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Kirkpatrick

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[54] **UNIDIRECTIONAL THERMAL TRANSFER MEANS**

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[21] Appl. No.: **95,488**

[52] **U.S. Cl.**.....**165/32,** 165/105

[51] **Int. Cl.**.....**F28d 15/00**

[58] **Field of Search**.....165/32, 105

[56] **References Cited**

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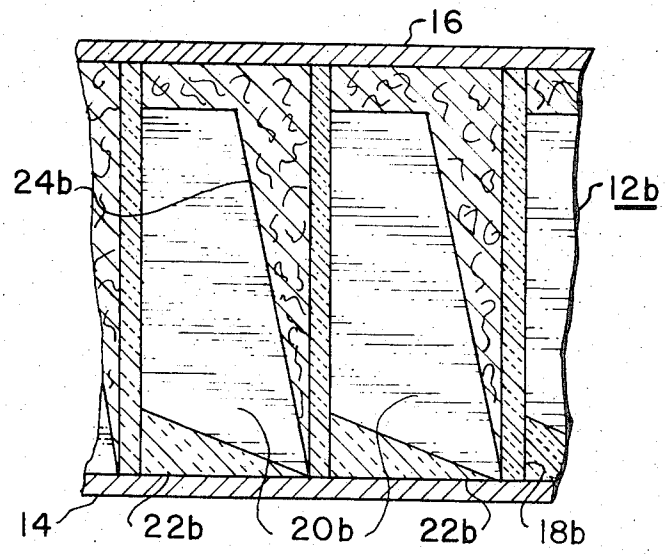
Primary Examiner—Albert W. Davis, Jr.

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[57] **ABSTRACT**

A unidirectional thermal transfer panel of cellular construction wherein each cell has an upper end wall that bears an internal capillary structure and an opposing lower end wall that has an inclined surface devoid of capillary structure. Thermal transfer in the same direction as the force of gravity occurs through vaporization of working fluid liquid from the upper capillary structure and condensation of the working fluid vapor on the inclined surface below. A conduit connected between the lowermost point on the inclined surface and the capillary structure above has high liquid capillary flow properties to transfer the working fluid liquid condensate to the capillary structure above in opposition to the force of gravity and high thermal impedance to prevent thermal conduction in that direction.

7 Claims, 5 Drawing Figures



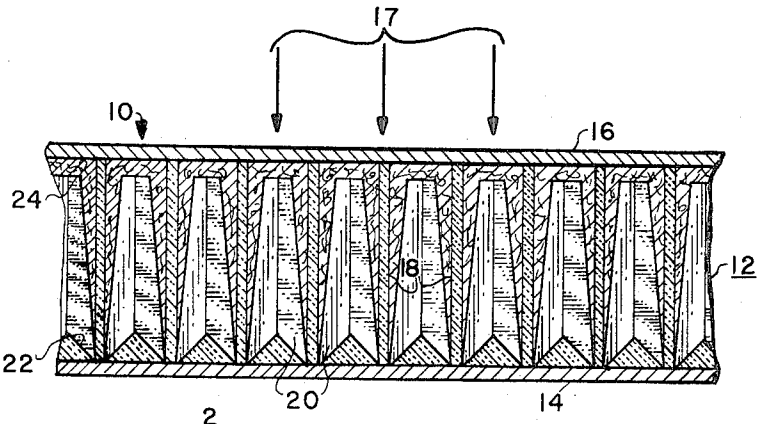


FIG. 2

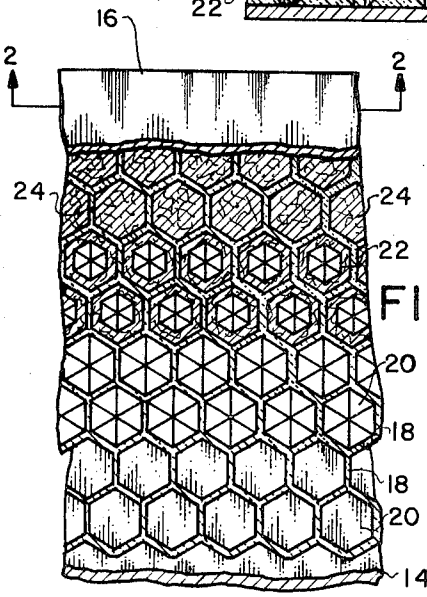


FIG. 1

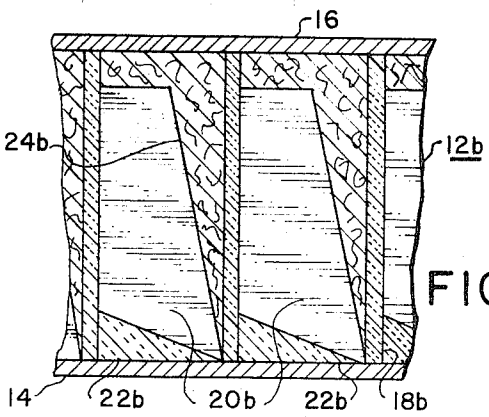


FIG. 5

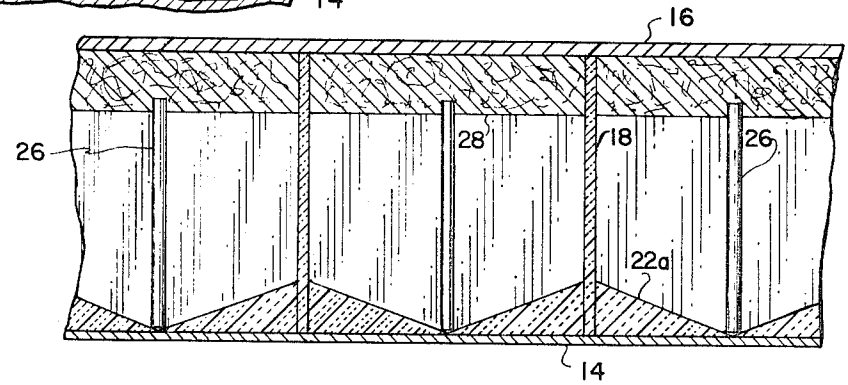
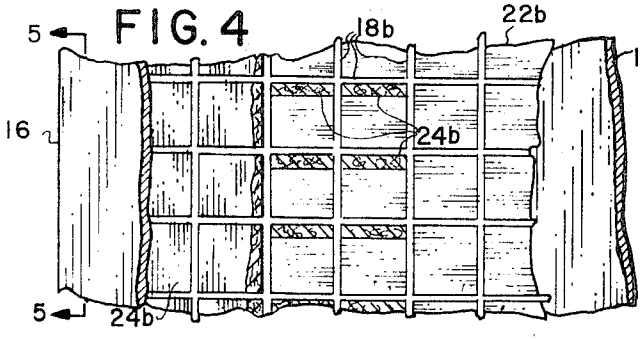


FIG. 3

FIG. 4



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UNIDIRECTIONAL THERMAL TRANSFER MEANS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to thermal transfer devices and more particularly to wall panels of cellular construction that employ reflux boiler action of fluids to transfer heat efficiently in one direction through the panel but not in the opposite direction.

2. Description of the Prior Art

In U.S. Pat. No. 3,018,087 issued Jan. 23, 1962 to Roger C. Steele, there is disclosed a panel structure having a different coefficient of heat transfer in one direction through its thickness than in the opposite direction. The panel has a honeycomb core sandwiched between two parallel face sheets that seals the opposite sides of the core to form a multiplicity of cells. The cells are arranged at some angle with respect to the horizontal. Each cell is partially filled with a volatile liquid, or working fluid, and by the nature of the honeycomb geometry and orientation of the panel, the pool of working fluid contacts only one of the two face sheets.

The panel will transmit heat efficiently in one direction when it is applied to the face sheet in contact with the working fluid. More particularly, a thermal input applied to the face sheet will cause the working fluid in contact therewith to vaporize, whereupon the vapor migrates through the cells carrying with it thermal energy equivalent to the heat of vaporization. The vapor condenses on the cool surface of the other face sheet where it gives up the heat of vaporization and the condensate returns to the pool of working fluid by the force of gravity. The foregoing cycle consisting of liquid evaporation, vapor migration, vapor condensation and liquid return of condensate is known as reflux boiler action.

On the other hand, if a thermal input is applied to the opposing face sheet, the thermal transfer rate will be much slower because the liquid is not maintained at that face sheet and any thermal transfer must occur solely by conduction.

One drawback of the aforementioned panel structure is that while it is effective when the thermal flux is applied from below or along the sides of a structure formed of such panels, it will not function when the thermal flux is applied from above, such as sunlight falling on a flat horizontal roof.

SUMMARY OF THE INVENTION

In accordance with the invention, a panel is provided that will transmit efficiently thermal energy that is directed vertically downward, or in the same direction as the force of gravity, such as the direct rays of the sun, but that will substantially block thermal energy coming from the opposite direction, or vertically upward. The panel includes first and second plates that are flat, parallel, substantially horizontally disposed and facing one another with the first plate spaced vertically above the second plate. A multi-cellular structure is sandwiched between the two plates. The multi-cellular structure includes vertical wall partitions extending between and intersecting the plates to form a multiplicity of closed, evacuated cells.

In each of the cells there is provided capillary means covering the interior surface of the first or upper disposed plate. The interior of the second or lower disposed plate is provided with an inclined surface in each cell. In each cell, a conduit of high thermal impedance and high capillary flow extends between the lowermost point of the inclined surface on the lower plate and the capillary means on the upper plate. The inclined surface is otherwise devoid of any capillary structure. A working fluid saturates the capillary means and the conduits, but there is no excess of working fluid beyond the saturatable amount.

Considering each cell as an elemental heat pipe and the upper plate as constituting the heat input zone, the lower plate constitutes the condensing zone. Thus, a thermal input applied to the upper plate will cause the working fluid to vaporize and the vapor to migrate vertically downward where it condenses on the inclined surface, giving up its heat of vaporization. Thermal energy thus is transmitted vertically downward through the panel.

The condensate moves down the inclined surface to its lowest point where it engages the conduit, whereupon the condensate is transported up the conduit by capillary action to the capillary means at the heat input zone.

On the other hand, if a thermal input is applied to the lower plate, it will heat a dry surface because of the absence of capillary structure. There will be no vaporization action to transmit the thermal energy to the upper plate. The transfer of heat through the panel by conduction will be negligibly low due to the high thermal impedance nature of the conduit. The transfer of heat by radiation between the two panels will also be negligibly small. The resultant total rate heat transfer in the upward direction through the panel is much slower than in the downward direction, and the panel can be said as having a unidirectional thermal transfer quality.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing:

FIG. 1 is a fragmentary plan view, with portions removed, of a panel constructed according to the invention;

FIG. 2 is a section taken along line 2—2 of FIG. 1;

FIG. 3 is a fragmentary sectional view of a modified panel constructed according to the invention;

FIG. 4 is a fragmentary plan view, with portions removed, of still another modified panel constructed according to the invention; and

FIG. 5 is a section taken along line 5—5 of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown a thermal transfer panel 10 including a cellular or honeycomb structure 12 sandwiched between a pair of flat parallel plates 14 and 16. The panel 10 is shown in the orientation it would assume when positioned in normal operating use to receive thermal energy from a direction vertically above the panel 10, such as from solar rays 17. Accordingly, the plates 14 and 16 are horizontally disposed.

The walls 18 of the cellular structure 12 extend vertically at right angles to the plates 14 and 16 and intersect each other to form a multiplicity of hexagonal cells 20. The plates 14 and 16 are hermetically sealed to the honeycomb structure 12 and the cells 20 are evacuated of non-condensable gas.

The walls **18** of the cellular structure **12** are made of thermal insulation material such as plastic, Fiberglas, or other suitable non-metallic material. The material from which the plates **14** and **16** are made can be thermally conductive or thermally insulating depending upon the particular application to which the panel **10** is put.

The internal construction of one of the cells **20** will now be described, it being understood that all of the cells **20** are of identical construction. The lower plate **14** supports a base member **22** having a smooth inclined surface in the form of a six-sided pyramid. The base member **22** is made of thermal insulation material finished smooth to permit liquid to roll off its sides, as will be explained in more detail. The walls **18** of the cell **20** and the surface of the upper plate **16** are lined with a capillary structure **24.** That portion of the capillary structure **24** lining the walls **18** tapers in thickness to its thinnest dimension where it engages the lowermost edges of the base member **22.**

The capillary structure **24** is made of thermal insulation material such as plastic mesh, glass cloth or the like. A working fluid that is compatible with the capillary material is provided in sufficient quantity to just saturate the capillary structure **24** without producing an excess thereof. The working fluid may be selected to satisfy the particular operating temperature of the panel **10.** For receiving solar energy, the working fluid may be water, alcohol, or ammonia, for example.

The panel **10** is designed to exhibit a higher rate of heat transfer in the downward direction from upper plate **16** to lower plate **14** than in the opposite direction. The transfer of thermal energy through the thickness of the panel **10** may occur by radiation, conduction, and convection. The transfer by radiation will be rather slow in either direction because the incident thermal energy must be conducted through either the capillary structure **24** or the base member **22,** both of which are thermally insulating, before it can radiate therefrom. The radiation rate can be minimized in both directions by providing the base member with a light colored radiation reflecting low emissive surface.

The transfer by conduction is low in either direction because of the insulating properties of the walls **18** as well as the high thermal impedance of the capillary structure **24,** where it has the least cross-sectional thickness, namely where it engages the base member **22.**

The transfer of thermal energy by the process of convection is more significant and as to this process the transfer rate is substantially higher in the downward direction than in the upward direction. If the temperature of the upper plate **16** is raised above that of the lower plate **14,** as by the reception of solar rays **17** from above, and the temperature rise is sufficient to approach the working temperature range of the working fluid, vapor will be driven off from the cooling fluid. The vapor will drift down and condense on all cooler surfaces, where it gives up its heat of vaporization, thereby raising the temperature of those surfaces. The liquid condensate resulting from vapor that condenses on the base member **22** flows down the sides and collects at the lowermost corners of the cell **20** where it is absorbed by the capillary structure **24** and returned to the higher temperature zone. Ultimately, the entire capillary structure **24** becomes an isothermal evaporator and the base member **22** the condenser, with only a slight temperature differential between the two.

When the temperature of the upper plate **16** cools down below that of the lower plate **14,** as when the sun's rays **17** are no longer incident thereon, there is no liquid on the base member **22** from which vapor can be given off. There can be no transfer of thermal energy by convection in the upward direction and therefore the lower plate **14** will maintain its higher temperature relative to the upper plate **16.**

FIG. **3** shows a different embodiment wherein the base member **22*a*** has a central depression from which the surface slopes upward toward the walls **18** of the cellular structure. The walls **18** are free of capillary material. Instead, the capillary structure includes a fine capillary tube **26** that rises vertically upward from the depression, where one end is anchored, to join a capillary lining **28** covering the upper plate **16.** The capillary tube **26** is made of thermal insulation material and has a minimum outside diameter to minimize the thermal conductance between the plates **15** and **16.**

FIGS. **4** and **5** show another embodiment wherein the cells **20*b*** of the cellular structure **12*b*** have a square shape. In this embodiment, the base member **22*b*** has a cross section in the form of a right triangle. The capillary structure **24*b*** covers the upper plate **16** and one wall **18*b*** of the cell **20*b*** that intersects the lowermost edge of the base member **22*b***. The other three walls **18*b*** of the cell **20*b*** are free of capillary material.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. Unidirectional thermal transfer device, comprising:

a pair of vertically spaced, oppositely disposed end walls joined by side walls to form a closed, evacuated chamber;

capillary means covering the interior surface of the upper one of said end walls;

means forming an inclined surface on the interior of the lower one of said end walls;

means forming a conduit of high thermal impedance and high liquid capillary flow extending between said capillary means and the lowermost point on said inclined surface, said conduit comprising a capillary structure that tapers in thickness towards said lowermost point;

said inclined surface being otherwise devoid of capillary means; and

a working fluid within said chamber in a quantity which is sufficient to saturate said capillary means and conduit without producing an excess thereof.

2. Unidirectional thermal transfer device, comprising:

a pair of vertically spaced, oppositely disposed end walls joined by side walls to form a closed, evacuated chamber;

capillary means covering the interior surface of the upper one of said end walls;

means forming an inclined surface on the interior of the lower one of said end walls;

a capillary structure on at least a portion of said sidewalls and having a thickness that tapers towards the lowermost point on said inclined surface;

said inclined surface being otherwise devoid of capillary means; and

a working fluid within said chamber in a quantity which is sufficient to saturate said capillary means and conduit without producing an excess thereof.

3. The invention according to claim 2, wherein said capillary structure covers the entire internal surface of said sidewalls.

4. Unidirectional thermal transfer panel, comprising:

first and second flat, parallel, substantially horizontally disposed plates;

said plates facing one another, with said first plate spaced vertically above said second plate;

wall partitions extending between said plates to form a multiplicity of closed, evacuated cells;

in each of said cells:

a. capillary means covering the interior surface of said first plate;

b. means forming an inclined surface on the interior of said second plate;

c. means forming a conduit of high thermal impedance and high capillary flow extending between said capillary means and the lowermost point on said inclined surface, said conduit comprising a capillary structure that tapers in thickness towards said lowermost point;

d. said inclined surface being otherwise devoid of capillary means; and

e. a working fluid in a quantity which is sufficient to saturate said capillary means and conduit without producing an excess thereof.

5. The invention according to claim 4, wherein said wall portions intersect to form hexagonal shaped cells.

6. Unidirectional thermal transfer panel, comprising:

first and second flat, parallel, substantially horizontally disposed plates;

said plates facing one another, with said first plate spaced vertically above said second plate;

wall partitions extending between said plates to form a multiplicity of closed, evacuated cells;

in each of said cells:

a. capillary means covering the interior surface of said first plate;

b. a base member in the shape of a pyramid on the interior of said second plate;

c. a capillary structure covering said wall partitions and tapering in thickness towards the peripheral edges of said pyramid;

d. said inclined surface being otherwise devoid of capillary means; and

e. a working fluid in a quantity which is sufficient to saturate said capillary means and conduit without producing an excess thereof.

7. The invention according to claim 4, wherein said wall partitions and said conduit are made of thermal insulation material.

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