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VACUUM INSULATED SORBENT-DRIVEN REFRIGERATION DEVICE
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(56) Prior Art Documents
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(57) Claim

1. A self-contained cooling device comprising:
a liquid that, in operation of the device, evaporates to form a vapor;
a first evacuable chamber containing a sorbent for receiving the vapor;
a second chamber substantially surrounding and thermally enclosing the first chamber that is adapted to serve both as a conduit for passage of the vapor into the first chamber and as a thermal insulator of the first chamber when the second chamber is substantially evacuated;
a valve to prevent the vapor from flowing into the first chamber until desirable; and
a means for actuating the valve, thereby commencing operation of the device.
2. The apparatus of Claim 1, wherein said first chamber is mounted substantially concentrically within said second chamber.
3. The apparatus of Claim 1, wherein said first chamber is mounted to said second chamber so that said liquid vapor must flow substantially around said first chamber and into said first chamber.
4. The apparatus of Claim 1, further comprising a third chamber surrounding said second chamber, wherein said liquid is supported by a wettable material in a layer adjacent to an inner wall of the third chamber

both prior to and during operation of the device.

5. The apparatus of Claim 4, wherein said wettable material for said liquid comprises a hydrophilic gel-forming polymer.

16. A method for cooling, comprising the steps of:

(a) providing a cooling device comprising:

i) a liquid that, in operation of the device, evaporates to form a vapor;

ii) a first ^{evacuatable} ~~evacuated~~ chamber containing a sorbent for receiving the vapor;

iii) a second chamber substantially surrounding and thermally enclosing the first chamber that is adapted to serve both as a conduit for passage of the vapor into the first chamber and as a thermal insulator of the first

chamber when the second chamber is substantially evacuated;

iv) a valve to prevent the vapor from flowing into the first chamber until desirable; and

v) a means for actuating the valve, thereby commencing operation of the device;

(b) opening the valve to permit gaseous communication between the first chamber, the second chamber and the liquid whereby the pressure around the liquid is reduced, causing the liquid to boil, forming a vapor, which vapor is collected by the sorbent material in the first chamber;

(c) removing vapor from the first chamber by collecting it in the sorbent until an equilibrium is reached, wherein the sorbent is substantially saturated or substantially all of the liquid has been collected in the sorbent; and

(d) containing heat generated in the sorbent within the first chamber by means of a vacuum in the second chamber which substantially surrounds the first chamber.

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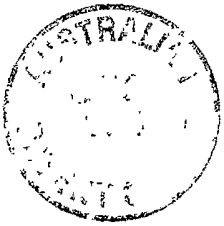
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(54) Title: VACUUM INSULATED SORBENT-DRIVEN REFRIGERATION DEVICE			
(57) Abstract Disclosed is a self-contained, rapid cooling device that retains heat produced from the cooling process and can be stored for indefinite periods without losing its cooling potential. A liquid (18) in a first chamber (12) undergoes a change of phase into vapor which cools the first chamber (12). A second chamber (20) forms a vacuum insulation about a third chamber (21) which contains a sorbent. The sorbent (24) in the third chamber (21) is in fluid communication with the vapor and removes the vapor from the first chamber (12). The device is self-contained because a material (25) in contact with the sorbent (24) removes the heat from the sorbent (24) to prevent the reduction in the cooling effect produced by the first chamber. In addition, a vacuum insulation about the third chamber (21) keeps the heat sorbent (24) from diminishing that cooling effect.			

VACUUM INSULATED SORBENT-DRIVEN REFRIGERATION DEVICE

Background of the Invention

The invention relates to temperature changing devices and, in particular, to self-contained cooling devices such as portable or disposable food or beverage coolers. The invention also extends to a method for cooling.

There are many foods and beverages that may be stored almost indefinitely at average ambient temperature of 20°-25°C but that should be cooled immediately before consumption. In general, the cooling of these foods and beverages is accomplished by electrically-run refrigeration units. The use of these units to cool such foods and beverages is not always practical because refrigerators generally require a source of electricity, they are not usually portable, and they do not cool the food or beverage quickly.

An alternate method for providing a cooled material on demand is to use portable insulated containers. However, these containers function merely to maintain the previous temperature of the food or beverage placed inside them, or they require the use of ice cubes to provide the desired cooling effect. When used in conjunction with ice, insulated containers are much more bulky and heavy than the food or beverage. Moreover, in many locations, ice may not be readily available when the cooling action is required.

Ice cubes have also been used independently to cool food or beverages rapidly. However, use of ice independently for cooling is often undesirable because ice may be stored only for limited periods above 0°C. Moreover, ice may not be available when the cooling action is desired.

In addition to food and beverage cooling, there are a number of other applications for which a portable cooling device is extremely desirable. These include medical



applications, including cooling of tissues or organs; preparation of cold compresses and cryogenic destruction of tissues as part of surgical procedures; industrial applications, including production of cold water or other liquids upon demand; preservation of biological specimens; cooling of protective clothing; and cosmetic applications. A portable cooling apparatus could have widespread utility in all these areas.

Most attempts to build a self-contained miniaturized cooling device have depended on the use of a refrigerant liquid stored at a pressure above atmospheric pressure, so that the refrigerant vapor could be released directly to the atmosphere. Unfortunately, many available refrigerant liquids for such a system are either flammable, toxic, harmful to the environment, or exist in liquid form at such high pressures that they represent an explosion hazard in quantities suitable for the intended purpose. Conversely, other available refrigerant liquids acceptable for discharge into the atmosphere (such as carbon dioxide) have relatively low heat capacities and latent heats of vaporization. As a result, some cooling devices which release carbon dioxide are more bulky than is commercially acceptable for a portable device.

An alternate procedure for providing a cooling effect in a portable device is to absorb or adsorb the refrigerant vapor in a chamber separate from the chamber in which the evaporation takes place. In such a system, the refrigerant liquid boils under reduced pressure in a sealed chamber and absorbs heat from its surroundings. The vapor generated from the boiling liquid is continuously removed from the first chamber and discharged into a second chamber containing a desiccant or sorbent that absorbs the vapor.

The use of two chambers to produce a cooling effect around one chamber is illustrated in U.S. Patent Nos. 4,250,720 and 4,736,599 to Siegel and Great Britain Patent No. 2,095,386 to Cleghorn, et al. These patents disclose a two-chamber apparatus connected by a tube. The Siegel

patent uses water as the refrigerant liquid, while the Cleghorn, et al. patent is not limited to water. The Siegel patent envisions the use of such a cooling device to cool food or beverages. However, both systems produce heat in the absorption chamber, and the chamber must be distanced from the area cooled
5 by the first chamber so that the cooling effect is not compromised.

Furthermore, in both the Siegel and Cleghorn, et al. patents, the rapid initial cooling effect gradually slows as a result of the decrease in temperature of the object to be cooled. None of the prior art effectively deals with the problem of heat buildup in the sorbent chamber; thus, none of the prior
10 sorption-cooling devices are fully suitable for use in miniaturised food, beverage and other cooling systems.

Accordingly, one objective of the present invention is to provide a self-contained cooling device with a means for handling heat produced in the sorbent so that the cooling effect in the evaporation chamber is not effectively
15 diminished.

Other objectives will become apparent from the appended drawing and the following Detailed Description of the Invention.

Summary of the Invention

The present invention is a self-contained cooling device comprising a
20 liquid that, in operation of the device, evaporates to form a vapour, a first evacuable chamber containing a sorbent for receiving the vapour, and a second chamber substantially surrounding and thermally enclosing the first chamber that is adapted to serve both as a conduit for passage of the vapor into the first chamber and as a thermal insulator of the first chamber when the second
25 chamber is substantially evacuated. A valve prevents the vapor from flowing into the first chamber until desirable. Means is provided for actuating the valve, thereby commencing operation of the device.

The invention also provides a method for cooling, comprising providing a cooling device as just described, and then the following steps.

30 Opening the valve to permit gaseous communication between the first chamber, the second chamber and the liquid whereby the pressure around the liquid is reduced, causing the liquid to boil, forming a vapor, which vapor is



collected by the sorbent material in the first chamber;

removing vapor from the first chamber by collecting it in the sorbent until an equilibrium is reached, wherein the sorbent is substantially saturated or substantially all of the liquid has been collected in the sorbent; and

- 5 containing heat generated in the sorbent within the first chamber by means of a vacuum in the second chamber which substantially surrounds the first chamber.

The liquid may be contained in a third chamber.

- By opening the valve, a drop in pressure occurs in the third chamber
10 because the first and second chambers are evacuated. This drop in pressure causes the liquid in the third chamber to vaporize, and, because this liquid-to-gas phase change can occur only if the liquid removes heat equal to the latent heat of vaporization of the evaporated liquid from the third chamber, the third chamber cools. The vapor passes through the second chamber into the first
15 chamber where it is absorbed and adsorbed by the sorbent. The sorbent also gains all of the heat contained in the absorbed or adsorbed vapor, and, if the absorption-adsorption process involves an exothermic chemical reaction, the sorbent must also absorb the reaction heat.

- The heat contained within the sorbent is preferably removed from the
20 sorbent by a heat removing material. Preferably, that heat removing material is a phase change material which is thermally coupled to the sorbent. It has a thermal mass different from the material comprising the first chamber in contact with the sorbent and has a heat capacity greater than that of the sorbent. The heat is also contained within the first chamber by a vacuum
25 which insulates the first chamber. In a preferred embodiment, the first chamber is mounted substantially concentrically within the second chamber, and in one embodiment the liquid vapor must flow substantially around the first chamber and into that first chamber.

- In another preferred embodiment, the liquid is water. In still another, a
30 highly hydrophilic polymer lines the interior surface of the third chamber to maximize the surface area from which boiling may occur. The liquid may be mixed with a nucleating agent that promotes ebullition of the liquid.

The present invention provides a self-contained rapid cooling device that cools a food, beverage or other material article from ambient temperature on demand in a timely manner, exhibits a useful change in temperature, retains the heat produced from the cooling process or retards the transfer of
5 the heat from the sorbent back to the material being cooled, can be stored for unlimited periods without losing its cooling potential, and is able to meet government standards for safety in human use.

Description of the Drawings

Figure 1 is a schematic representation of a cooling device according to
10 the present invention, wherein the second and third chambers are wholly within the first chamber.

Figure 2 is a schematic representation of a cooling device according to the present invention, wherein the second and third chambers are outside of the first chamber.

Detailed Description of the Preferred Embodiment

As is shown in the figures, the cooling device 10 includes a first chamber 21, a second chamber 20 which surrounds first chamber 21, and a third chamber 12 containing a refrigerant liquid 18 and having its interior surface coated with a wicking material 16. The first chamber 21 is at least
20 partially filled with a sorbent 24, which is optionally in contact with a heat-removing material 25. As is schematically shown in the figures, the second chamber 20 and the first chamber 21 are in constant fluid communication. Initially, at least one of the two chambers is evacuated, thus creating a vacuum within the other.

25 Positioned between the third chamber 12 and the second chamber 20 is a valve 30, which allows fluid communication between the chambers 12 and 20 only when the valve 30 is open. As is shown in Figure 2, a conduit 28 may connect the third chamber 12 and the second chamber 20 with the valve 30 interposed in the conduit 28. In a more preferred embodiment which is shown
30 in Figure 1, however, the second chamber 20 and thus the first chamber 21 are wholly contained within the third chamber 12 so that no conduit is needed to connect the third chamber 12 and the second chamber 20.



The operation of the cooling device 10 is suspended (i.e., the system is static and no cooling occurs) until the valve 30 is opened, at which time the conduit 28 provides fluid communication between the first, second, and third chambers, 21, 20 and 12 respectively. Opening the valve 30 between the third and second chambers 10 and 20 causes a drop in pressure in chamber 12 because the second chamber 20 is evacuated. The drop in pressure in the third chamber 12 upon opening of the valve 30 causes the liquid 18 to boil at ambient temperature into a liquid-vapor mixture 32. This liquid-to-gas phase change can occur only if the liquid 18 removes heat equal to the latent heat of vaporization of the evaporated liquid 18 from the third chamber 12. This causes the third chamber 12 to cool. The cooled third chamber 12, in turn, removes heat from its surrounding material as indicated by the arrows 33.

Once inside the first chamber 21, the vapor is absorbed or adsorbed by the sorbent 24. This facilitates the maintenance of a reduced vapor pressure in the third chamber 12 and allows more of the liquid 18 to boil and become vapor, further reducing the temperature of chamber 12. The continuous removal of the vapor maintains the pressure in chamber 12 below the vapor pressure of the liquid 18, so that the liquid 18 boils and produces vapor continuously until sorbent 24 is saturated, until the liquid 18 has boiled away or until the temperature of the liquid 18 has dropped below its boiling point.

When the sorbent 24 absorbs or adsorbs the vapor, a heat of absorption or adsorption is generated. The optional heat-removing material 25, which is thermally coupled to the sorbent 24 (and preferably is mixed with the sorbent 24) removes heat from the sorbent 24, preventing or slowing a rise in temperature in both the sorbent 24 and the first chamber 21, which rise in temperature might compromise the cooling effect produced by the third chamber 12.

The relationship of the three chambers performs another function which prevents any compromising of the cooling effect produced by chamber 12. Because the second chamber 20 is substantially evacuated and surrounds the first chamber 21, it forms an insulator so that the heat contained within the first chamber 21 remains within that chamber. The vacuum insulation about

the first chamber 21 inhibits that chamber from warming the cooling third chamber 12. Preferably, the first chamber 21 is mounted substantially concentrically within the second chamber 20. In one embodiment, the entrance to the first chamber 21 is positioned so that the liquid vapor must
5 flow substantially around the first chamber 21 until it enters the first chamber 21 and is sorbed by the sorbent 24.

As is shown in Figure 1, the aforementioned configuration allows the construction of the cooling device 10 to be miniaturized and compact. Its size can be greatly reduced by placing the second and first chambers 20 and 21
10 within the third chamber 12. Nevertheless, it is understood that the second and first chambers 20 and 21 can be situated alongside of the third chamber 12 as is depicted in Figure 2 as long as the second chamber 20 insulates the third chamber 21 to prevent heat from compromising the cooling effect.

It is preferred that there is enough sorbent 24 within the first chamber
15 21 so that substantially all of the liquid 18 is absorbed or adsorbed in the sorbent 24. By having an excess of sorbent 24, the device ensures that a vacuum will remain in the second chamber 20 at the most critical time to ensure insulation about the first chamber 21 - after the sorption process is complete. It is also preferable that, while there may not be a complete
20 vacuum in the second chamber 20, it is at a pressure substantially lower than atmospheric during and after evaporation so that a substantial vacuum exists to insulate about the first chamber 21.

Two important components of the present invention are the evaporating liquid and the sorbent. The liquid and the sorbent must be complimentary
25 (i.e., the sorbent must be capable of absorbing or adsorbing the vapor produced by the



liquid), and suitable choices for these components would be any combination able to make a useful change in temperature in a short time, meet government standards for safety and be compact.

5 The refrigerant liquids used in the present invention preferably have a high vapor pressure at ambient temperature, so that a reduction of pressure will produce a high vapor production rate. The vapor pressure of the liquid at 20°C is preferably at least about 9 mm Hg, and
10 more preferably is at least about 15 or 20 mm Hg. Moreover, for some applications (such as cooling of food products), the liquid should conform to applicable government standards in case any discharge into the surroundings, accidental or otherwise, occurs. Liquids
15 with suitable characteristics for various uses of the invention include: various alcohols, such as methyl alcohol and ethyl alcohol; ketones or aldehydes, such as acetone and acetaldehyde; water; and freons, such as freon C318, 114, 21, 11, 114B2, 113 and 112. The preferred
20 liquid is water.

 In addition, the refrigerant liquid may be mixed with an effective quantity of a miscible nucleating agent having a greater vapor pressure than the liquid to promote ebullition so that the liquid evaporates even more quickly
25 and smoothly, and so that supercooling of the liquid does not occur. Suitable nucleating agents include ethyl alcohol, acetone, methyl alcohol, propyl alcohol and isobutyl alcohol, all of which are miscible with water. For example, a combination of a nucleating agent with a
30 compatible liquid might be a combination of 5% ethyl alcohol in water or 5% acetone in methyl alcohol. The nucleating agent preferably has a vapor pressure at 25°C of at least about 25 mm Hg and, more preferably, at least about 35 mm Hg. Alternatively, solid nucleating agents may
35 be used, such as the conventional boiling stones used in chemical laboratory applications.

The sorbent material used in the ~~third~~^{first} chamber 21 is preferably capable of absorbing and adsorbing all the vapor produced by the liquid, and also preferably will meet government safety standards for use in an environment where
5 contact with food may occur. Suitable sorbents for various applications may include barium oxide, magnesium perchlorate, calcium sulfate, calcium oxide, activated carbon, calcium chloride, glycerine, silica gel, alumina gel, calcium hydride, phosphoric anhydride, phosphoric
10 acid, potassium hydroxide, sulphuric acid, lithium chloride, ethylene glycol and sodium sulfate.

The heat-removing material may be one of three types:
(1) a material that undergoes a change of phase when heat is applied; (2) a material that has a heat capacity greater
15 than the sorbent; or (3) a material that undergoes an endothermic reaction when brought in contact with the liquid refrigerant.

Suitable phase change materials for particular applications may be selected from paraffin, naphthalene,
20 sulphur, hydrated calcium chloride, bromocamphor, cetyl alcohol, cyanamide, eleudic acid, lauric acid, hydrated sodium silicate, sodium thiosulfate pentahydrate, disodium phosphate, hydrated sodium carbonate, hydrated calcium nitrate, Glauber's salt, potassium, sodium and magnesium
25 acetate. The phase change materials remove some of the heat from the sorbent material simply through storage of sensible heat. In other words, they heat up as the sorbent heats up, removing heat from the sorbent. However, the most effective function of the phase change material is in
30 the phase change itself. An extremely large quantity of heat can be absorbed by a suitable phase change material in connection with the phase change (i.e., change from a solid phase to a liquid phase, or change from a liquid phase to a vapor phase). There is typically no change in the
35 temperature of the phase change material during the phase change, despite the relatively substantial amount of heat required to effect the change, which heat is absorbed



during the change. Phase change materials which change from a solid to a liquid, absorbing from the sorbent their latent heat of fusion, are the most practical in a closed system. However, a phase change material changing from a liquid to a vapor is also feasible. Thus, an environmentally-safe liquid could be provided in a separate container (not shown) in contact with the sorbent material (to absorb heat therefrom) but vented in such a way that the boiling phase change material carries heat away from the sorbent material and entirely out of the system.

Another requirement of any of the phase change materials is that they change phase at a temperature greater than the expected ambient temperature of the material to be cooled, but less than the temperature achieved by the sorbent material upon absorption of a substantial fraction (i.e., one-third or one-quarter) of the refrigerant liquid. Thus, for example, in most devices according to the present invention which are intended for use in cooling a material such as a food or beverage, the phase change material could change phase at a temperature above about 30°C, preferably above about 35°C but preferably below about 70°C, and most preferably below about 60°C. Of course, in some applications, substantially higher or lower phase change temperatures may be desirable. Indeed, many phase change materials with phase change temperatures as high as 90°C, 100°C or 110°C may be appropriate in certain systems.

Materials that have a heat capacity greater than that of the sorbent simply provide a thermal mass in contact with the sorbent that does not effect the total amount of heat in the system, but reduces the temperature differential between the material being cooled and the ~~third~~^{first} chamber 21, with two results. First, the higher the temperature gradient between two adjacent materials, the more rapid the rate of heat exchange between those two materials, all else being equal. Thus, such thermal mass materials in the ~~third~~^{first} chamber 21 slow the transfer of heat



out of the ~~third~~^{first} chamber 21. Second, many sorbent materials function poorly or do not function at all when the temperature of those materials exceeds a certain limit. Heat-absorbing material in the form of a thermal mass can substantially reduce the rate of the sorbent's temperature increase during the cooling cycle. This, in turn, maintains the sorbent at a lower temperature and facilitates the vapor-sorption capabilities of the sorbent. Various materials which have a high specific heat include cyanimide, ethyl alcohol, ethyl ether, glycerol, isoamyl alcohol, isobutyl alcohol, lithium hydride, methyl alcohol, sodium acetate, water, ethylene glycol and paraffin wax.

Care must be taken, of course, when selecting a high specific heat material (or high thermal mass material) to ensure that it does not interfere with the functioning of the sorbent. If the heat-absorbing material, for example, is a liquid, it may be necessary to package that liquid or otherwise prevent physical contact between the heat-absorbing material and the sorbent. Small individual containers of heat-absorbing material scattered throughout the sorbent may be utilized when the sorbent and the heat-absorbing material cannot contact one another. Alternatively, the heat-absorbing material may be placed in a single package having a relatively high surface area in contact with the sorbent to facilitate heat transfer from the sorbent into the heat-absorbing material.

The third category of heat-removing material (material that undergoes an endothermic reaction) has the advantage of completely removing heat from the system and storing it in the form of a chemical change. The endothermic material may advantageously be a material that undergoes an endothermic reaction when it comes in contact with the refrigerant liquid (or vapor). In this embodiment of the invention, when the valve 30 in the conduit 28 is opened, permitting vapor to flow through the conduit 28 into the ~~third~~^{first} chamber 21, the vapor comes in contact with some of the endothermic material, which then undergoes an



endothermic reaction, removing heat from the sorbent 24. Such endothermic materials have the advantage that the heat is more or less permanently removed from the sorbent, and little, if any, of that heat can be retransferred to the material being cooled. This is in contrast to phase change materials and materials having a heat capacity greater than the sorbent material, both of which may eventually give up their stored heat to the surrounding materials, although such heat exchange (because of design factors that retard heat transfer, such as poor thermal conductivity of the sorbent 24) generally does not occur with sufficient rapidity to reheat the cooled material prior to use of that material.

Heat-absorbing materials which undergo an endothermic reaction may variously be selected from such compounds as H_2BO_3 , $PbBr_2$, $KBrO_3$, $KClO_3$, $K_2Cr_2O_7$, $KClO_4$, K_2S , SnI_2 , NH_4Cl , $KMnO_4$ and $CsClO_4$. Furthermore, the heat-removing material may be advantageously in contact with the sorbent. In various embodiments of the invention, the sorbent and heat-removing material could be blended, the heat-removing material could be in discrete pieces mixed with the sorbent, or the material could be a mass in contact with, but not mixed into, the sorbent.

In selecting the wicking material 16, any of a number of materials may be chosen, depending upon the requirements of the system and the particular refrigerant liquid 18 being used. The wicking material may be something as simple as cloth or fabric having an affinity for the refrigerant liquid 18 and a substantial wicking ability. Thus, for example, when the refrigerant liquid is water, the wicking material may be cloth, sheets, felt or flocking material which may be comprised of cotton, filter material, natural cellulose, regenerated cellulose, cellulose derivatives, blotting paper or any other suitable material.

The most preferred wicking material would be highly hydrophilic, such as gel-forming polymers which would be capable of coating the interior surface of the evaporation

chamber. Such materials preferably consist of alkyl, aryl and amino derivative polymers of vinylchloride acetate, vinylidene chloride, tetrafluoroethylene, methyl methacrylate, hexanedioic acid, dihydro-2,5-furandione, propenoic acid, 1,3-isobenzofurandione, 1 h-pyrrole-2,5-dione or hexahydro-2 h-azepin-2-one.

- 5 The wicking material may be sprayed, flocked, or otherwise coated or applied onto the interior surface of the third chamber 12. In a preferred embodiment, the wicking material is electrostatically deposited onto that surface. In another embodiment, the wicking material is mixed with a suitable solvent, such as a non-aqueous solvent, and then the solution is applied to the
- 10 interior surface of the third chamber 12.

- In another preferred embodiment, the wicking material is able to control any violent boiling of the evaporator and thus reduces any liquid entrainment in the vapor phase. In such an embodiment, the wicking material is a polymer forming a porous space-filling or sponge-like structure, and it may
- 15 fill all or part of the third chamber 12.

- The valve 30 may be selected from any of the various types shown in the prior art. The valve 30 may be located at any location between the first chamber 21 and the third chamber 12 so long as it prevents vapor from being sorbed by the sorbent 24. However, if the entire cooling device 10 is within a
- 20 pressurized container 50, a pressure responsive valve can be used which can actuate the cooling device upon the release of the pressure within the container.

- The invention also includes a method of using the cooling device described herein. In a preferred embodiment, now to be described, this
- 25 method includes the step of providing a cooling device of the type set forth herein; opening the valve between the third chamber 12 and the second chamber 20, whereby the pressure in the third chamber is reduced, causing the liquid to boil, forming a vapor, which vapor is collected by the sorbent material; removing vapor from the second chamber by collecting the



same in the sorbent until an equilibrium condition is reached wherein the sorbent is substantially saturated or substantially all of the liquid originally in the first chamber has been collected in the sorbent; and

5 simultaneously removing heat from the sorbent by means of the heat-removing material described above. The process is preferably a one-shot process; thus, opening of the valve 30 in the conduit 28 connecting the ~~first~~^{third} chamber 12 and the second chamber 20 is preferably irreversible. At the

10 same time, the system is a closed system; in other words, the refrigerant liquid does not escape the system, and there is no means whereby the refrigerant liquid or the sorbent may escape either the ~~first~~^{third} chamber 12 or the second chamber 20.

15 Although the invention has been described in the context of certain preferred embodiments, it is intended that the scope of the invention not be limited to the specific embodiment set forth herein, but instead be measured by the claims that follow.

20



THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A self-contained cooling device comprising:
a liquid that, in operation of the device, evaporates to form a vapor;
5 a first evacuable chamber containing a sorbent for receiving the vapor;
a second chamber substantially surrounding and thermally enclosing the
first chamber that is adapted to serve both as a conduit for passage of the
vapor into the first chamber and as a thermal insulator of the first chamber
when the second chamber is substantially evacuated;
10 a valve to prevent the vapor from flowing into the first chamber until
desirable; and
a means for actuating the valve, thereby commencing operation of the
device.
2. The apparatus of Claim 1, wherein said first chamber is mounted
15 substantially concentrically within said second chamber.
3. The apparatus of Claim 1, wherein said first chamber is mounted
to said second chamber so that said liquid vapor must flow substantially
around said first chamber and into said first chamber.
4. The apparatus of Claim 1, further comprising a third chamber
20 surrounding said second chamber, wherein said liquid is supported by a
wetable material in a layer adjacent to an inner wall of the third chamber
both prior to and during operation of the device.
5. The apparatus of Claim 4, wherein said wettable material for
said liquid comprises a hydrophilic gel-forming polymer.
- 25 6. The apparatus of Claim 4, wherein said wettable material for
said liquid consists of alkyl, aryl and amino derivative polymers selected from
the group comprising vinylchloride acetate, vinylidene chloride,
tetrafluoroethylene, methyl methacrylate, hexanedioic acid, dihydro-2, 5-
furandione, propenoic acid, 1,3-isobenzofurandione, 1 h-pyrrole-2,5-dione and
30 hexahydro-2



h-azepin-2-one.

7. The apparatus of Claim 4, wherein said wettable material for said liquid consists of cotton, natural cellulose, regenerated cellulose, or cellulose derivatives.

5 8. The apparatus of Claim 1, wherein said liquid has a vapor pressure at 20°C of above about 9 mm Hg.

9. The apparatus of Claim 1, wherein said liquid is water.

10 10. The apparatus of Claim 1, further comprising a nucleating material having a vapor pressure at 25°C of above about 25 mm Hg amongst said liquid to facilitate boiling of said liquid when the pressure around said liquid drops as a result of opening said valve.

11. The apparatus of Claim 10, wherein said nucleating material is ethyl alcohol, acetone, methyl alcohol, propyl alcohol or isobutyl alcohol.

12. The apparatus of Claim 1, wherein said first chamber is wholly contained within said second chamber.

13. The apparatus of Claim 1, wherein said second chamber is initially evacuated.

14. The apparatus of Claim 1, wherein said first chamber contains sufficient sorbent to absorb or adsorb substantially all of the liquid.

15. The apparatus of Claim 1, further comprising a method thermally coupled to said sorbent for removing heat from said sorbent.

16. A method for cooling, comprising the steps of:

(a) providing a cooling device comprising:

30 i) a liquid that, in operation of the device, evaporates to form a vapor;

ii) a first ^{evacuatable} ~~evacuated~~ chamber containing a sorbent for receiving the vapor;

35 iii) a second chamber substantially surrounding and thermally enclosing the first chamber that is adapted to serve both as a conduit for passage of the vapor into the first chamber and as a thermal insulator of the first



chamber when the second chamber is substantially evacuated;

iv) a valve to prevent the vapor from flowing into the first chamber until desirable; and

v) a means for actuating the valve, thereby commencing
5 operation of the device;

(b) opening the valve to permit gaseous communication between the first chamber, the second chamber and the liquid whereby the pressure around the liquid is reduced, causing the liquid to boil, forming a vapor, which vapor is collected by the sorbent material in the first chamber;

10 (c) removing vapor from the first chamber by collecting it in the sorbent until an equilibrium is reached, wherein the sorbent is substantially saturated or substantially all of the liquid has been collected in the sorbent; and

(d) containing heat generated in the sorbent within the first chamber
15 by means of a vacuum in the second chamber which substantially surrounds the first chamber.

17. The method of Claim 16, wherein said first chamber is mounted substantially concentrically within said second chamber.

18. The method of Claim 16, wherein said first chamber is mounted
20 to said second chamber so that said liquid vapor must flow substantially around said first chamber and into said first chamber.

19. The method of Claim 16, further comprising a third chamber surrounding said second chamber, wherein said liquid is supported by a wettable material in a layer adjacent to an inner wall of the third chamber
25 both prior to and during operation of the device.

20. The method of Claim 19, wherein said wettable material for said liquid comprises a hydrophilic gel-forming polymer.

21. The method of Claim 19, wherein said wettable material for said liquid consists of alkyl, aryl and amino

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derivative polymers selected from the group comprising vinylchloride acetate, vinylidene chloride, tetrafluoroethylene, methyl methacrylate, hexanedioic acid, dihydro-2,5-furandione, propenoic acid, 1,3-
5 isobenzofurandione, 1 h-pyrrole-2,5-dione and hexahydro-2 h-azepin-2-one.

22. The method of Claim 19, wherein said wettable material for said liquid consists of cotton, natural cellulose, regenerated cellulose, or cellulose derivatives.

10 23. The method of Claim 16, wherein said liquid has a vapor pressure at 20°C of about 9 mm Hg.

24. The method of Claim 16, wherein said liquid is water.

15 25. The method of Claim 16, further comprising a nucleating material having a vapor pressure at 25°C of above about 25 mm Hg amongst said liquid to facilitate boiling of said liquid when the pressure around said liquid drops as a result of opening said valve.

20 26. The method of Claim 25, wherein said nucleating material is ethyl alcohol, acetone, methyl alcohol, propyl alcohol or isobutyl alcohol.

27. The method of Claim 16, wherein said first chamber is wholly contained within said second chamber.

25 28. The method of Claim 16, wherein said second chamber is initially evacuated.

29. The method of Claim 16, wherein said first chamber contains sufficient sorbent to absorb or adsorb substantially all of the liquid.

30 30. The method of Claim 16, further comprising a material thermally coupled to said sorbent for removing heat from said sorbent.

31. The method of Claim 16, wherein said method comprises a one-shot process.

35 32. The apparatus of Claim 1, wherein the valve is positioned between said ^{liquid and said} ~~first and~~ second chamber.

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STATEMENT UNDER ARTICLE 19

CLAIMS 1,2,8,9 and 14

Under Item III of the International Report, the Examiner cited U.S. Patent No. 2,871,674 to Koivisto et al as relevant to Claims 1,2,8,9 and 14, citing to Category X, which states that "the claimed invention cannot be considered novel or cannot be considered to involve an inventive step."

In response, Claim 1, and its accompanying method Claim 16, have now been amended to further clarify the invention in light of the cited reference. The cited reference, Koivisto et al, discloses a multichamber device with a coiled conduit connecting an inner and outer chamber, and with a solid insulating material about the inner chamber. The Applicants Claim 1, as amended, describes a multichamber cooling device wherein an inner chamber is substantially surrounded by an outer chamber which serves the dual function of a vacuum insulator of the inner chamber and of a conduit for passage of vapor into the inner chamber. The Koivisto et al reference does not teach the use of a chamber which serves the dual function of a conduit and an insulator, and thus is not relevant to the present invention.

CLAIMS 4,7,10,11,13,16-19 AND 22-32

Under Item III of the International Report, the Examiner cited U.S. Patent No. 3,642,059 to Greiner and Patent No. 2,871,674 to Koivisto et al as relevant to Claims 4,7,10,11,16-19 and 22-32. The Examiner cited these references as relevant to Category Y, which states that "the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art."

Claim 4, and its accompanying method Claim 19, have now been amended to distinguish them from the cited Greiner reference. Greiner discloses a heating and cooling device wherein one chamber contains a wicking material for drawing a liquid into that chamber, thereby initiating operation of the device. The present invention, as described in the amended claims 4 and 19, is a cooling device utilizing a wettable material for supporting a vaporizable liquid adjacent to its cooling wall both prior to and during operation of the device. The Greiner reference does not teach the use of a material for supporting a liquid in such a position, nor does it provide for the presence of the liquid in this position before operation of the device.



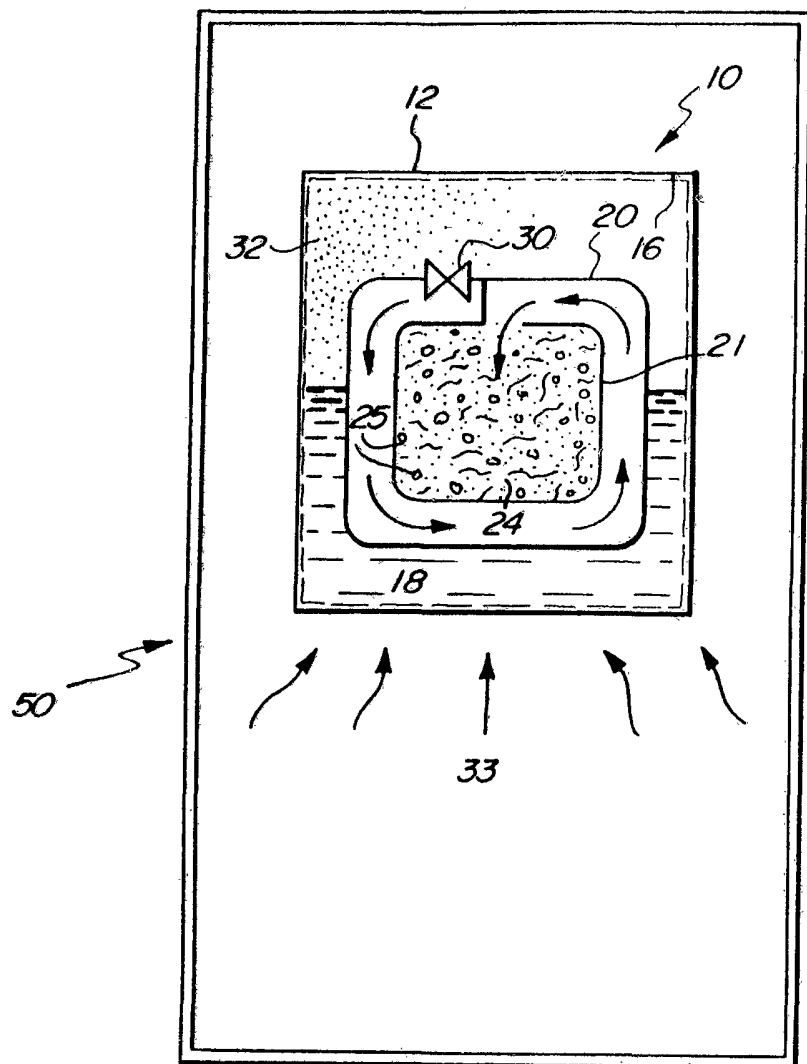


FIG. 1

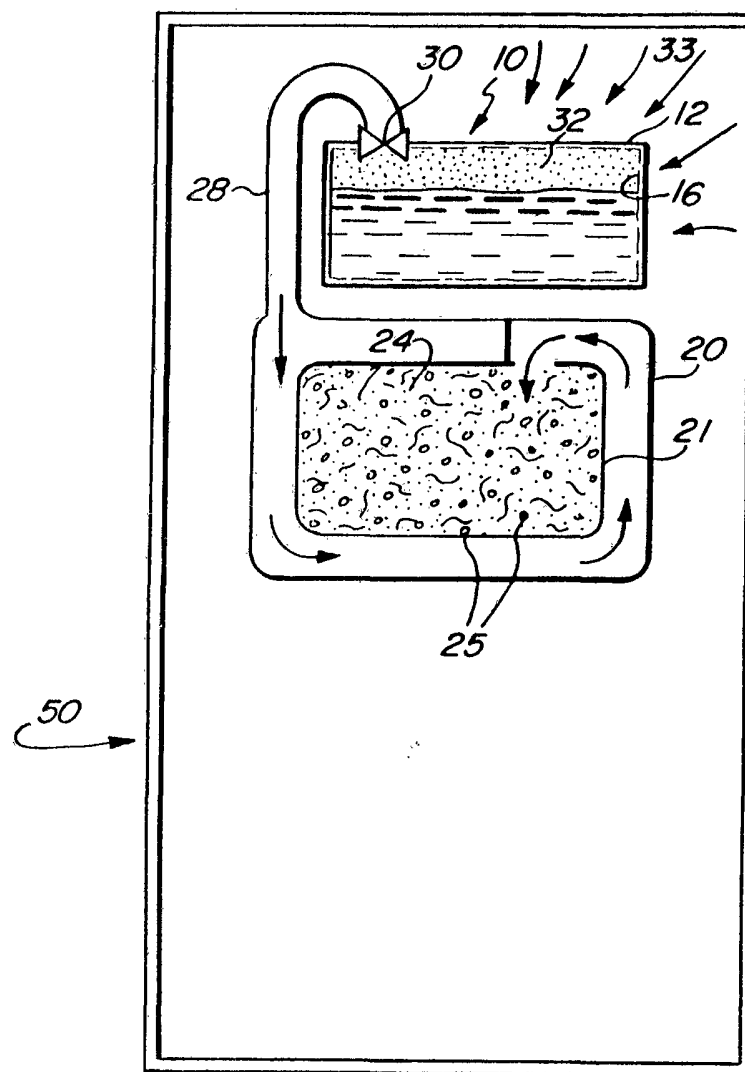


FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US90/00043

I. CLASSIFICATION OF SUBJECT MATTER		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC (5); F25 B 15/00 U.S. CL. 62/101, 476		
II. FIELDS SEARCHED		
Minimum Documentation Searched:		
Classification System	Classification Symbols	
U.S.	62/101, 476, 477, 478, 479	
Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched:		
III. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Character of Document with indication where appropriate of the relevant passages	Publication No.
Y	US, A, 3,642,059 (GREINER) 15 FEBRUARY 1972, See Column 5 lines 5-18	4,7,10,11 13,16-19 and 22-32
X	US, A, 2,871,37- (ROIVISTO et al)	1,2,8,9,14
Y	03 FEBRUARY 1959, See Column	4,7,10,11,13, 16-19,22-32
A	US, A, 4,250,720 (SIEGEL) 17 FEBRUARY 1981, See Entire Document	1-26
A	US, A, 4,205,531 (BRUNBERG et al) 03 June 1980, See Entire Document	1-32
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
23 FEBRUARY 1990	26 MAR 1990	
International Searching Authority	Signature of Authorized Officer	
ISA/US	HENRY A. BENNETT	