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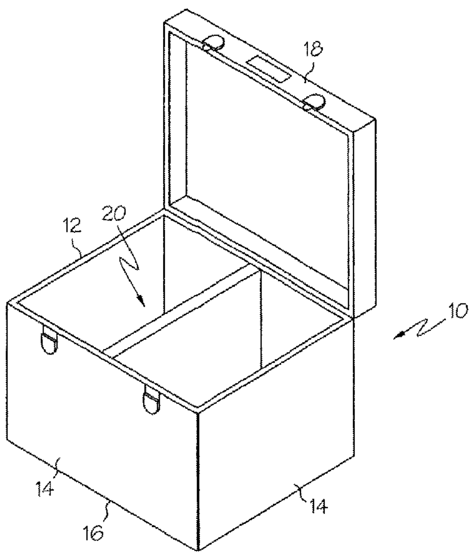
(54) Title: TEMPERATURE-CONTROLLED SYSTEM INCLUDING A THERMAL BARRIER



(57) Abstract: A temperature-controlled system (10) for storing or transporting temperature sensitive material is provided which includes a closable housing (12) including means for cooling or heating temperature sensitive material contained therein, and at least one thermal barrier (20) positioned in the housing (12) which contains a phase change material therein. The thermal barrier (20) is positioned in the temperature-controlled system (10) so as protect separate temperature-sensitive material, which is already at a desired temperature from temperature-sensitive material being introduced into the temperature-controlled system (10).

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

TEMPERATURE-CONTROLLED SYSTEM INCLUDING A THERMAL BARRIER

The present invention relates to a temperature-controlled system for protecting temperature sensitive materials, and more particularly, to a temperature-controlled system including a thermal barrier containing a phase change material. The thermal barrier protects temperature sensitive materials when such materials are exposed to temperatures outside their desired temperature range.

In temperature controlled environments where temperature sensitive materials, such as food products, are maintained within a particular temperature range, such as in a refrigerator, it is well known that when a material is added to the environment which is not within the desired temperature range, it may cause the temperature within the environment to change so that it is outside the desired temperature range. For example, if a warm liquid is placed in a refrigerator next to a cool liquid, the cool liquid may be warmed before the refrigeration system can remove enough heat from the environment to lower the temperature of the warm liquid to the desired temperature range of the refrigerator. While this occurrence is no more than a nuisance in food storage applications, it is a more serious problem in applications where maintaining a specific temperature is critical, such as in the storage of medicines such as vaccines or other temperature sensitive biological materials such as blood platelets. In such instances, newly introduced material which is either too warm or too cold when first placed in the temperature controlled environment may warm or cool the existing materials, causing at least some degree of degradation before the environmental temperature controls can adjust the temperature within safe limits. In addition, many materials may experience cumulative degradation from exposure to unacceptable temperatures.

Many containment systems are known which utilize a phase change material to help control the temperature range of temperature sensitive products. See for example, U.S. Patent Nos. 6,482,332, 6,308,518, and 5,950,450. However, such systems do not provide a means of protecting temperature sensitive items when new materials are introduced into the environment which are outside the desired temperature range.

Accordingly, there is a need in the art for a method of protecting temperature sensitive materials stored in a temperature controlled environment such that the materials remain within a safe range when new materials are introduced into the environment.

The present invention meets that need by providing a temperature-controlled system utilizing a thermal barrier containing a phase change material. The thermal barrier protects temperature-controlled materials from transient heat flow into or out of the temperature controlled-system due to the introduction of materials at temperatures outside an acceptable range for maintaining safe storage.

According to one aspect of the present invention, a temperature-controlled system for storing or transporting temperature sensitive material is provided comprising a closable housing including means for cooling or heating temperature sensitive material contained therein, and at least one thermal barrier positioned in the housing which contains a phase change material therein. The thermal barrier is positioned so as to separate temperature-sensitive material which is already at a desired temperature from temperature-sensitive material being introduced into the temperature-controlled system.

In a preferred embodiment of the invention, the thermal barrier comprises a sealed container having top, bottom and side walls containing the phase change material. The container is preferably in the form of a hollow wall or shelf which functions to divide the housing into two separate storage areas.

In an alternative embodiment of the invention, the thermal barrier comprises a sealed, liquid impervious envelope comprised of a plastic or film containing the phase change material.

In one embodiment of the invention, the phase change material is enclosed in a liquid impervious envelope within the thermal barrier. This configuration is preferred in embodiments where the phase change material is in liquid form.

In another embodiment of the invention, the thermal barrier may contain insulation in addition to the phase change material. Insulation included around, inside, or adjacent to the thermal barrier slows the rate at which the phase change material changes phase. The insulation may comprise conventional insulation materials or may be in the form of a vacuum insulation panel. The insulation may extend around the perimeter of the container wall to form a thermal impedance to heat.

In another embodiment of the invention, the thermal barrier may contain a thermally conductive material. The thermally conductive material may be included around, inside, adjacent to or coated on the thermal barrier. The thermally conductive material functions to enhance heat transfer between the thermal barrier (phase change material) and any adjacent thermally sensitive material.

In an alternative embodiment of the invention, the temperature-controlled system may include two phase change materials, where the first phase change material has a first phase change temperature and the second phase change material has a second phase change temperature which is different from that of the first phase change material. In this embodiment, the first and second phase change materials are preferably enclosed in separate liquid impervious envelopes which are placed in adjacent position within the thermal barrier.

The phase change material is preferably selected from the group consisting of water, linear crystalline alkyl hydrocarbons, alcohols, organic or inorganic salts, hydrated salts, and mixtures thereof. The phase change material preferably has a melting and freezing point of between about –250°C to about 250°C, but may vary within this range depending on the desired application. The phase change material may be provided in a number of different forms including a phase change material/silica gel, a phase change material/silica powder, or a melt mix. The phase change material may also be provided in the form of pellets. The phase change material may also be imbibed into a porous product such as fiberboard which is contained in the thermal barrier.

In another embodiment of the invention, the temperature-controlled system may further include a second thermal barrier positioned in the housing so as to provide additional storage compartments for materials stored in the housing.

The temperature-controlled system of the present invention may be used in a number of applications including hot or cold food transport, as well as the transport of temperature sensitive products for the health industry, such as test specimens, blood, organs, or tissue.

Accordingly, it is a feature of the present invention to provide a temperature-controlled system including a thermal barrier containing a phase change material which protects temperature sensitive materials from temperature fluctuations which occur when new materials are introduced into the system. Other features and advantages of the invention will be apparent from the following description, the accompanying drawings, and the appended claims.

Figs. 1 and 1A are perspective views of the temperature-controlled system of the present invention;

Fig. 2 is a perspective view illustrating an alternative embodiment of the temperature-controlled system;

Fig. 3 is a perspective view illustrating another alternative embodiment of the temperature-controlled system;

Fig. 4 is a sectional view taken along lines 2—2 shown in Fig. 1;

Fig. 5 illustrates a phase change material contained in a liquid impervious envelope;

Fig. 6 is an alternative embodiment of the invention illustrating the use of two phase change materials in the thermal barrier;

Fig. 7 is an alternative embodiment of the invention illustrating the inclusion of insulating materials in the thermal barrier; and

Fig. 8 is another embodiment of the invention illustrating a side view of the thermal barrier including the use of thermally conductive materials.

The temperature-controlled system of the present invention which uses a phase change material in a thermal barrier provides an advantage over simple insulated barriers because it absorbs or release heat, which protects temperature-sensitive materials as an independently temperature-controlled barrier would do. A phase change material changes its state of matter at temperatures determined by its composition. In the process, it gives off or absorbs heat in an amount equal to the heat of that transformation. For example, water absorbs about eighty calories per gram when it thaws from the solid to the liquid state, and gives up that amount when the process is reversed. During this change, any object which is hotter or cooler than the freezing point of water and which is placed in contact with it, must release or absorb enough heat to finish thawing or freezing the water before the temperature of the water will be changed significantly.

While insulation allows heat to move around its edges through interior environment surfaces, the phase change material barrier acts as a heat sink, and is better at preventing heat from progressing beyond the perimeter of the thermal barrier. In addition, while insulation only slows the flow of heat, it does not stop it, so protection by insulated walls does not offer a fixed temperature limit, but rather is limited to the time it takes a thermal transient to cross the insulation, after which the heat exchange commences through it.

Referring now to Figs. 1 and 1A, a temperature-controlled system 10 is shown which includes a closable housing 12 in the form of a refrigerated box as shown. The housing preferably comprises side walls 14, a bottom wall 16, and a top wall 18 which may be in the form of a lid. As shown, the housing includes at least one thermal barrier 20 which contains a phase change material therein. In this embodiment, the thermal barrier 20 is in the form of a dividing wall which separates the housing into two separate storage areas.

In an alternative embodiment shown in Fig. 2, the thermal barrier 20 is in the form of a shelf which also separates the housing into two separate storage areas. The thermal barrier may be comprised of any suitable material capable of containing the phase change material including, but not limited to, barrier films, fiberglass, shrink wrap film, molded plastic, such as a plastic bottle, or metal, such as a metal can. Depending on the material comprising the barrier and the phase change material incorporated therein, the barrier may be sealed in a number of ways including adhesives, heat sealing, shrink wrap, or dip or spray coating a material such as a silicone or rubber material. The phase change material may also be enclosed in a vacuum, roto, or injection molded plastic shell or sheet metal shell which is sealed by gluing or ultrasonic welding over the entire seal perimeter. The plastic or sheet metal shell is preferred where the phase change material is in liquid, powder or pellet form. Alternatively, a bottle neck could be incorporated (with a cap) into a molded wall fabricated into the form of a flat wall shaped plastic "bottle". This form is preferred where the phase change material is in liquid form. A two piece metal shell could be sealed by crimping or welding. Plastic envelopes formed by solvent, hot air, or dielectric welding may be also be used. The phase change material may also be placed in a liquid impervious envelope comprised of any of the above materials and then placed inside the thermal barrier. The phase change material may also be placed into a "hybrid" container in which each side of the container is formed from a different material.

While it is preferable that the temperature-controlled system include at least one thermal barrier, it should be appreciated that the system may include multiple thermal barriers to provide a number of different storage areas. For example, as shown in Fig. 3, the interior of the temperature-controlled system may include two thermal barriers 20 to form 3 separate compartments for storage of materials. The thermal barriers may include one or more phase change materials as described herein.

Fig. 4 illustrates the thermal barrier 20 of the present invention which is in the form of a container. As shown, the thermal barrier includes a phase change material 24 therein. A number of suitable phase change materials may be used in the present invention. The phase change material is preferably selected from the group consisting of water, linear crystalline alkyl hydrocarbons, alcohols, organic or inorganic salts, hydrated salts, and mixtures thereof. Other suitable phase change materials for use in the present invention are disclosed in U.S. Patent No. 4,797,160 to Salyer, the disclosure of which is hereby incorporated by reference. The phase change material preferably has a melting and freezing point of between about –250°C to about 250°C, but may vary within this range depending on the desired application. For example, where the phase change materials are used in a thermal barrier for storage of blood products and pharmaceuticals, the melting and freezing point is preferably between about –30°C and 24°C. Where the thermal barrier is used for temperature sensitive electronics, the phase change material preferably has a melting and freezing point of between about –10°C and 65°C. Where the thermal barrier is used for food storage, serving or delivery, the phase change material preferably has a melting and freezing point of between about –20°C and 96°C. Where the thermal barrier is used for human tissues such as skin for transplants, the phase change material preferably has a melting and freezing point of between about –196°C and –78°C.

The phase change material may be provided in a number of forms including powders, gels, polymeric melt mixes, granules or pellets, and imbibed fiberboard. Examples of phase change materials provided in powder form are described in U.S. Patent Nos. 5,106,520 and 5,282,994, which are incorporated herein by reference. Examples of melt mixes are described in U.S. Patent No. 5,565,132, incorporated herein by reference. The phase change materials may also be provided in the form of granules or pellets as described in U.S. Reissued Patent No. Re 34,880, incorporated herein by reference. The phase change materials may also be imbibed into a porous product such as fiberboard as described in U.S. Patent No. 6,079,404, incorporated herein by reference. The phase change material may also be imbibed into a microporous foam, such as a polymer foam designed for use as a vacuum insulation panel core materal.

Fig. 5 illustrates a phase change material 24 contained in a liquid impervious envelope 26 for placement in a thermal barrier 20. Where the phase change material is in liquid form, the phase change material is preferably contained in such an envelope within the thermal barrier.

Referring now to Fig. 6, a thermal barrier 20 is illustrated which includes two phase change materials 24, 24', each contained within a liquid impervious envelope 26 to prevent the materials from mixing. The phase change material 24 has a phase change temperature near the high end of the desired range, while the other phase change material 24' has a phase change temperature near the low end of the desired range. The phase change materials within the envelopes 26 are formed such that the sum of their thicknesses will fit within the thermal barrier 20. By using two phase change materials having different phase change temperatures, temperature sensitive materials can be protected from being either too warm or too cold. In this embodiment, the first and second phase change materials are selected from linear alkyl hydrocarbons, alcohols, organic or inorganic salts, hydrated salts, and mixtures thereof. It should be appreciated that the materials chosen for the first and second phase change materials are chosen or mixed in different combinations to as to provide the desired different phase change temperatures.

The thickness of the two phase change materials may vary depending on their properties, such as enthalpy of phase change. The thickness may also be varied depending on the size, heat capacity, and temperature of the materials being placed into the temperature-controlled system.

In another embodiment of the invention illustrated in Fig. 7, the thermal barrier 20 may include a phase change material 24 in combination with insulation 28. The insulation may comprise conventional insulation materials or may be in the form of a vacuum insulation panel 28 as shown. As shown in Fig. 7, the phase change material 24 is preferably provided in a liquid impervious envelope 26 as shown and placed adjacent the insulated panel 28. The use of the phase change material in combination with insulation slows the rate at which the phase change material is compelled to change phase while still establishing a fixed temperature limit of exposure for the established material. Suitable conventional insulation materials include polystyrene or polyurethane foam. Suitable vacuum insulation panels include those described in U.S. Patent Nos. 5,943,876 and 6,192,703, incorporated herein by reference.

If desired, the thermal barrier may further include a metal plate (not shown) in addition to the phase change material. The metal plate may extend to the perimeter of the container wall to form a thermal guard against heat conduction around the thermal barrier. The metal plate may also be used in combination with insulating materials such as those described above.

The thermal barrier may also include include thermally conductive conforming materials for the purpose of enhancing heat transfer between the thermal barrier and any adjacent thermally sensitive material. The thermally conductive material may be included around, inside, adjacent to, or coated on the thermal barrier. For example, the thermally conductive material may be used to enhance heat transfer between the thermal barrier and a newly introduced ("warm") thermally sensitive item, where the phase change material speeds the cooling of the warm material. The phase change material may also be used to maintain the temperature of a previously cooled material against the presence of a warm material by reversing the side of the thermal barrier which is adjacent to the "warm" and "cold" materials.

Suitable thermally conductive materials for use in this embodiment include thermally conductive silicone rubbers, thermally conductive epoxy or silicone adhesives, thermally conductive greases or pastes such as heat sink compounds, metal impregnated polymers such as polyethylene, or metals such as aluminum, copper, or stainless steel, or metals covered with heat transfer improving coatings, such as black anodized aluminum, black chrome plated steel, black platinum plated copper, black copper plated copper or brass, or a thermal compound coating such as high silver or cerium oxide impregnated grease, or combinations of the above materials.

Fig. 8 illustrates a side view of the thermal barrier 20 where the thermal barrier utilizes a thermally conductive material. In the embodiment shown, the thermal barrier 20 preferably comprises a low conductivity wall or shell 30 on the "cold" side (the side adjacent cooled temperature sensitive materials), formed from a material such as ABS plastic. The wall 30 may include a layer of insulation (not shown) and/or a thermally reflective coating 34 such as anodized aluminum or heat reflective ceramic or paint. While the thermally reflective coating is shown on the external side of the wall, it should be appreciated that the coating may be included on either the external or internal side of the wall. The opposite wall 32 of the thermal barrier on the "warm" side (the side adjacent newly introduced temperature sensitive materials) includes a thermally conductive material 36 comprising an aluminum face which has been black anodized and adhered to a thermally conductive low durometer silicone rubber. If desired, the wall 32 may be made to conform to the surface of the packaging of a warm/hot payload added to the refrigerated environment.

The thermal barrier may also be surface treated with radiant barriers, such as evaporated infra-red reflecting metals, reflective ceramic coatings, high emissivity coatings such as black anodizing, black metal plating, or black paint, depending on the desired application.

The thermally-controlled system of the present invention may be used in a variety of applications. For example, the thermally-controlled system may comprise a refrigerator, where the thermal barrier separates refrigerated materials on one side from newly introduced materials on the other side. The thermal barrier protects the refrigerated materials from freezing if an object having a temperature lower than the freezing point of the phase change material is introduced on the other side of the barrier. The thermal barrier will continue to protect the materials until the newly introduced cold object has absorbed enough heat to freeze the phase change material. Because the thermal barrier is inside a temperature controlled environment (refrigerator), during the time it takes for the cold object to freeze the phase change material in the thermal barrier, the environmental controls of the refrigerator are able to warm the cold object to an acceptable temperature, thus protecting the materials on the other side of the thermal barrier. Adequate time must then pass for the phase change material to thaw before another object is introduced into the refrigerated environment.

Where the thermal barrier is intended to protect materials from cold temperatures, the phase change material is selected so that its phase change temperature is at the low end of the environmental control range so that it maintains a warm state during storage. Where the thermal barrier is intended to protect materials from high temperatures, the phase change material is selected to have a phase change temperature near the high end of the acceptable temperature range so that it remains in its cold state at the controlled temperature (e.g., frozen). The material already maintained in the correct temperature range is maintained on one side of the thermal barrier within the temperature-controlled environment. Materials which are subsequently introduced into the temperature controlled environment (which are outside the desired temperature range) are introduced on the opposite side of the thermal barrier, thus protecting the remaining temperature sensitive materials.

It will be apparent to those skilled in the art that various changes may be made without departing from the scope of the invention which is not considered limited to what is described in the specification.

CLAIMS:

1. A temperature-controlled system for storing or transporting temperature sensitive material comprising:

a closable housing including means for cooling or heating temperature sensitive material contained therein;

at least one thermal barrier positioned in said housing, said thermal barrier containing a phase change material therein; wherein said thermal barrier is positioned so as to separate temperature-sensitive material which is already at a desired temperature from temperature-sensitive material being introduced into said temperature-controlled system.

2. The temperature-controlled system of claim 1 wherein said thermal barrier comprises a sealed container having top, bottom and side walls.

3. The temperature-controlled system of claim 2 wherein said container is in the form of a wall which divides said housing into two separate areas.

4. The temperature-controlled system of claim 2 wherein said container is in the form of a shelf which divides said housing into two separate areas.

5. The temperature-controlled system of claim 1 wherein said thermal barrier comprises a sealed, liquid impervious envelope comprised of a plastic or film.

6. The temperature-controlled system of claim 1 wherein said phase change material is enclosed in a liquid impervious envelope within said thermal barrier.

7. The temperature-controlled system of claim 1 wherein said thermal barrier further contains insulation therein.

8. The temperature-controlled system of claim 1 wherein said thermal barrier further contains a vacuum insulation panel therein.

9. The temperature-controlled system of claim 1 wherein said thermal barrier includes a thermally conductive material therein.

10. The temperature-controlled system of claim 1 including two phase change materials, wherein the first phase change material has a first phase change temperature and the second phase change material has a second phase change temperature which is different from that of said first phase change material.

11. The temperature-controlled system of claim 8 wherein said first and second phase change materials are enclosed in separate liquid impervious envelopes within said thermal barrier.

12. The temperature-controlled system of claim 1 wherein said phase change material is provided in a form selected from the group consisting of a phase change material/silica gel, a phase change material/silica powder, a melt mix, and pellets.

13. The temperature-controlled system of claim 1 wherein said phase change material is selected from the group consisting of water, linear crystalline alkyl hydrocarbons, alcohols, organic or inorganic salts, hydrated salts, and mixtures thereof.

14. The temperature-controlled system of claim 1 wherein said phase change material has a melting and freezing point of between about -250°C to 250°C.

15. The temperature-controlled system of claim 1 wherein said phase change material has been imbibed into a porous product.

16. The temperature-controlled system of claim 1 further including a second thermal barrier positioned in said housing.

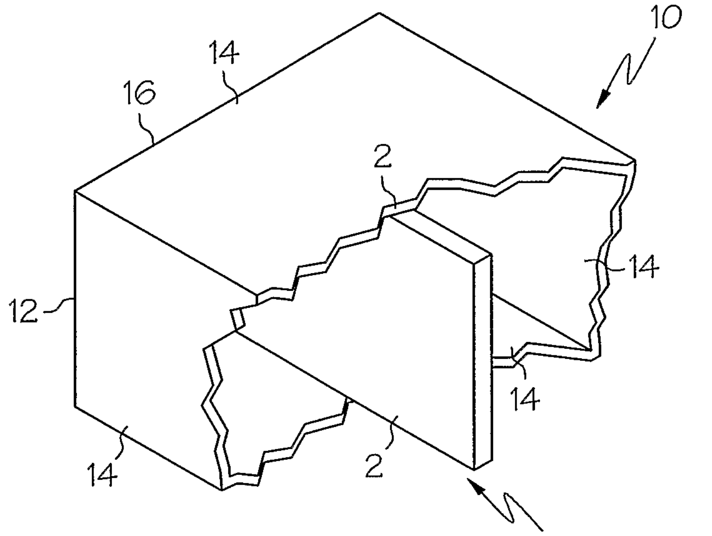

FIG. 1

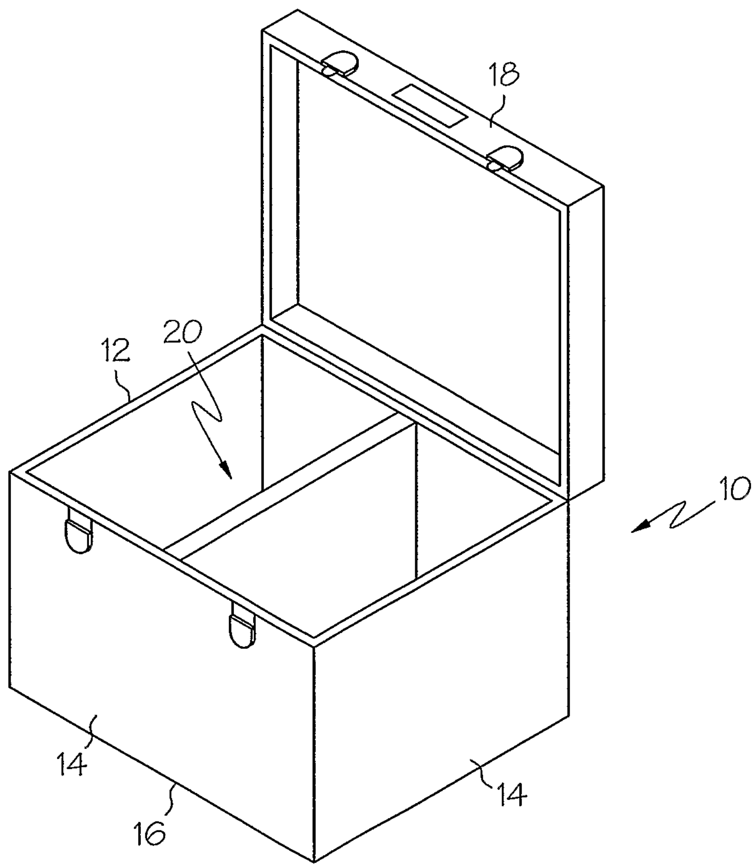

FIG. 1A

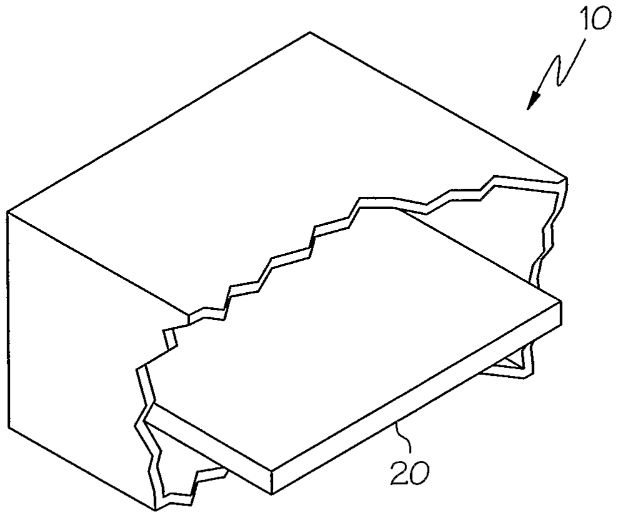

FIG. 2

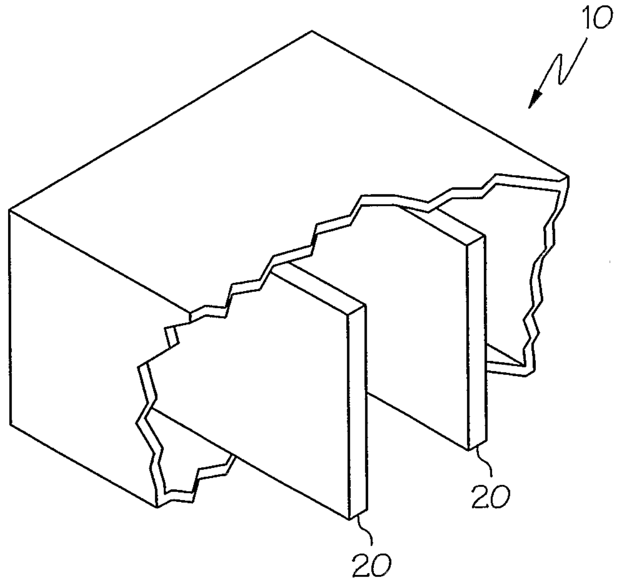

FIG. 3

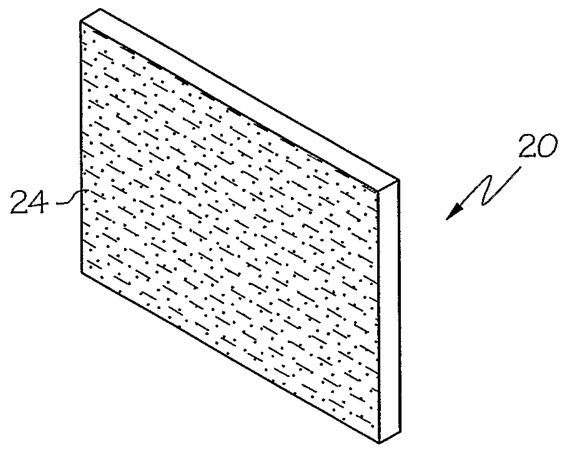

FIG. 4

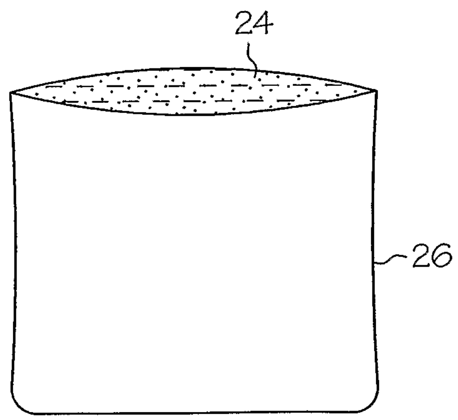

FIG. 5

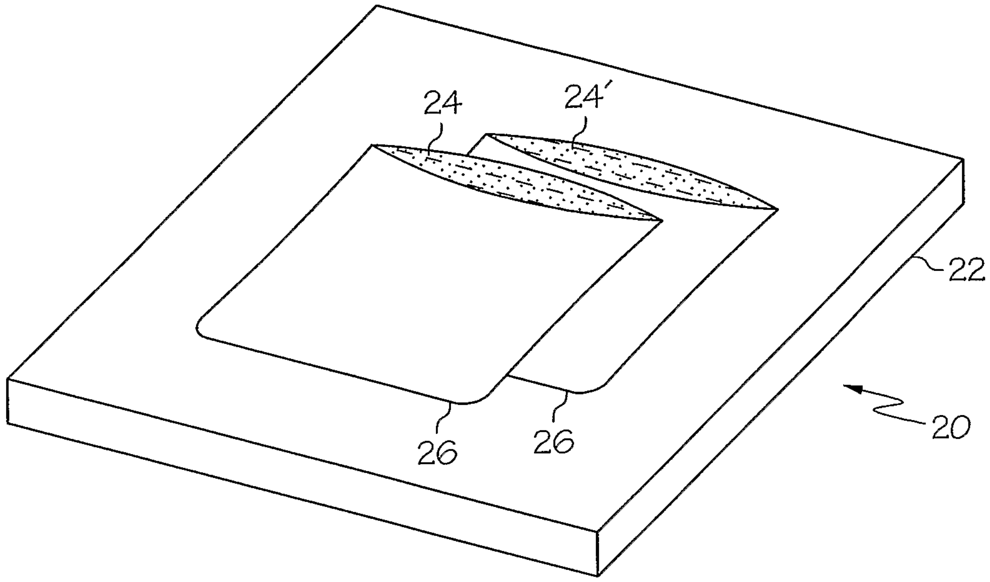

FIG. 6

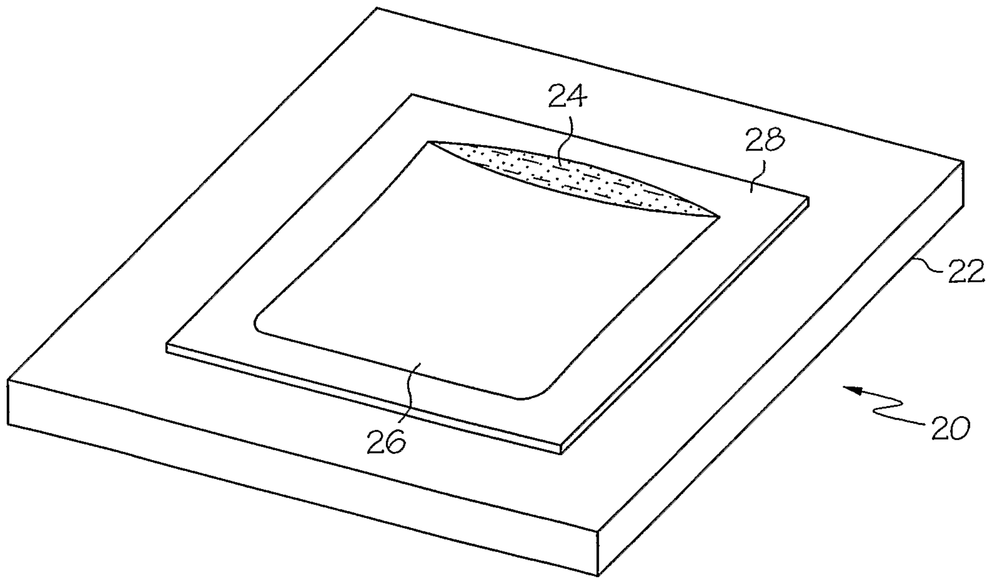

FIG. 7

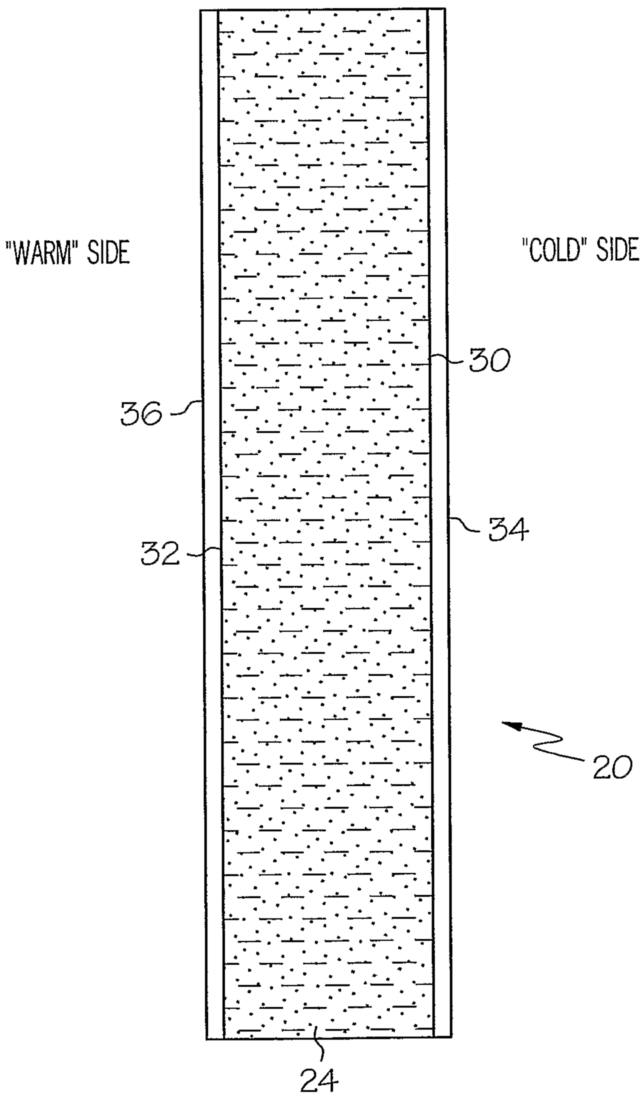

FIG. 8

INTERNATIONAL SEARCH REPORT

Inte nal Application No
PCT/US 03/05935

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F25D23/06 F25D3/06

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 F25D

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)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 15 01 216 A (BBC BROWN BOVERI & CIE) 23 October 1969 (1969-10-23)	1-3,5,6, 14,16
Y	figures 1-5	4,8,9, 12,13,15
	page 2, paragraphs 2,4 page 3, paragraphs 1,2,6 page 3, paragraphs 1,2	
A		10,11

X	US 6 109 059 A (LEBRUN CAMIL) 29 August 2000 (2000-08-29)	1
Y	abstract; figure 2 column 2, line 56 - line 59	4
A		2,3

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

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 July 2003	11/07/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Yousufi, S

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A	abstract; figures 1-6 page 9, paragraph 2 -page 11, paragraph 5	2,11

INTERNATIONAL SEARCH REPORT

Information on patent family members

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