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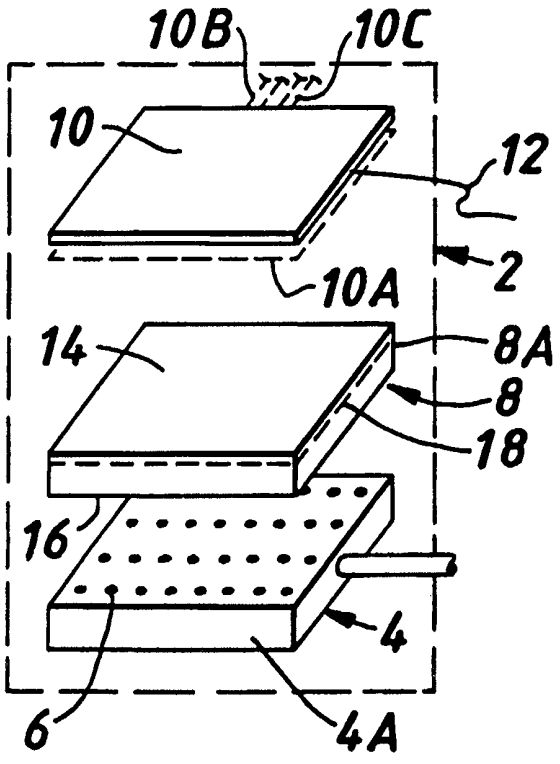
(54) Title: RADIANT BURNER SCREEN

(57) Abstract

A radiant burner screen (8) comprises a substrate formed by a heat resistant, porous, rigid, ceramic foam material having a thin tracery or reticular form demarcating the pores which open one into another and of which there are about 30 pores or less per 645.16 square millimetres. This ceramic foam material can be readily and easily permeated by hot gaseous products of combustion from a fluid fuel, for example natural gas, burner (4). The ceramic foam material which may be a silicate of alumina with preferably no free silica, bears a sprayed on radiation emitter coating at side (14) of the screen (8). The emitter coating comprises a rare earth element and/or a compound of a rare earth. The rare earth may be ytterbium or erbium and the compound may be ytterbia or erbia. Heat from the hot products of combustion causes the emitter coating to emit radiation incident on a photovoltaic cell arrangement (10) to produce electrical power therein output on line (12).



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RADIANT BURNER SCREEN

This invention concerns a radiant burner screen, and also concerns apparatus or equipment comprising the screen.

An object of the invention is to provide a screen which can be used to convert thermal energy derived from hot gaseous products of combustion into radiant energy which is converted by photoconversion into electrical energy. Thereby such a screen may be used, for example, in a form of combined heat and power system.

According to the invention a radiant burner screen comprises a substrate comprising heat resistant porous or foramenous material through which substrate hot gaseous products of combustion can pass, and said substrate having at least one side bearing a coating comprising a rare earth element and/or a compound of a rare earth element.

Apparatus may be provided comprising said radiant burner screen, burner means to burn fuel, photovoltaic cell means, the screen being disposed between the burner means and the photovoltaic cell means facing said side for radiation energy emitted by the coating to make incidence on the cell means for production of electrical power by said cell means, and the screen being arranged for hot gaseous products of combustion resultant from burning the fuel by said burner means to pass through the porous substrate and heat the substrate and coating.

A rare earth or a compound thereof can produce a peak of radiative energy of a particular wavelength usually in the range of about 900nm to about 3000nm rather than a blackbody spectrum. By matching this peak

radiation to performance or response of a given photovoltaic cell, it is possible to improve electrical conversion efficiency.

Desirably, equipment may be provided comprising said apparatus, and wherein said equipment is electrically powered by said electrical power.

The invention will now be further described, by way of example, with reference to the accompanying drawings in which:-

Figure 1 is a diagrammatic representation of an embodiment of apparatus comprising fuel burner means, photovoltaic cell means, and a radiant burner screen formed according to the invention;

Figure 2 is a diagrammatic view, on a larger scale than in Figure 1, of a fragment of the screen;

Figure 3 is a diagrammatic representation of an alternative burner means to that in Figure 1;

Figure 4 is a diagrammatic representation of another embodiment of apparatus comprising fuel burner means, photovoltaic cell means, and a radiant burner screen formed according to the invention;

Figure 5 is a diagrammatic plan view of a modification of the apparatus in Figure 4;

Figure 6 is a diagrammatic fragmentary view of a boiler comprising apparatus represented in Figure 1, and

Figure 7 is a diagrammatic view of a vehicle comprising an electrical propulsion system provided with electrical power by apparatus as represented in Figure 1.

In the drawings like references identify like or comparable parts.

With reference to Figures 1 and 2, an apparatus is indicated at 2 for performing a process of thermophotovoltaic energy conversion in which heat energy from burning fuel is converted to radiant energy converted by a photovoltaic effect to electrical energy or power.

The apparatus 2 comprises a burner means 4, for example a burner 4A having a burner plate with orifices 6, whereat fluid fuel which may be supplied pre-mixed with combustion air or oxygen is burned. Hot gaseous products of combustion can pass through a radiant burner screen 8, which may be a plate-like form 8A, from which radiant energy is emitted to make incidence on a photovoltaic cell arrangement 10 converting the radiant energy to electrical energy or power appearing on power line 12.

The photovoltaic cell arrangement 10 may be provided with or comprise a thermal barrier providing resistance to transference of heat through the thermal barrier to the cell arrangement, but such a thermal barrier is formed by or comprises at least in part a thermal barrier portion 10A between the photovoltaic cell arrangement and the radiant burner screen 8 which thermal barrier portion 10A is transparent to radiant energy emitted by the radiant burner screen towards the photovoltaic cell arrangement. This thermal barrier can control, or at least assist in controlling, the operating temperature of the photovoltaic cell arrangement 10 substantially to keep it at, or bring it closer to, a desirable operating temperature for efficient energy conversion by the cell arrangement, for

example not greater than about 200° C. The thermal barrier portion 10A may be a glass, for example a high temperature glass. If desired, the operating temperature of the photovoltaic cell arrangement 10 may also be controlled by providing the cell arrangement with cooling means, for example heat exchange means exemplified in Figure 1 by a coolant inlet conduit 10B and a coolant outlet conduit 10C.

The fluid fuel may be liquid or gaseous fuel, for example liquid or gaseous hydrocarbon fuel. In the case of fuel gas it may be or comprise natural gas.

The radiant burner screen 8 is formed of a rigid, ceramic, foraminous or porous material resistant to heat. It can be resistant to heat up to substantially 1400°C or, up to substantially 1600°C, or up to one hundred or two hundred °C above 1600°C. Before the material forming the ceramic screen is fired to form the ceramic it is foamed to create the desired porosity. Preferably in the ceramic foam screen 8, the porosity is substantially 30 pores per 645.16 square millimetres (30 pores per square inch) or less, for example 20 pores or 15 pores per 645.16 square millimetres. In the screen 8, the pores are provided by voids or cavities defined by the structure of the ceramic, which voids or cavities open one into another to allow a relatively free flow of hot gases through the screen, but the flow path through the pores being twisting or zig-zag to encourage heat exchange between the hot gases and the screen. The pores or voids very largely or mainly occupy the volume of the screen 8 so that the screen structure demarcating the pores is of a thin tracery or reticular form. So the screen 8 may have considerable transparency, rather like a net curtain, even when ten, twenty or more millimetres thick.

The aforesaid porous ceramic material of the screen 8 forms a substrate bearing a radiation emitter coating comprising a rare earth element and/or a rare earth compound. The aforesaid rare earth element and/or compound may be applied to the substrate or screen 8 in the form of a liquid or slip into which the substrate may be dipped, though preferably the liquid or slip is sprayed onto the substrate. The emitter coating may be formed by a plurality of successively applied layers of the rare earth element and/or rare earth compound. The number of layers may be four or more, for example at least five. Whilst the whole of the substrate or screen 8 may be covered in the emitter coating, preferably only side 14 of the screen facing towards the photovoltaic cell arrangement 10 need be coated since it is only radiant emissions towards the cell arrangement which are utilised to produce the electric power. The other sides of the screen 8 and in particular side 16 facing the burner 8 and opposite to the side 14 need not be coated and this represents a cost saving of expensive rare earth material. The emitter coating of rare earth material can penetrate into the substrate or screen 8 for some distance from the side 14 (for example a possible extent of penetration is indicated by dash-line 18). This is because the voids or cavities opening on the side 14 provide recesses in the side to receive the applied emitter coating. This is desirable as the photovoltaic cell arrangement 10 may then "see" a more or less continuous surface of emitter coating formed by the rare earth material at the side 14 over the whole of that side even though that observed continuous surface is in different planes facing towards the cell arrangement.

The substrate or screen 8 can be formed from a mullite or silicate of alumina ($3Al_2O_3.2SiO_2$). It can be prepared from or comprise at least substantially 52% by weight of alumina and 45% by weight of silica, but this can result in the existence of free silica in the ceramic foam which

free silica can detrimentally interfere with radiation properties of the emitter coating. This interference may be reduced by first providing a barrier coating to the substrate 8 before applying the emitter coating, though preferably the amount of free silica is reduced if the mullite or silicate of alumina forming the substrate 8 is prepared from about or substantially 72% by weight of alumina and substantially 28% by weight of silica. It is believed that the occurrence of free silica is avoided if the mullite or silicate of alumina is prepared from about or substantially 78% by weight of alumina and substantially 22% by weight of silica.

Alternatively the screen or substrate 8 can be prepared from substantially pure alumina, for example, at least 90% by weight of alumina and more preferably about or substantially 95% by weight of alumina.

The emitter coating applied to screen 8 can be or comprise ytterbium and/or a compound of ytterbium, one example of a suitable compound being ytterbia, and another being ytterbium substituted yttrium aluminium garnet (Yb:YAG).

A compound of a rare earth element may be used as an aforesaid barrier coating, for example ytterbium niobate.

An emitter coating comprising ytterbium and/or a compound of ytterbium can give a peak radiation having a wavelength in the range of about 900nm to 1100nm. This makes screens 8 with such coatings particularly suitable for emitting radiation onto photovoltaic cells based on silica.

Another emitter coating which can be used comprises erbium and/or a compound of erbium, an example of a suitable compound being erbia. In

this case such an emitter coating is particularly suitable for emitting radiation onto photovoltaic cells based on gallium arsenide.

If desired the ceramic, foam screen 8 may have a thickness between its opposite main sides 14, 16 of about 30mm or less, for example a thickness of about 26mm for foams having about 15 pores per 645.16 square millimetres or not greater than about 12mm for foams having about 30 pores per 645.16 square millimetres.

Burner 4A in Figure 1 may be substituted by a plaque burner 4B in Figure 3 wherein a burner plate 20 comprises a porous ceramic through which the fluid fuel passes to combustion.

In Figure 4, the burner generally identified at 4 is specifically indicated at 4B and is of a tubular form surrounded by the screen 8 in the form of a cylindrical shroud or tube 8B dome-shaped at one end and closed at its other end by an end cover 22. The screen 8B is formed of ceramic foam material similar to that described above for the screen or substrate 8 in Figures 1 and 2 and thus has a similar porosity. An outer side 24 of the screen 8B bears an emitter coating comprising a rare earth element and/or a compound of a rare earth element such as described above which emits radiation onto the photovoltaic cell arrangement 10. There may be an arrangement of photovoltaic cells extending substantially wholly or partly around the tubular screen 8B, for example in Figure 5 a disposition of the cell arrangements 10 surrounds the screen.

In Figure 6 a boiler is indicated at 26 comprising a casing 28 and a heat exchanger 30 to be heated by hot products of combustion making their way from the apparatus 2 to a flue 32. The heat exchanger 30 may produce hot water or steam. Electrical power generated at the photovoltaic

cell arrangement 10 can be used to electrically power equipment and the boiler 26 may be considered as a combined heat and power system. For example the electrical power generated may be used as a substitute for mains power or be fed into an electrical grid supply system. The electrical output from the cell arrangement 10 may be used to satisfy electrical power needs of the boiler 26, for example by normally powering electrical boiler controls or arranged to come in as a substitute for the electrical mains supply to continue to power the controls, normally powered by the mains, should the mains supply be interrupted. Should the boiler 26 be connected to other equipment, for example to a central heating system comprising electrically powered controls and water pump, those controls and water pump may be normally powered by an electrical output from the cell arrangement 10 or in an emergency may be arranged to be powered by an electrical output from the cell arrangement should the controls and pump be normally powered by the electrical mains supply which has been interrupted.

In Figure 7 a vehicle 34, for example a motor car, runs on wheels 36. The vehicle has a propulsion system to drive the vehicle, that propulsion system comprises an electric motor 38 to provide vehicle propulsion power and the motor is provided with electrical power generated in the photovoltaic cell arrangement in the apparatus 2.

CLAIMS

1. A radiant burner screen comprising a substrate comprising heat resistant porous or foramenous material through which substrate hot gaseous products of combustion can pass, and said substrate having at least one side bearing a coating comprising a rare earth element and/or a compound of a rare earth element.

2. A screen as claimed in claim 1, in which the substrate is a rigid foam material.

3. A screen as claimed in claim 2, in which said substrate comprises a structure defining voids or cavities which open one onto another.

4. A screen as claimed in any one preceding claim, in which the substrate is a ceramic.

5. A screen as claimed in any one preceding claim, in which the substrate has a porosity of substantially 30 pores or less per 645.16 square millimetres (30 pores or less per square inch).

6. A screen as claimed in any one preceding claim, in which the substrate comprises a mullite or silicate of alumina.

7. A screen as claimed in claim 6, in which said mullite or silicate of alumina has substantially no free silica.

8. A screen as claimed in claim 6, in which the mullite or silicate of alumina is prepared from substantially 72% by weight of alumina and substantially 28% by weight of silica.

9. A screen as claimed in claim 7, in which the mullite or silicate of alumina is prepared from substantially 78% by weight of alumina and 22% by weight of silica.

10. A screen as claimed in any one of claims 1 to 6, in which the substrate is formed of or comprises alumina.

11. A screen as claimed in claim 10, in which the substrate is prepared from a material comprising at least 90% by weight of alumina.

12. A screen as claimed in claim 11, in which the substrate is prepared from material comprising about or substantially 95% by weight of alumina.

13. A screen as claimed in any one preceding claim, in which said coating is initially applied in a liquid form to the substrate.

14. A screen as claimed in claim 13, in which said liquid form is a slip.

15. A screen as claimed in claim 13 or claim 14, in which said coating is sprayed on to the substrate.

16. A screen as claimed in any one preceding claim, in which the rare earth is ytterbium.

17. A screen as claimed in any one of claims 1 to 16, in which the compound of the rare earth element is ytterbia.

18. A screen as claimed in any one of claims 1 to 16, in which the compound of the rare earth element is ytterbium substituted yttrium aluminium garnet (Yb:YAG).

19. A screen as claimed in any one of claims 1 to 13, in which the rare earth is erbium.

20. A screen as claimed in any one of claims 1 to 13 to as claimed in claim 19, in which said compound of the rare earth is erbia.

21. A screen as claimed in any one preceding claim, in which said coating is adhered to a barrier coating adhered to the substrate.

22. A screen as claimed in claim 21 in which the barrier coating comprises a compound of a rare earth element.

23. A screen as claimed in claim 22, in which the barrier coating comprises ytterbium niobate.

24. Apparatus comprising a said radiant burner screen as claimed in any one preceding claim, burner means to burn fuel, photovoltaic cell means, the screen being disposed between the burner means and the photovoltaic cell means facing said side for radiation energy emitted by the coating to make incidence on the cell means for production of electrical power by said cell means, and the screen being arranged for hot gaseous products of combustion resultant from burning the fuel to pass through the porous substrate and heat the substrate and coating.

25. Apparatus as claimed in claim 24, in which the fuel is a fluid fuel.

26. Apparatus as claimed in claim 25, in which the fluid fuel is gaseous fuel.

27. Apparatus as claimed in claim 26, in which the fuel is natural gas.

28. Apparatus as claimed in any one of claims 24 to 27, in which said screen extends substantially wholly around the burner means.

29. Apparatus as claimed in any one of claims 24 to 28, in which said photovoltaic cell means extends substantially wholly or at least partially around the burner means.

30. Equipment comprising apparatus as claimed in any one of claims 24 to 29, in which at least part of said equipment is electrically powered by said electrical power.

31. A vehicle comprising said apparatus as claimed in any one of claims 24 to 29 and electrical motor means powered by said electrical power.

32. Equipment comprising apparatus as claimed in any one of claims 24 to 29 or equipment as claimed in claim 30, in which said equipment is heating equipment further comprising heat exchange means arranged to be heated by said products of combustion.

33. Equipment as claimed in claim 32, in which said equipment is boiler means.

34. A radiant burner screen as claimed in claim 1, and substantially as hereinbefore described.

35. Apparatus comprising a radiant burner screen, said apparatus being substantially as hereinbefore described with reference to Figures 1 and 2, or Figures 1 to 3, or Figure 4 or Figure 5 of the accompanying drawings.

36. Heating equipment substantially as hereinbefore described with reference to Figure 6 of the accompanying drawings.

37. A vehicle substantially as hereinbefore described with reference to Figure 7 of the accompanying drawings.

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FIG. 1.

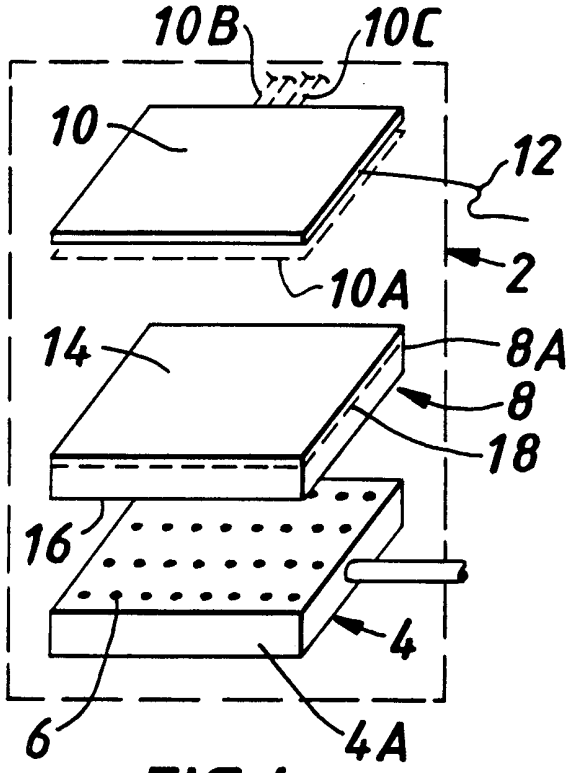


FIG. 2.

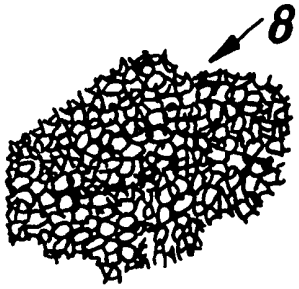


FIG. 3.

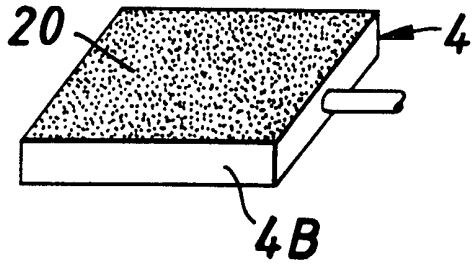


FIG. 4.

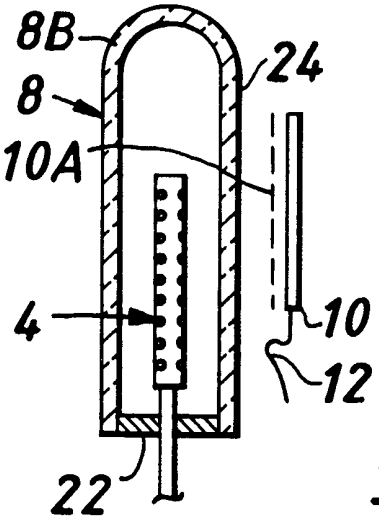


FIG. 5.

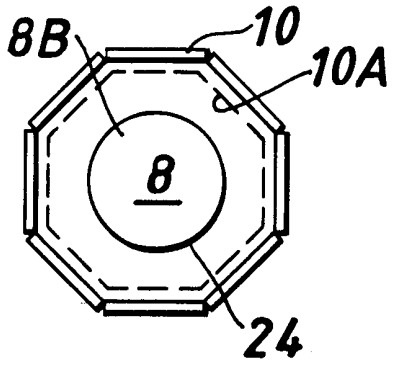


FIG. 7.

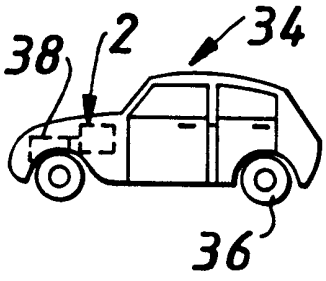
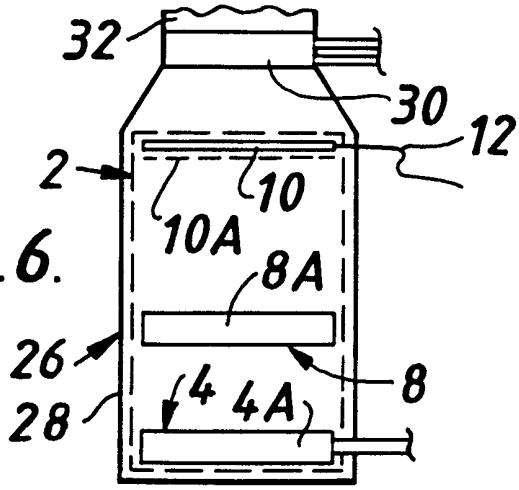


FIG. 6.



INTERNATIONAL SEARCH REPORT

Inte. nal Application No
PCT/GB 00/00535

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F23D14/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F23D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 681 143 A (QUANTUM GROUP INC) 8 November 1995 (1995-11-08)	1,4,10, 16,17, 24-26, 28,32-36
Y	page 2, line 3 - line 7 page 2, line 31 -page 3, line 11 page 3, line 52 -page 4, line 50 page 5, line 42 - line 47 page 6, line 57 -page 7, line 12 page 7, line 35 - line 50 figures 1-4,7,8	2,3,6, 13,19,29

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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INTERNATIONAL SEARCH REPORT

Inte nal Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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