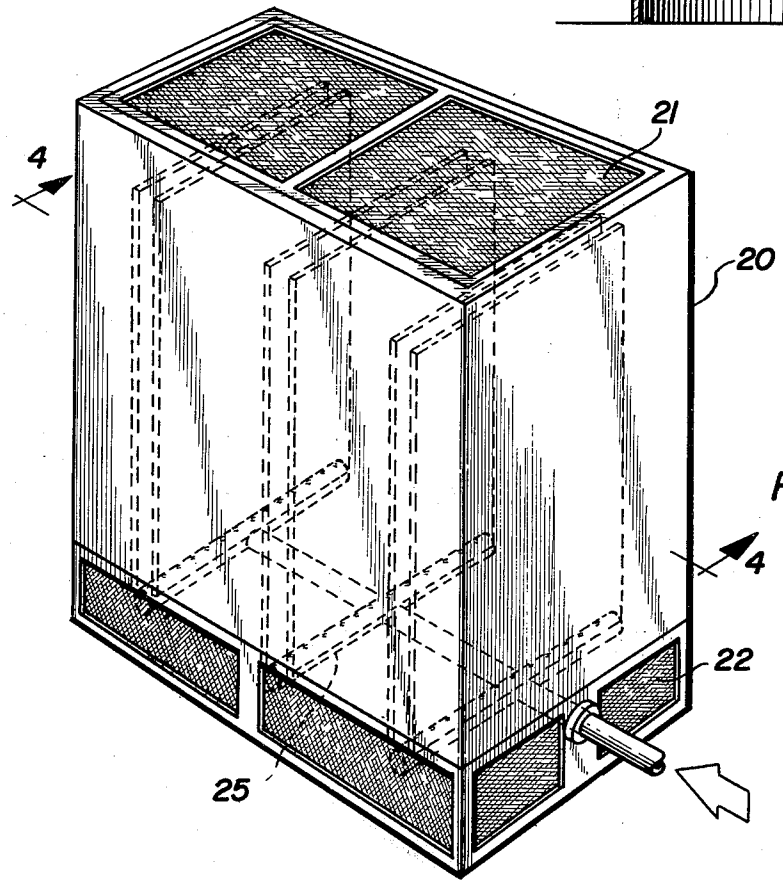


FIG. 3

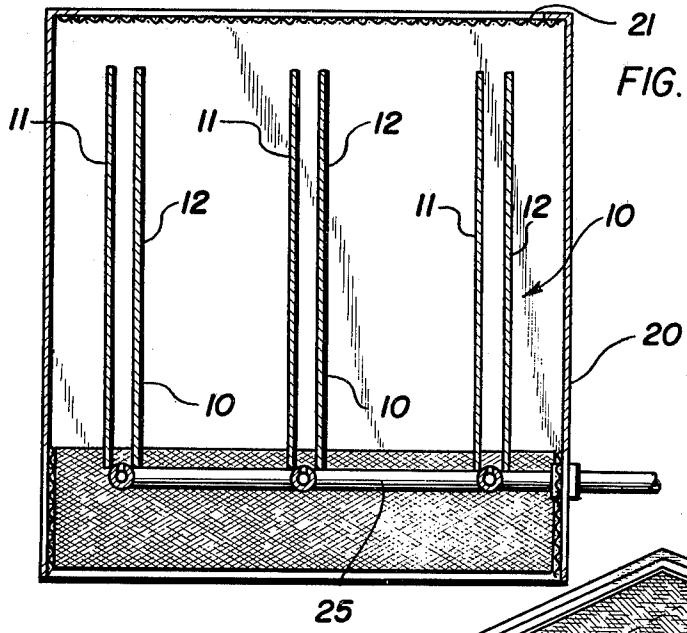


FIG. 4

FIG. 5

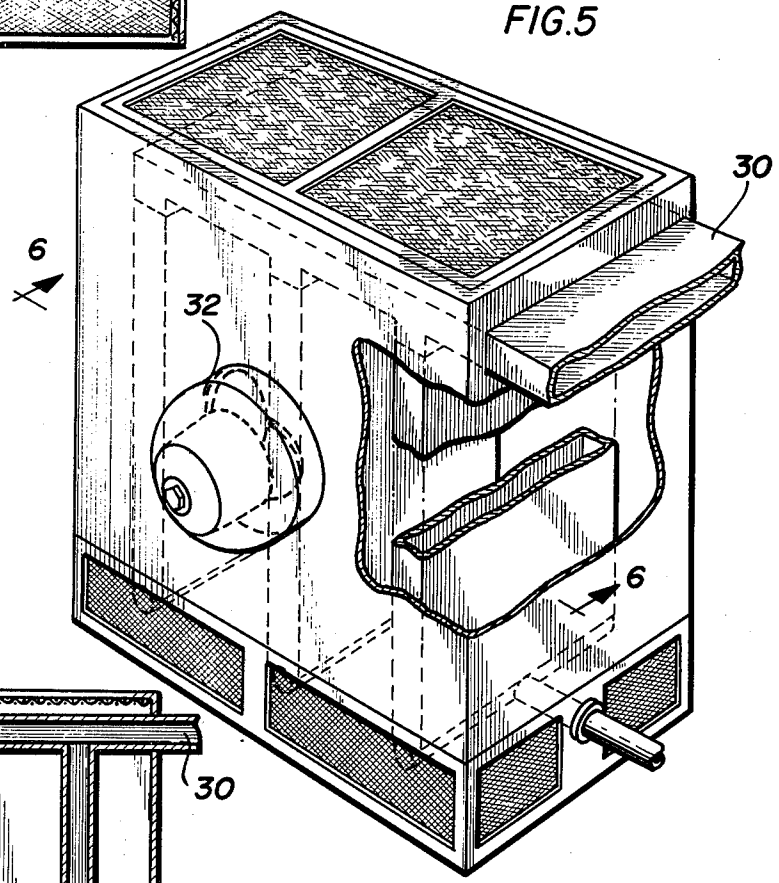
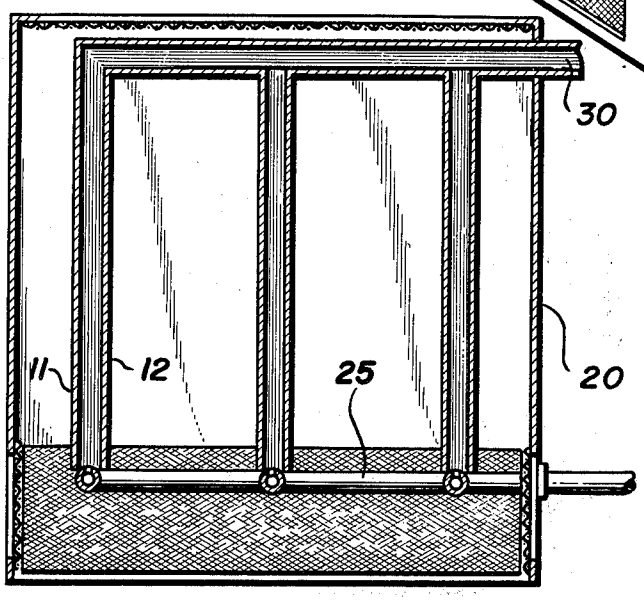


FIG. 6



HEAT EXCHANGE APPARATUS

This invention relates to an improved catalytic combustion cell of a construction such that catalytic combustion occurs directly on one side of a heat exchange surface that is cooled on the opposite side by the fluid to which heat is being transferred so as to prevent flame ignition due to overheating of the catalyst and at the same time provide efficient heat transfer.

In attempting to develop atmospheric burners in which fuel is oxidized without flame through the use of a catalyst, it is found that for mixtures exceeding the lower flammable limit of the gas-air mixture, there is a tendency for the temperature of the catalytic bed or surface to rise above the ignition point of the mixture. When this occurs, the resulting flame flashes back to the gas orifice and continues to burn there. This condition is particularly likely to occur with fast burning gases such as hydrogen.

In accordance with the present invention, the temperature of the catalyst can be maintained well below the flame ignition point of the gas-air mixture while at the same time providing excellent heat exchange between the combustion zone and cooling medium, by cooling the surface upon which the catalyst is deposited by a flow of air or other fluid over the other side of it.

The catalytic combustion cell, in its simplest form, is formed of two closely spaced parallel plates having facing surfaces coated with a suitable catalyst containing materials such as alumina-platinum and with a gas orifice arranged so as to discharge a jet of gas into the narrow space between the plates. Cooling air is free to flow over the outer surface of the plates. When gas is allowed to flow from the orifice, its jet action induces a flow of air which mixes with the gas and initiates combustion as the mixture passes in contact with the catalytic surfaces. As the temperature rises, additional air is induced by thermo-syphon or chimney action. By the same chimney action, a flow of cooling air takes place over the outer or untreated surfaces to remove heat as rapidly as it is generated by catalytic combustion. The result is that the gas is burned without flame on the catalytic surface which is kept well below the flame ignition temperature of the gas-air mixture. Also, since combustion occurs within the catalyst applied directly to the heat exchanger surface, barriers to heat transfer are extremely small and heat transfer is very efficient. A multiplicity of such combustion cells can be arranged to form a room heater or a very efficient and compact vented warm air furnace. Further still, the combustion cells can be surrounded with a water jacket to form a hot water heater or boiler.

Accordingly, it is an object of the present invention to provide an improved catalytic combustion cell.

A further object is to provide an improved catalytic combustion cell which can be arranged in a multiple fashion such as to form a room heater, a warm air furnace or surrounded with a water jacket to form a hot water heater or boiler.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings in which:

FIG. 1 is a perspective view of a catalytic combustion cell exemplary of the present invention;

FIG. 2 is a sectional view taken along lines 2—2 of FIG. 1;

FIG. 3 is a perspective view illustrating the manner in which a multiplicity of such combustion cells can be arranged to provide a room heater;

FIG. 4 is a sectional view taken along lines 4—4 of FIG. 3;

FIG. 5 is a perspective view generally illustrating the manner in which a multiplicity of the combustion cells can be arranged to provide a compact vented warm air furnace; and

FIG. 6 is a sectional view taken along lines 6—6 of FIG. 5.

Similar reference characters refer to similar parts throughout the several views of the drawings.

Referring now to the drawing, in FIGS. 1 and 2 there is illustrated a catalytic combustion cell **10** which, in its simplest form, consists of two closely spaced parallel plates **11** and **12** having facing surfaces coated with a suitable catalyst to oxidize the fuel without flame. A gas orifice or manifold **14** is arranged so as to discharge a jet of gas into the narrow space between the plates **11** and **12.** The plates **11** and **12** are surrounded with a cylindrical tube **16** which may be fabricated of any common metal such as steels or stainless steel, aluminum, copper, nickel, titanium, etc., with an insulating material **18** provided around its outer periphery, from its upper edge to a point just above a number of combustion air inlets **19** provided about the tubing **16** in radially spaced positions, below the gas orifice **14.** With this arrangement, cooling air is free to flow over the outer surfaces of the plates **11** and **12.** When gas is allowed to flow from the orifice **14,** its jet action induces a flow of air which mixes with the gas and initiates combustion as the mixture passes in contact with the catalytic surfaces on the plates **11** and **12.** As the temperature rises, additional air is induced by thermo-syphon or chimney action. By the same chimney action, a flow of cooling air takes place over the outer or untreated surfaces of the plates **11** and **12** to remove heat as rapidly as it is generated by catalytic combustion. The result is that the gas is burned without flame on the catalytic surface which is kept well below the flame ignition temperature of the gas-air mixture. Accordingly, it can be seen that catalytic combustion occurs directly on one side of a heat exchange surface that is cooled on the opposite side by the fluid to which heat is being transferred so as to prevent flame ignition due to overheating of the catalyst and at the same time provide efficient heat transfer.

In FIG. **3,** there is illustrated a rectangular-shaped housing **20** having an open top wall with a screen or grid **21** provided on it and a combustion air inlet **22** formed of a number of screened areas about the periphery of its base. Contained within the housing **20** are a number (**3** as illustrated) of combustion cells **10** of the type described above, each formed with two spaced parallel plates **11** and **12** which have a catalyst material coated on the facing surfaces thereof. These combustion cells **10** each are supported in a perpendicular fashion and at right angles to a common gas manifold **25,** so that each combustion cell **10** is separated from the next by a space to provide cooling air. The gas manifold **25** supplies gas to each of the individual combustion cells **10.** As described above, when gas is allowed to flow through the gas manifold **25,** its jet action induces a flow of air which mixes with the gas and initiates combustion as the mixture passes in contact with

the catalytic surfaces on the plates **11** and **12** of each of the combustion cells **10.** As the temperature rises, additional air is induced by chimney action, and the latter causes a flow of cooling air to take place over the outer surface of the plates **11** and **12.** The air flowing over the outer surface of the plates **11** and **12** prevent flame ignition due to overheating of the catalyst and at the same time provides efficient heat transfer to the air. The air in being heated is passed through the screen or grid **20** on the top of the cabinet **21,** into the room in which the cabinet **20** is contained. It can therefore be seen that this arrangement makes an excellent room heater when the combustion cells are operated on hydrogen, reformed natural gas or very low carbon monoxide content manufactured gases which are rich in hydrogen. In such a case, the catalyst applied to the surfaces of the plates **11** and **12** can be any one of a number of commonly available noble catalysts such as platinum, platinum-ruthenium, platinum-rhodium, palladium or the like, deposited on an alumina or other porous material substrate, or a highly active non-precious metal oxide catalyst, preferably in the manner disclosed in copending application "A Catalytic Fluid Heater", Ser. No. 484,402, filed July 17, 1974, which is a continuation-in-part application of Ser. No. 443,128, filed Feb. 15, 1974, now abandoned. In such a case, ambient air supplies the required oxygen, and the combustion product is water.

In FIGS. **5** and **6,** there is illustrated an arrangement which is generally similar to the arrangement disclosed in FIGS. **3** and **4,** however, in this case the sides of the combustion cells **10** are sealed and the upper discharge openings at the top of each of the combustion cells **10** are manifolded into a common duct **30.** In addition, a fan **32** is provided for blowing air over the exterior surfaces of the combustion cells **10.** Such an arrangement provides a basis for a very efficient and compact vented warm air furnace which could be fueled with hydrogen, reformed natural gas or very low carbon monoxide content manufactured gases which are rich in hydrogen, or any fuel which is oxidized without flame through the use of a catalyst.

From the above description, it can be seen that an arrangement for burning a combustible gas on a catalyst so as to assure efficient heat transfer to a secondary fluid and at the same time to prevent the temperature of the catalyst from rising to the point where flame ignition would occur is provided. In particular, a catalytic combustion cell consisting of two closely spaced plates having a suitable catalyst deposited on their facing surfaces together with a gas orifice located so as to inject a flow of gas-air mixture between the catalytically treated surfaces and having a free flow of secondary fluid passing over the outer or untreated surfaces of the plates to absorb useful heat and to maintain the temperature of the catalyst below the flame ignition temperature of the gas-air mixture is provided. A multiplicity of such combustion cells can be arranged on gas manifolds so as to provide free circulation of fluid to be heated between adjoining cell pairs to form a room heater. In such a case, the fluid to be heated is room air that is caused to circulate by thermosyphon or chimney action. Further still, a very efficient and compact vented warm air furnace can be formed by providing a fan which blows air over the outer surface of the combustion cells, and by sealing the outer edges of the combustion cells and manifolding the upper discharge openings into a common vent.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and certain changes may be made in the above construction. Accordingly, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

Now that the invention has been described, what is claimed as new and desired to be secured by Letters Patent is:

1. Apparatus comprising at least one catalytic combustion cell formed of a pair of closely spaced parallel plates having the facing surfaces thereof coated with a catalyst selected from the class consisting of a noble metal catalyst and a non-precious metal oxide catalyst for combusting a fuel discharged between said plates, orifice means positioned below said plates for discharging fuel supplied thereto between said plates, and a housing about said plates having combustion air inlets therein to permit a flow of air into said housing to mix with fuel discharged from said orifice to initiate flameless combustion as the fuel-air mixture passes in contact with said catalyst and over the outer surfaces of said plates to remove heat from them as it is generated by catalytic combustion, said catalyst thereby being kept below the flame ignition temperature of the fuel-air mixture and heat transfer between said plates and the air flowing over the outer surfaces of said plates occurring so as to heat said air, whereby flameless catalytic combustion occurs directly on one side of a heat exchange surface that is cooled on the opposite side by the fluid to which heat is being transferred so as to prevent flame ignition due to overheating of the catalyst and at the same time provide efficient heat transfer.

2. The apparatus of claim **1,** wherein the fuel supplied thereto comprises hydrogen.

3. The apparatus of claim **1,** wherein the fuel supplied thereto comprises reformed natural gas.

4. The apparatus of claim **1,** wherein the fuel supplied thereto comprises a very low carbon monoxide content manufactured gas which is rich in hydrogen.

5. The apparatus of claim **1,** comprising a plurality of said catalytic combustion cells, each supported in a perpendicular fashion in spaced relation to one another to provide cooling air and at right angles to a common gas manifold which supplies fuel to each of said individual cells, whereby said apparatus can be utilized as a room heater or the like.

6. The apparatus of claim **5,** wherein each of said pair of plates of said cells are sealed on the side edges thereof and the upper ends thereof are manifolded into a common exhaust duct.

7. The apparatus of claim **6,** further including a fan for blowing air over the exterior surfaces of said combustion cells, whereby said apparatus can be utilized as an efficient and compact vented warm air furnace.

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