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(54) **PERVAPORATIVELY COOLED CONTAINERS**

PERVAPORATIV GEKÜHLTE BEHÄLTER

RECEPTACLES REFROIDIS PAR PERVAPORATION

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## Description

### Background of the Invention

### Field of the Invention

**[0001]** This invention relates to a device and method of construction of a container or closure used to cool a liquid by means of pervaporation.

### Description of the Related Art

**[0002]** Evaporative cooling of both dwellings and water originated in Ancient Egypt and subsequently spread eastward through the Middle-East and Iran, to the north of India, westward across north Africa to southern Spain and other regions suffering from a hot and dry climate. In the initial use of this process non-glazed clay pots were used for centuries for the storage of water with the added side benefit of cooling the liquid water contents by absorbing and wicking the water to the outer clay surface followed by the evaporation of the water from this surface. Unfortunately, evaporation directly from the outer clay surface eventually lead to scale formation and reduced cooling efficiency as the minerals build up on this surface reducing the liquid permeability and lowering the liquid vapor pressure.

**[0003]** Other methods based on heat transfer reduction from the environment to the liquid have been used. Methods that have been used include vacuum and air gap thermoses, and foam insulative jackets. Additional devices using ice, frozen cold packs or sticks have been used to compensate for heating by surrounding environment and the return of the liquid in the container to ambient temperature. In all these cases the design of the system necessitates that either the liquid contents, a separate chamber and /or the shell of the bottle be cooled which can lead to excessive weight issues in addition to a liquid volume displacement loss in the container. In all of these methods the temperature of the liquid will equilibrate and eventually return to the ambient temperature.

**[0004]** Pervaporation (PV) is defined as a combination of matrix vapor permeation and evaporation. From 1987 on, membrane pervaporation has gained wide acceptance by the chemical industry for the separation and recovery of liquid mixtures (Chemical Engineering Progress, pp. 45-52, July 1992). The technique is characterized by the introduction of a barrier matrix between a liquid and a gaseous phase. A liquid is in intimate contact with one side of the matrix. Mass transfer of vapor occurs selectively to the gas side of the matrix resulting in the loss of liquid or the loss of select volatile liquid components and the loss of evaporative latent heat. The process is termed pervaporation because of the unique combination of vapor "permeation" through the porous matrix and the liquid to vapor phase change "vaporization". Without heat added to the liquid, the temperature falls due to the latent heat of vaporization until an equilibrium temperature is reached where the heat absorbed from the environment is equal to the latent heat lost due to liquid evaporation at the matrix surface or within the pores.

**[0005]** U.S. Patent Number 5,946,931 illustrates the use of an evaporative cooling PTFE membrane device using a stream of fluid in a laminar flow profile above a membrane in order to cool an attached device or environment. U.S. Patent Number 4,824,741 illustrates the use of a pervaporative cooling matrix to cool the surface of the plate of an electrochemical cell. The moist plate may be made from uncatalyzed PTFE-bonded electrode material, a suitable porous sintered powder, porous fibers, or even a porous polymer film. U.S. Patent 4,007,601 demonstrates the use of evaporative cooling in a circulating porous hollow heat exchanger to obtain a cooled fluid. A pervaporatively self-cooling water container is disclosed by US-A-4368766

### Summary of the Invention

**[0006]** Disclosed herein is a pervaporative cooling system for beverage and liquid containers that does not use any mechanical pumps to supply liquid to the pervaporative matrix surface and does not rely on a vacuum to enhance the cooling efficiency. A container is defined as any apparatus or enclosure that holds liquid whether it is open or closed to the external environment. This approach utilizes a pervaporative matrix that forms part of the container body and preferably comprises between 5 to 100% of the total surface area of the container. The liquid contents of the container are then cooled directly at the surrounding liquid/membrane interface due to the latent heat of evaporation of the water. The resulting liquid vapor is lost through the matrix . Preferred containers include bottles, jars, carboys, and pouches. The containers in accordance with the present invention further comprise a regenerable or disposable outer layer as defined in claim 1, directly adjacent to or in contact with the pervaporative layer, comprising a desiccant or an absorbent material that absorbs the moisture or other fluid resulting from pervaporation.

## Brief Description of the Drawings

**[0007]**

Figures 1A and 1B illustrate a bottle in plan and exploded view in which a generally planar porous matrix may be wrapped around or pushed over a bottle body as a cylinder.

Figure 2 shows a partially exploded view of a multilayered structure including, a thin membrane layered between two macroporous layers

Figures 3A, 3B, 3C and 3D, illustrates plan and cut away views of bottles in which support ribs enhance the rigidity of a porous matrix.

Figure 4 shows a container comprising an outer porous insulative layer. This sleeve reduces direct radiative warming of the inner bottle surface, yet allows for the pervaporative flux and loss of latent heat.

Figure 5 illustrates a container comprising a pleated matrix which serves as a method for increasing the effective cooling surface area of the container. This allows for a higher surface area and quicker liquid cool down time for the container.

Figures 6A and 6B show a container in plan and cutaway view comprising an adjustable sleeve to limit the extent of pervaporative flux and liquid loss from the container. This sleeve preferably also reduces direct radiative warming of the inner bottle surface, yet allows for the pervaporative flux and loss of latent heat.

Figure 7 illustrates a cross section of a two-layer pervaporative sleeve comprising a sponge or sponge-like material that can be used with a container.

Figure 8 shows a cutaway view of of a pervaporative cooling jacket that is used on a central housing containing a liquid, such as a carbonated beverage.

Figure 9 is a graph of time versus cooling pertaining to pervaporative cooling equilibrium using a variety of porous matrices.

Figure 10 illustrates a pervaporatively-cooled drinking cup.

**[0008]** The figures are intended to be merely exemplary whereby figure 2 shows a layed structure in accordance with the invention. To that end, several figures contain optional features that need not be included in any particular embodiment of the invention, and the shape, type, or particular configuration of container or closure illustrated should not be taken as limiting on the invention.

## Detailed Description of the Preferred Embodiments

**[0009]** Disclosed herein are containers that use pervaporative cooling to cool a liquid or item residing in such container. The containers are comprised of porous vent materials, also called porous matrices.

**[0010]** Porous matrices may be made of any of a wide variety of materials, including, but not limited to, plastics, elastomers, metals, glass, and ceramics. Combinations of plastics, elastomers, metals, glasses, or ceramics may also be used. The combinations may be intimate, such as from blending of two or more components to become co-sintered, or may be layered, such as from laminate structures derived from two or more materials. Combinations of different plastics, elastomers, metals, glasses, or ceramics can also be co-sintered or fabricated into laminate structures for use in pervaporative containers. Preferred plastics for porous vent materials include, but are not limited to thermoplastic polymers, thermoset elastomers, and thermoplastic elastomers. Preferred thermoplastic polymers include, but are not limited to, low density polyethylene (LDPE), linear low density polyethylene (LLDPE), medium density polyethylene (MDPE), high-density polyethylene (HDPE), ultra-high molecular weight polyethylene (UHMWPE), polypropylene (PP) and its copolymers, polymethylpentene (PMP), polybutylene terephthalate (PBT); polyethyleneterephthalate (PET), polyethyleneterephthalate glycol modified (PETG), polyetheretherketone (PEEK), ethylenevinylacetate (EVA), polyethylenevinylalcohol (EVOH), polyacetal, polyacrylonitrile (PAN), poly(acrylonitrile-butadiene-styrene) (ABS), poly(acrylonitrile-styrene-acrylate) (AES), poly(acrylonirile-ethylene-propylene-styrene) (ASA), polyacrylates, polymethacrylates, polymethylmethacrylate (PMMA), polyvinylchloride (PVC), chlorinatedpolyvinylchloride (CPVC), polyvinyldichloride (PVDC) fluorinated ethylenepropylene (FEP), polyvinylfluoride (PVF), polyvinylidinefluoride (PVDF), polytetrafluoroethylene (PTFE), polyester, cellulosics, polyethylenetetrafluoroethylene (ETFE), polyperfluoroalkoxyethylene (PFA), nylon 6 (N6), polyamide, polyimide, polycarbonate, polyetheretherketone (PEEK), polystyrene (PS), polysulfone, and polyethersulfone (PES). Preferred thermoset elastomers include styrene-butadiene, polybutadiene (BR), ethylene-propylene, acrylonitrile-butadiene (NBR), polyisoprene, polychloroprene, silicone, fluorosilicone, urethanes, hydrogenated nitrile rubber (HNBR), polynorborene (PNR), butyl rubber (IIR) to include chlorobutyl (CIIR) and bromobutyl (BIIR), fluoroelastomers such as Viton® and Kalrez®, Fluorel™, and chlorosulfonated polyethylene. Preferred thermoplastic elastomer (TPE) categories include thermoplastic olefins (TPO) including those commercially available as Dexflex® and Indure®; elastomeric PVC blends and alloys; styrenic block copolymers (SBC) including styrene-butadiene-styrene (SBS), styreneisoprene-styrene (SIS), styrene-ethylene/butylene-styrene (SEBS), and styrene-ethylene-propylene-styrene (SEPS), some commercially available SBCs include those sold under the trademarks Kraton®, Dynaflex®, and Chronoprene™; thermoplastic vulcanizate (TPV, also known as dynamically vulcanized alloys) including those commercially available under the trademarks Versalloy®, Santoprene®, and Sarlink®; thermoplastic polyurethane (TPU) including those commercially available under the trademarks ChronoThane®, Versollan™, and Texrin®; copolyester thermoplastic elastomers (COPE) including those commercially available as Ecdel®; and polyether block copolyamides (COPA) including those commercially available under the trademark PEBAX®. Preferred metals for porous materials include stainless steel, aluminum, zinc, copper and its alloys. Preferred glass and ceramics for porous materials include quartz, borosilicate, aluminosilicate, sodiumaluminosilicate, preferably in the form of sintered particles or fibers derived from said materials.

**[0011]** A preferred method of making macroporous plastic is by a process called sintering, wherein powdered or granular thermoplastic polymers are subjected to the action of heat and pressure to cause partial agglomeration of the granules and formation of a cohesive macroporous sheet or part. The macroporous material comprises a network of interconnected macropores that form a random tortuous path through the sheet. Typically, the void volume or percent porosity of a macroporous sheet is from 30 to 65% depending on the conditions of sintering although it may be greater or lesser than the stated range depending on the specific method of manufacturer. Due to the adjustment of chemical or physical properties , the surface tension of a macroporous matrix can be tailored to repel or absorb liquids , but air and vapors can readily pass through. For example, U.S. Patent No. 3,051,993 to Goldman, herein incorporated by reference in its entirety, discloses the details of making a macroporous plastic from polyethylene.

**[0012]** Porous plastics, including macroporous plastics, suitable for making a pervaporatively-cooled container in accordance with preferred embodiments, can be manufactured in sheets or molded to specification and is available for purchase from a number of sources. Porex Corporation (Fairburn, Georgia, U.S.A.) is one such source, and provides porous plastic under the trademark, POREX®. Porous plastic sold under the name POREX® can be purchased in sheets or molded to specification from any one of the thermoplastic polymers previously described. The average porosity of such POREX® materials can vary from about 1 to 350 microns depending on the size of polymer granules used and the conditions employed during sintering. GenPore® (Reading, Pennsylvania, U.S.A.) is another manufacturer of porous plastic products, with pore sizes ranging from 5 to 1000 microns. MA Industries Inc. (Peachtree City, Georgia, U.S.A.) also manufactures porous plastic products. Porvair Technology Ltd (Wrexham North Wales, U.K.) is another manufacturer of porous products supplying both porous plastic (range of 5 to 200um pore size under brand name Vyon™) and porous metal media (under brand name Sinterflo®).

**[0013]** The basic size, thickness and porosity of the plastic chosen to make a pervaporative matrix may be determined by calculating the amount of vapor that must pass through the vent in a given period of time (flow rate) and the heat transfer rate from the environment back into the liquid. The flux rate (flow rate per unit area) of a given macroporous plastic varies depending on factors including the pore size, percent porosity, and cross sectional thickness of the matrix and is generally expressed in terms of volume per unit time per unit area. To achieve a sufficient degree of pervaporative cooling, the flow rate of vapor through the matrix should be such that the thermodynamic heat removed from the liquid initially at room temperature due to vaporization is greater than the heat absorbed from the environment. During the pervaporative process the container liquid temperature cools until the heat loss of the liquid due to vaporization of the liquid contents through the matrix matches the heat gain from the surrounding environment.

**[0014]** In common usage, "Macroporosity" generally refers to the overall void volume of a material or its macrostructure. The term "Macroporous" is generally used to classify a material's individual pores that are considered large in size. The term "Microporosity" generally refers to the individual pore sizes or distribution of pore sizes that constitute the microstructure of a porous material. The term "Microporous" is generally used to classify a material's individual pores that are considered small in size. For purposes of the disclosure herein, pore size (diameter) is classified according to the International Union of Pure and Applied Chemistry (IUPAC) Subcommittee of Macromolecular Terminology, definitions of terms drafted on February 26, 2002. This standard divides pore size classification into three categories: Microporous ($< 0.002\mu m$), Mesoporous (0.002 to $0.050\mu m$) and Macroporous ($>0.050\mu m$). Also for the purposes of this disclosure herein, void volume will be discussed in terms of the "Percent Porosity" of the material. Both macroporous as well as mesoporous materials with pore sizes of 0.05 μm or less can be used for pervaporative cooling. Preferred methods for fabrication include casting or stretching membranes of such materials.

**[0015]** Preferred porous materials include those in which the pores on opposite surfaces (what will become the interior and exterior surfaces) are interconnected such that the two sides are in communication with each other. Such interconnections are preferably not, however, straight through as to create a single cylindrical tube through which material passes; instead a network of pores creates a tortuous path.

**[0016]** For a single layer pervaporative matrix, the porous materials are preferably macroporous with pore sizes greater than or equal to 0.05μm, preferably about 0.1 to 500μm, and about 0.5 to 10μm, including 0.25, 0.5, 1, 5, 15, 20, 40, 60, 80, 100, 150, 200, 250, 300, 350, 400, and 450 μm. In one embodiment, the matrix materials used in conjunction with the pervaporative containers are between 0.1 and 100μm, preferably between 0.5 and 75μm. The percent porosity (percent open area) of the materials are preferably about 10 to 90%, preferably 30 to 75% or 50 to 70%, including 20%, 40%, 60%, and 80%. The thickness of the porous materials preferably ranges from 0.025 to 7mm, including between 1 and 3mm. Preferred thickness for matrix materials used in pervaporative containers are about 0.05 to 5mm and about 0.1 to 3.0mm, including 0.2, 0.3, 0.5, 0.7, 1.0, 1.25, 1.5, 1.75, 2.0, and 2.5mm. Other embodiments may have values for the above parameters that are above or below those set forth above. For single layer matrices, it is preferred that the material be hydrophobic or have a hydrophobic coating. For the values set forth in this paragraph, as well as elsewhere in the specification, the stated ranges include as the values contained in between the values specifically mentioned. In other embodiments, materials can have one or more properties having values lying outside the disclosed ranges.

**[0017]** The matrix material can be derived from plastic, elastomers, glass, metal, or combinations thereof. Some preferred matrix materials, including thermoplastic polymers, thermoset elastomers, thermoplastic elastomer, metals, glass and ceramics are as detailed above. Matrix materials may be purchased from commercial sources, or they may be made according to a variety of techniques. U.S. Patent No. 4,076,656 to White et a1. details one technique in which porogens are added to molten or dissolved materials, which can be leached out with a solvent, or extracted with super-critical fluids after the material sets and is in its final form. U.S. Patent No. 5,262,444 to Rusincovitch et al. details another technique to create porous material by introducing porogens that evolve into gases after processing a material, to leave behind a porous structure. These patents are hereby incorporated by reference in their entireties.

**[0018]** Although many pervaporative matrix materials discussed herein are hydrophobic, oleophobic pervaporative materials may also be used when the pervaporation liquid is an organic liquids such as alcohol. Commodity plastic materials such as nylon, polysulfone, and the cellulosics, are available in hydrophilic grades. These hydrophilic materials can be milled into particles and sintered using techniques known to those familiar in the art to produce hydrophilic porous materials with high liquid flux rates. Porous hydrophilic plastic, including macroporous plastic can be manufactured in sheets or molded to specification and is available for purchase from a number of sources, including Porex Corporation. Porous hydrophilic fiber materials can range in pore size from 20 to 120μm with percent porosity ranging from 25 to 80 for the pore volume. Moreover, hydrophobic porous materials can be rendered hydrophilic by one or more treatment processes familiar to those skilled in the art including, but not limited to, plasma etching, chemical etching, impregnation with wetting agents, or application of hydrophilic coatings. In addition, a masking process can be used in conjunction with one or more treatment processes to selectively pattern a hydrophobic porous material with regions of hydrophilicity with high liquid flux rates, if desired.

**[0019]** For example, multilayered porous constructs containing two or more layers of porous material. Thin layers can be laminated to make thicker layers using techniques familiar to those in the art. Multilayered constructs may be used to obtain a mechanical and physically superior matrix as previously observed in our tests. For instance, combining a sintered macroporous matrix of polyethylene with a thin layer of expanded PTFE on the liquid side of the container increases the hydrophobicity and liquid breakthrough pressure of water from 5 psi to over 30 psi, yet the layered matrix still maintains a similar pervaporative flux to that obtained using porous polyethylene by itself. Thickness of laminates preferably ranges from about 0.025 to 7000μm with average pore sizes, percent porosity and other properties preferably as described above.

**[0020]** Pervaporative matrix materials may also be derived from porous materials made from blends. In a preferred embodiment, the porous materials comprise a fluorinated resin, including, but not limited to, polyvinylfluoride (PVF), polyvinylidinefluoride (PVDF), polytetrafluoroethylene (PTFE), polyethylenetetrafluoroethylene (ETFE), fluorinated ethylene propylene (FEP), polyperfluoroalkoxyethylene (PFA), and/or fluorinated additives such as Zonyl®, blended with selected polyolefin or other resins, preferably those selected from the series of polyethylenes (LLDPE, LDPE, MDPE, HDPE, UHMWPE) polypropylene, polyesters, polycarbonates, ABS, acrylics, styrene polymethylpentene (PMP), polybutylene terephthalate (PBT); polyethyleneterephthalate (PET), polyetheretherketone (PEEK), ethylenevinylacetate (EVA), polyacetal, poly(acrylonitrile-butadiene-styrene) (ABS), poly(acrylonitrile-styrene-acrylate) (AES), poly(acrylonitrile-ethylene-propylene-styrene) (ASA), polyesters, polyacrylates, polymethacrylates polymethylmethacrylate (PMMA), polyvinylchloride (PVC), polyvinyldichloride (PVDC) nylon 6 (N6), polyamide, polyimide, polycarbonate, polystyrene, and polyethersulfone (PES). Elastomers may also be used alone or in blends. Preferred elastomers include those of the thermoset type such as styrene-butadiene, polybutadiene (BR), ethylene-propylene, acrylonitrile-butadiene (NBR), polyisoprene, polychloroprene, silicone, fluorosilicone, urethanes, hydrogenated nitrile rubber (HNBR), polynorborene (PNR), butyl rubber (IIR) to include chlorobutyl (CIIR) and bromobutyl (BIIR). The resulting blends, including sintered blends, have porous structures with varying amounts of porosity, flexibility and mechanical strength determined predominately from the non-PTFE or other non-fluorinated resin, and high water intrusion pressures determined predominately from the fluorinated resin due to its preferential migration to the pore surface during the sintering process. The percent porosity, pore size, and thickness are preferably as noted above. Blended matrix materials may be purchased from commercial sources, or they may be made according to a variety of techniques. U.S. Patent No. 5,693,273 to Wolbrom details a process of cosintering to produce multi-porosity porous plastic sheets that can be derived from two or more polymeric resin materials and U.S. Patent No. 5,804,074 to Takiguchi et al. et al. details a process to produce a plastic filter by cosintering two or more polymeric resins in a molding process to produce filter parts. Both of these patents are hereby incorporated by reference into this disclosure in their entirety.

Pervaporative Cooling

**[0021]** In accordance with claim 1, a pervaporative cooling system for containers is presented that does not use any mechanical pumps to supply liquid to the pervaporative matrix surface and does not rely on a vacuum to enhance the cooling efficiency. The present approach utilizes a pervaporative matrix that forms part of the container, preferably the housing of the container, and comprises between about 5 to 100% of the total surface area of the container, including about 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90% of the total surface area. The liquid contents of the container are preferably cooled directly at the surrounding liquid/matrix interface due to the latent heat of evaporation of the liquid, such as water or a water/dissolved solid mixture or solution, in the container.

**[0022]** The resulting liquid vapor is lost to the surrounding environment, in particular to an absorbent material, through the matrix. In most containers, natural convection and conductive heat transfer within the liquid are predominant heat transfer mechanisms responsible for cooling the liquid contents of the container. Depending upon the dimensions and other properties of the container, the cooling may be substantially uniform throughout the container.

**[0023]** The liquid contents of the pervaporative container or sleeve acts as a coolant. Preferably the liquid volume loss is marginal; for example, in one embodiment, the liquid volume loss of approximately 15% over a 24 hour time period even with significant external air circulation. Due to the high latent heat of vaporization of water (583 cal/g at 75°F), for example, approximately seven times as much weight in ice would be required to maintain the same temperature drop as a loss of water due to vaporization. An added benefit of the porous matrix in addition to pervaporative cooling is in venting any pressure differential developed in the container due to the release of carbonation from a beverage or due to the consumption of the contents.

**[0024]** Referring now to the drawings, there is shown in Figures 1A and 1B a vented pervaporative cooling container. The wall 501 of the container is formed at least in part of pervaporative matrix. This vapor permeable matrix can be from about 5 to 100% of the total surface area of the container. Approximately 100% coverage is achieved if the entire cap and housing (comprising the top 500 walls 501 and bottom 502) are made from porous matrix material. In one preferred embodiment, the pervaporative surface area is greater than about 30% of the total container surface and provides a substantial amount of pervaporative flux to effectively cool the contained liquid below ambient temperature and maintain a subambient liquid temperature.

**[0025]** As shown in Figure 2, a multilayered construct comprising two or more layer is used. Three layers of porous material 503, 504 and 505 are used to obtain a multilayer or laminate matrix. In one embodiment, a sintered macroporous matrix of polyethylene 505 with a thin layer of expanded PTFE 504 on the liquid side of the container increases the hydrophobicity and liquid intrusion pressure but helps to maintain a similar pervaporative flux and good mechanical stability as is obtained using porous polyethylene by itsel. In addition, a third layer of porous polyethylene 503 forming a sandwich with the expanded PTFE in the middle 504 provides a scratch resistance surface close to the inside of the container making it dishwasher safe and substantially preventing or reducing the soft expanded PTFE layer from being damaged. In related embodiments, laminates can comprise greater or fewer than three layers and/or different porous matrix materials.

**[0026]** Alternatively, the inner layer 503 comprises a pervaporative matrix or laminated matrix, middle layer 504 comprises a thermally insulative material with pores or other open spaces to allow passage of the vapor, and outer layer 505 comprises a desiccant or absorbent material as defined in claim 1.

**[0027]** A preferred orientation of the matrix is where a higher liquid intrusion membrane faces the inside of the container and the porous matrix support is exposed to the air outside of the container. Thicknesses for these porous materials in a preferred embodiment are in the range from about 1/1000" (0.025 mm) to 1/4" (6.4 mm). The porous matrices can also provide structural rigidity, scratch resistance, and/or mechanical integrity to the walls of the container.

**[0028]** Preferably, a membrane or thin layer of material with a small pore size (<10 $\mu$m) can be selected from a group of highly hydrophobic materials such as expanded polytetrafluoroethylene (ePTFE) and laminated in between thicker highly porous supports such as sintered polyethylene, which allow for a substantial pervaporative flux. If only two layers are used, Each of these layers can vary in thickness from a monoatomic surface treatment to 1/4" (6.4 mm) in thickness or greater for a foam insulation or porous composite. Porous ceramic materials including molecular sieves (zeolites) or porous polymer films (CSP Technologies - Auburn, Alabama) and organic matrices such as activated carbon can be used to substantially prevent or reduce odors from the environment from contaminating the liquid contents of the pervaporative cooling device or container.

**[0029]** A preferred layered construct comprises five layers: an inner ePTFE layer, a porous polypropylene, a thermally insulative urethane foam layer, a ceramic such as zeolite and a thin nonporous polyolefin or polyester outer wrap. This device can be used to maintain a pervaporative cool within the device in a humid environment. Upon absorption of the vapor released from the liquid, the zeolite or other desiccant transfers the heat directly or indirectly into the environment while the insulated liquid contents within the pervaporative sleeve are cooled. In accordance with claim 1, the outer two layers comprising zeolite and a nonporous film are disposable or regenerable such as by drying in an oven.

**[0030]** Except for any surface treatments that may be applied directly to the porous matrices in the constructs, the porosities of the matrices or composite are preferably maintained between about 10 to 95%. This provides for structural support within the matrix and enhances the available pervaporative surface area and hence the overall cooling rate of the container. The pore size of the matrix can also have an effect with Knudsen diffusion predominating below a pore size of 200 nm, effectively decreasing the vapor permeation rate and extending the liquid to vapor transition and cooling zone to the air/vapor surface of the material. In accordance with one embodiment, preferred pore sizes include those between about 0.5 μm to 30 μm, which are larger than the Knudsen diffusion range. The liquid intrusion pressure decreases substantially above a 100 μm pore size, making the use of a single layer of macroporous material less desirable in some instances. If a combination of a membrane and a macroporous support are used, then larger pore sizes in the macroporous support become more desirable than in the absence of the combination.

**[0031]** As shown in Figures 3A, 3B, 3C, and 3D ribs 508 and 514 may be added to the inside and/or outside walls of the container to enhance the structural rigidity of the container, prevent or reduce damage to the pervaporative matrix 507 and 513 and/or provide a handhold 514. Figures 3C and 3F show a sports version of the ribbed design with a narrowed neck 512.

**[0032]** Figure 4 shows a layer of open cell porous insulator 518 which is added to the outside surface of the container to allow for relatively unimpeded vapor diffusion out of the system but reduced convective and radiative heat flow from the surrounding environment through to the inner container walls 517 and into the liquid. A beneficial feature of this insulator 518 is that it aides as an additional structural support, provides a hand grip on the container and to reduce or prevent damage to the matrix 517. As used herein, "pleated" includes rippled surfaces and other configurations for increasing surface area. Pleated matrices include those in which the entire surface is pleated, or in which one or more portions are pleated and others are left smooth.

**[0033]** Use of a pleated membrane or pleated porous sintered matrix 520, as shown in Figure 5, can enhance the pervaporative cooling of the container since the rate of pervaporative cooling is a direct function of the surface area of the container.

**[0034]** Pervaporative containers may comprise an adjustable or movable sleeve on the outside of the pervaporative matrix to allow for selective covering or uncovering of some or all of the pervaporative material. Covering some of the pervaporative material reduces the vapor flux rate is while still maintaining some pervaporative cool. Covering all substantially stops the pervaporation and can serve as a type of"on-off" switch for the container or garment.

**[0035]** For example, sleeves 524 and 525, as shown in Figures 6A and 6B can be provided as a means to reduce the exposed porous surface area 527 and overall evaporative cooling rate of the container and hence reduce the liquid vaporization rate and cooling rate allowing for greater control of the temperature of the container contents. Reduced cooling may be desired in some situations such as when the absolute pressure, relative humidity and/or ambient temperature are low. As shown in Figure 6B, there is preferably a separation or gap 530 between one or more portions between the container and the surrounding sleeve. The gap can serve as an insulating region and/or as a region of buoyant natural convective flow of vapor, allowing for the maintenance of pervaporative cooling and the minimization of radiative heat transfer to the liquid contents 529 of the container. The inner sleeve 524 on the outside of the porous matrix 523 of the container is preferably attached to the pervaporative matrix at least at the top 522 and bottom 526 portions of the container housing, especially if such portions are non-porous.

**[0036]** Some or all of a pervaporative container may comprise a pervaporative sponge which both holds water within the body of the sponge and also serves to provide cooling by pervaporation. One preferred embodiment is a two-layer pervaporative sponge having an inner sponge comprising a hydrophilic material and an outer hydrophobic layer attached thereto. In this configuration, the inner sponge can be soaked with water or another vaporizable liquid prior to use and the porous hydrophobic top layer substantially prevents or reduces the leakage of the pervaporative liquid at the outer surface of the pervaporative matrix. The liquid provides a heat transfer path through the wet matrix directly to the inner container wall surface.

**[0037]** Figure 7 illustrates a two-layer pervaporative sponge 533 that can be used on glasses, bottles and containers. This configuration allows the inner sponge layer 534 to be soaked with water or another vaporizable liquid and a porous hydrophobic top layer 535 substantially prevents or reduces the leakage of the liquid coolant at the outer surface of the pervaporative matrix 535. The liquid provides a heat transfer path through the wet matrix directly to the inner container wall surface 532.

**[0038]** Figure 8 shows an alternate configuration in which a cooling jacket 542 holding water or another pervaporative fluid 541 is filled through the port 543 and used to cool the contents of an enclosed container housing 539. The housing comprises one or more sections of pervaporative matrix 537 and optionally comprises one or more ribs 538 to enhance structural strength. The liquid contents 540 within the enclosed central housing 539 can thus be sealed, substantially preventing or reducing the loss of liquid volume or carbonation within this region. In addition, the pervaporative cooling efficiency of the container is not dependent on the nature of the enclosed liquid; it depends only on the volatility, heat of vaporization, ionic strength (tonicity) and solute content of the water or liquid 541 used to fill the surrounding housing. As shown in Figure 7 the cooling jacket may also be made of a detachable sleeve consisting of an outer hydrophobic pervaporative layer 535 and an inner porous liquid holding or absorbing layer 534.

**[0039]** Figure 10 illustrates a pervaporatively-cooled drinking cup similar in function to the pervaporative bottles shown in Figures 1 A, 1B, 2, 3 A and 3B. As soon as liquid is poured into the cup the porous matrix 555 allows the liquid to pervaporatively chill. The bottle housing and support ribs 556 provide structural support and insulation.

**[0040]** The following is brief look at the thermodynamic feasibility of such a construction. Assuming an average water vapor pervaporative flux through a porous matrix of 4*10-6 g*cm-2*s-1 at 75°F in still air from Table 1 and assuming the water vapor flux is doubled at 95°F gives 8*10-6 g*cm-2*s-1as the flux. If the enthalpy of vaporization at 95°F is 2400 J/g, then the energy dissipation per unit area of the matrix is 1.9*10-2 Watts*cm-2. In order to achieve a power dissipation of 25 Watts approximately 1500 cm2 or 1.5 ft2 of available matrix surface area needs to be used in the construction the hydration pack. Use of a pleated membrane or a pleated porous sintered matrix to enhance the pervaporative cooling power, since pervaporative cooling power is a direct function of the porous surface area of the jacket. In order to cool for 4 hours at this rate approximately 150 mL of water will be spent in the process. Thereby a little under 0.5 lbs. of water will be used in the process. It would seem reasonable that a water filled jacket like this may be made to weigh approximately 3 lbs or less.

## Methods of Manufacture

**[0041]** Several processes are available for the manufacture of pervaporative containers including, but not limited to, sintering sub-millimeter size plastic beads in a mold cavity to directly form the pervaporation wall; thermal or ultrasonic lamination or welding of one or more pieces of pervaporative matrix together or to a suitable frame; insert molding whereby one or more sheets or a cylinder of the porous matrix is inserted into the cavity of a mold and a thermoplastic polymer is injection molded directly around the insert(s) to form the desired composite having porous matrix portions; heat sealing; attaching components using adhesives; and/or stitching techniques may also be used to assemble all or part of a pervaporative garment or container.

**[0042]** Multilayered constructs containing two or more layers of porous material may be used to obtain a mechanical and physically superior matrix. For instance, combining a sintered macroporous matrix of polyethylene with a thin layer of expanded PTFE on the liquid side of a container increases the hydrophobicity and liquid breakthrough pressure of water from 5 psi to over 30 psi, yet the layered matrix still maintains a similar pervaporative flux to that obtained using porous polyethylene by itself.

**[0043]** Figure 1A shows the construction of a pervaporative container with a wall portion 501 comprising pervaporative matrix. The wall 501 is fixed to the top 500 and bottom 502 portions of the container by a process such as by insert molding, thermal or ultrasonic welding, adhesive joining, or other suitable means. Insert injection molding may also be used to attach the matrix to the other portions of the container. The top of the bottle 500 illustrated in this example allows for a threaded fit and can be used with a vented bottle cap. The top 500 and bottom 502 portions of the container may be made by any suitable method, including injection molding, vacuum forming, and the like.

**[0044]** Figures 3A and 3B show a ribbed configuration for a thin pervaporative matrix 507 for which additional structural support 508 is desired. The ribs 508 give the container wall both structural integrity and a ridged surface for a firmer hand grasp on the container. The ribs 508 can be placed on the outside, inside and/or one or more sides of the pervaporative matrix. The ribs 508 are preferably injection molded by insert molding onto the pervaporative matrix 507. Alternatively, ribs 508 can be sealed to a porous matrix 507 or porous matrix 507 can be sealed to a ribbed container shell 508 by ultrasonic, thermal or adhesive means, among others.

**[0045]** Figures 3C and 3D demonstrate a sports version of this container which allows the container to be fixed securely in a holding bracket by the bottle neck 512. The mouth of the bottle 511 allows for the use of various closures, including a snap lid and threaded closure.

**[0046]** Figure 4 shows a thermally insulating, hydrophobic open cell foam layer 518 that allows water vapor to move through the open cell structure, but impedes the convective and radiative heating of the container contents. Table 1 demonstrates that the thermally insulating matrix reduces the liquid loss rate while maintaining a substantial pervaporative cool. In a preferred embodiment, the insulating foam 518 is placed or taken off of the bottle as an elastic sleeve.

**[0047]** Increases in pervaporative cooling efficiency can be achieved by increasing the surface area of the matrix in contact with the liquid by pleating the matrix. Figure 5 shows a pleated container body 520 that allows for a greater pervaporative surface area to be exposed per contained liquid volume. This configuration allows for a decrease in the time taken to pervaporatively cool the container volume. A container having this configuration can be made by insert molding or by potting both ends with adhesive to a bottom 521 and top 519 container elements or with molten plastic.

**[0048]** Figures 6A and 6B demonstrate a rotating sleeve 525 on the outside of the matrix body 523. As the outer sleeve 525 rotates past the inner sleeve 524, a set of vertical slits 527 is formed, which open and close to allow variable exposure to the pervaporative matrix 523, thereby reducing the vapor flux rate but still maintaining an adequate pervaporative cool. A vertical slip sleeve, whose slits are adjusted vertically instead of by rotation, may also be used in a configuration of this type. The inner and outer sleeves 524 and 525 are made of a substantially nonporous material such as plastic or metal that does not allow water vapor to pass. Figure 6B illustrates the annular sleeve which helps to maintain a very thin gap 530 between the porous matrix 523 and the inner stationary sleeve 524. This gap 530 is useful as a shield to substantially prevent or reduce direct conductive and radiative heat transfer to the porous matrix 523 of the main container body. In addition, this spacing 530 allows for vapor flux out of this annular region 527. The sleeves 524 and 525 may also be used over a pleated pervaporative surface 520 such as shown in Figure 5. Again, the sleeves 524 and 525 can be placed on the outside of the container by sliding them onto the outside of the container. The inner sleeve 524 may be attached or sealed in place.

**[0049]** Figures 7 and 8 show jacketed pervaporative containers. As shown in Figure 7 the cooling jacket may be made of a detachable sleeve consisting of an outer hydrophobic pervaporative layer 535 and an inner porous liquid holding or absorbing layer 534. In the embodiment of Figure 8, the outside jacket 541 is filled through special ports 543 with water or other volatile fluids 541 and the contents of the inner liquid container 540 are maintained at a sub-ambient temperature. One advantage to this configuration lies in that a carbonated beverage can be stored in this container without losing carbonation. In addition, a liquid with a low propensity to pervaporate, such as a liquid high in electrolytes or sugar can be placed in the inner chamber 540 of the container while distilled water or other easily pervaporated liquid 541 is placed in the outside chamber to obtain an adequate temperature drop.

**[0050]** Another embodiment for a sponge 533 or jacketed 542 pervaporative configuration as shown in Figures 7 and 8 is for the use of an oleophobic pervaporative matrix which retains organic liquids such as alcohol. In such a configuration the outside jacket 533, 542 are be filled with ethanol, and serves as the pervaporative coolant 534, 541.

**[0051]** Figure 10 illustrates a pervaporatively-cooled drinking cup similar in function to Figures 1A, 1B, 2, 3A and 3B. Assembly may be performed wrapping a planar pervaporative matrix around or pushing the matrix 555 over the cup body 556 as a cylinder and attaching the material by adhesive, potting, thermal welding or ultrasonic welding. Insert molding may be used to directly attach the material into the bottle frame and walls.

## Operation of a Pervaporatively Cooled Device

**[0052]** Preferred designs for pervaporative cooling devices are simple and can be operated under ambient conditions to cool and/or maintain the coolness of fluid or solid contents of the container without the weight and portability limitations associated with mechanical pumping or the need for the application of an external mechanical vacuum to increase the pervaporative cooling rate. In a preferred embodiment, the radial dimensions of a container of the type in Figure 1A are large enough such that convective mixing by natural convection of liquid contents is obtained. This is because, in some cases, the thermal conductivity of the liquid alone may not be high enough to effectively maintain a generally uniform temperature distribution throughout the container. When the liquid at the inner walls of the container are cooled, this reduces the density of the liquid at the inner walls as compared to that in the center. Because of this density difference, the cooler liquid flows down the inside walls of the container to the bottom of the container where it is entrained back up into a circulatory pattern within the middle of the container in a process called natural convection, as opposed to forced convection. When the cooling rate is high enough, convective eddies break off from the side of the container and enhance the mixing rate.

**[0053]** These phenomena and their occurrence can be predicted using a combination of calculated dimensionless parameters, namely the Grashof Number (parameter for fluid buoyancy in a gravitational field) and the Prandlt Number (parameter that describes the thermal and capacitive nature of the liquid). The combination of these two parameters leads to the calculation of the Nusslet Number (an overall heat transfer parameter). Natural convection within a pervaporative container will enhance the cooling efficiency and the cooling rate of the device by allowing for convective heat transfer through the buoyant fluid in lieu of thermal conduction through the same liquid medium.

**[0054]** Table 1 presents endpoint pervaporative cooling data at a relative air humidity of 30% to 41% and different ambient air velocities and the effect of a porous insulative matrix. Tables 2 and 3 present endpoint water pervaporative cooling data at different relative humidities and in the shade (Table 2) or in the presence of direct solar irradiation (Table 3). The pervaporative materials are PTFE (polytetrafluoroethylene) or sintered UHMWPE (ultra high molecular weight polyethylene). X-7744, X-6919, and 402HP are all UHMWPE materials of various porosity, pore size and thickness as outlined in the tables.

Table 1

| **Matrix Material** | **Porosity** | **Pore size (um)** | **Thickness (mm)** | **Liquid Loss (%/hr** | **Flux (g cm$^2$/s) x10$^6$** | **Cool (°F)** | **Cool at 2 mph (°F)** | **Cool at 5 mph (°F)** |
|---|---|---|---|---|---|---|---|---|
| Control 1 (PE) | None | None | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

(continued)

| **Matrix Material** | **Porosity** | **Pore size (um)** | **Thickness (mm)** | **Liquid Loss (%/hr** | **Flux (g cm$^2$/s) x10$^6$** | **Cool (°F)** | **Cool at 2 mph (°F)** | **Cool at 5 mph (°F)** |
|---|---|---|---|---|---|---|---|---|
| Control 2 (PE) | None | None | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PVDF | 75% | 0.5 | 0.1 | 0.4-3.0 | 1.9-7.6 | 12.7 | 14.3 | 14.8 |
| UHMWPE | 35-50% | 7 | 0.6 | 0.3-1.0 | 1.2-6.6 | 10.6 | 12.6 | 13.0 |
| PVDF w/ foam insulation | 75% | 13.5 | 5.1 | 0.4-1.9 | 2.0-6.5 | 12.1 | 11.5 | 10.7 |
| UHMWPE w/foam insulation | 35-50% | 20 | 5.6 | 0.3-0.8 | 2.2-5.2 | 9.8 | 10.5 | 11.2 |

Table 2

| **Shade RH 38.6% / 75°F** | | | | | |
|---|---|---|---|---|---|
| **Matrix Material** | **Porosity** | **Pore Size (pm)** | **Thickness (mm)** | **Temperature (°F)** | **Pervaporative Cool (°F)** |
| **Control #1 (PE)** | None | None | 1.5 | 72.2 | - |
| **Control #2 (PE)** | None | None | 1.5 | 71.9 | - |
| **X-7744** | 35 to 50% | 7 | 0.6 | 63.6 | 8.4 |
| **X-6919** | 35 to 50% | <15 | 1.6 | 65.1 | 6.9 |
| **402HP** | 40 to 45% | 40 | 0.6 | 63.4 | 8.7 |
| **402HP** | 40 to 45% | 40 | 1.3 | 64.7 | 7.3 |
| **Supported PTFE** | 75% | >50 | 0.3 | 63.4 | 8.7 |

Table 3

| **Full Sun / RH 41.0% / 77°F (Shaded Sensor)** | | | | | |
|---|---|---|---|---|---|
| **Matrix Material** | **Porosity** | **Pore Size (μm)** | **Thickness (mm)** | **Temperature (°F)** | **Pervaporative Cool (°F)** |
| **Control #1 (PE)** | None | None | 1.5 | 93.6 | - |
| **Control #2 (PE)** | None | None | 1.5 | 93.3 | - |
| **X-7744** | 35 to 50% | 7 | 0.6 | 71.3 | 22.2 |
| **X-6919** | 35 to 50% | <15 | 1.6 | 73.1 | 20.4 |
| **402HP** | 40 to 45% | 40 | 0.6 | 73.1 | 20.4 |
| **402HP** | 40 to 45% | 40 | 1.3 | 73.7 | 19.7 |
| **Supported PTFE** | 75% | >50 | 0.3 | 73.1 | 20.4 |

**[0055]** Table 1 sets forth endpoint water pervaporative cooling data at different ambient air velocities and the effect of a 1/16 " open-cell porous urethane insulative matrix at a relative humidity of 30%. Tables 2 and 3 set forth endpoint water pervaporative cooling data at different relative humidities and in the dark or in the presence of direct solar irradiation. The pervaporative materials in all three tables are PTFE or sintered UHMWPE (ultra high molecular weight polyethylene).

**[0056]** Additional enhancements in cooling efficiency may be seen with the container as the outside relative humidity drops and if the container is placed in direct sunlight. The lower external humidity increases the vapor concentration gradient, and the externally applied heat raises the liquid temperature and vapor pressure, which lead to a rise in the pervaporative flux. Depending on ambient conditions, the geometry and materials selection of the container, this process can maintain a sub-ambient cool in the container of 22°F below ambient temperature. See Table 3. The time to attain this cooled temperature for a liquid volume of 700 ml is around 2 hours as demonstrated in Figure 9 for a variety of pervaporative matrices and combinations thereof.

**[0057]** One preferred embodiment of evaporative cooling container includes a single or combined porous matrix having a pervaporative layer thickness of about 0.025 mm (0.001 in.) to 10 mm (0.394 in.). Additionally, to increase the efficiency of the pervaporative process, the matrix preferably has qualities such that it is minimally thermally conducting. It is preferable that the matrix does not substantially impede vapor diffusion, such that, in one embodiment, a pore size above about 100 nm is preferred. Preferred surface porosities of the matrix are between about 15 and 90% including about 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, and 85%. A porous matrix with a low thermal conductivity, such as a porous perfluorinated Styrofoam, an expanded porous matrix, or an open cell porous matrix made from hollow fused particles, can help to substantially prevent or reduce undue heat transfer from the surroundings into the container.

**[0058]** The various methods and techniques described above provide some of the numerous ways to carry out the invention. Of course, it is to be understood that not necessarily all objectives or advantages described may be achieved in accordance with any particular embodiment described herein or with any other single embodiment. Thus, for example, those skilled in the art will recognize that the methods may be performed and/or the articles made in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other objectives or advantages as may be taught or suggested herein.

**[0059]** Furthermore, the skilled artisan will recognize the interchangeability of various features from different embodiments. Similarly, the various features and steps discussed above, as well as other known equivalents for each such feature or step, can be mixed and matched by one of ordinary skill in this art to perform methods in accordance with principles described herein.

**[0060]** The invention is defined by the claim

## Claims

1. A pervaporatively cooled container, comprising:

   a container body comprising one or more walls; wherein at least a portion of said one or more walls comprises a pervaporative matrix (503), said matrix comprising a porous hydrophobic material, wherein said matrix allows for the passage of small quantities of molecules of a volatile liquid vapor through the matrix, the evaporation of which cools the container, and
   an outer layer (505) directly adjacent to at least a portion of the container body, being **characterised in that** said layer comprises a desiccant or an absorbent material that absorbs moisture or other fluid resulting from pervaporation whereby the said outer layer (505) is disposable or separately regenerable such as by drying in on oven

2. A pervaporatively cooled container according to Claim 1, wherein the matrix further comprises a thin hydrophobic or oleophobic porous material laminated to or deposited on the porous hydrophobic material.

3. A pervaporatively cooled container according to Claim 2, wherein the matrix is oriented on the container body such that the layer of porous hydrophobic material faces the interior of the container.

4. A pervaporatively cooled container according to Claim 1, wherein at least 10% of the surface of the one or more walls comprise said matrix.

5. A pervaporatively cooled container according to Claim 1, further comprising a base (502) attached to said one or more walls.

6. A pervaporatively cooled container according to Claim 1, wherein the matrix comprises an inner layer comprising

a highly hydrophobic porous material placed between two outer layers of porous hydrophobic material.

**7.** A pervaporatively cooled container according to Claim 6, wherein the inner layer has a pore size and thickness less than that of the outer layers.

**8.** A pervaporatively cooled container according to Claim 6, wherein the inner layer comprises PTFE and the outer layer comprises polyethylene.

**9.** A pervaporatively cooled container according to Claim 1, wherein the container further comprises a plurality of support ribs (508,514).

**10.** A pervaporatively cooled container according to claim 1, wherein the matrix (503) is comprised of hollow or expanded particles which are fused or adhered together to reduce the thermal conductivity of the matrix and the loss of pervaporative cooling efficiency.

**11.** A pervaporatively cooled container according to Claim 1, further comprising an insulating sleeve (518) surrounding at least a portion of the one or more walls.

**12.** A pervaporatively cooled container according to Claim 11, wherein the insulating sleeve (518) comprises a porous material.

**13.** A pervaporatively cooled container according to Claim 11, wherein the insulating sleeve (518) is generally tubular and has one or more openings in the wall thereof, whereby the sleeve may be rotated about the container to selectively cover or expose portions of said pervaporative matrix.

## Patentansprüche

**1.** Durch Pervaporation gekühlter Behälter, umfassend:

einen Behälterkörper mit einer Wand oder mehreren Wänden, wobei mindestens ein Teil der einen Wand oder der mehreren Wände eine Pervaporationsmatrix (503) aufweist, wobei die Matrix poröses hydrophobes Material umfasst, wobei die Matrix den Durchgang von geringen Mengen von Molekülen von Dampf einer flüchtigen Flüssigkeit durch die Matrix erlaubt, deren Verdampfung den Behälter kühlt, und
eine Aussenschicht (505) direkt neben mindestens einem Teil des Behälterkörpers, **dadurch gekennzeichnet, dass** die Schicht ein Trockenmittel- oder absorbierendes Material aufweist, das Feuchtigkeit oder anderes Fluid absorbiert, das aus der Pervaporation resultiert, wobei die Aussenschicht (505) zum Wegwerfen oder separat wiederverwendbar, beispielsweise durch Trocknen in einem Ofen, ist.

**2.** Durch Pervaporation gekühlter Behälter nach Anspruch 1, wobei die Matrix ferner ein dünnes hydrophobes oder oleophobes poröses Material umfasst, das auf das poröse hydrophobe Material laminiert oder auf dem porösen hydrophoben Material abgeschieden ist.

**3.** Durch Pervaporation gekühlter Behälter nach Anspruch 2, wobei die Matrix auf dem Behälterkörper so angeordnet ist, dass die Schicht von porösem hydrophoben Material dem Inneren des Behälters gegenübersteht.

**4.** Durch Pervaporation gekühlter Behälter nach Anspruch 1, wobei mindestens 10% der Oberfläche der einen Wand oder der mehreren Wände die Matrix aufweisen.

**5.** Durch Pervaporation gekühlter Behälter nach Anspruch 1, der ferner eine Basis (502) aufweist, die an der einen Wand oder den mehreren Wänden angebracht ist.

**6.** Durch Pervaporation gekühlter Behälter nach Anspruch 1, wobei die Matrix eine Innenschicht umfasst, die ein hoch hydrophobes poröses Material umfasst, dass zwischen zwei Aussenschichten von porösem hydrophoben Material plaziert ist.

**7.** Durch Pervaporation gekühlter Behälter nach Anspruch 6, wobei die Innenschicht eine Porengröße und -dicke kleiner als die der Aussenschichten hat.

**8.** Durch Pervaporation gekühlter Behälter nach Anspruch 6, wobei die Innenschicht PTFE umfasst und die Aussenschicht Polyethylen umfasst.

**9.** Durch Pervaporation gekühlter Behälter nach Anspruch 1, wobei der Behälter ferner eine Mehrzahl von Trägerlamellen (508, 514) umfasst.

**10.** Durch Pervaporation gekühlter Behälter nach Anspruch 1, wobei die Matrix (503) aus hohlen oder expandierten Teilchen zusammengesetzt ist, die miteinander verschmolzen oder verklebt sind, um die Wärmeleitfähigkeit der Matrix und den Verlust von Pervaporationskühlungswirksamkeit zu vermindern.

**11.** Durch Pervaporation gekühlter Behälter nach Anspruch 1, der ferner einen Isolierärmel (518) umfasst, der mindestens einen Teil der einen Wand oder der mehreren Wände umgibt.

**12.** Durch Pervaporation gekühlter Behälter nach Anspruch 11, wobei der Isolierärmel (518) ein poröses Material umfasst.

**13.** Durch Pervaporation gekühlter Behälter nach Anspruch 11, wobei der Isolierärmel (518) im Allgemeinen röhrenförmig ist und ein oder mehrere Öffnungen in seiner Wand hat, wodurch der Ärmel um den Behälter gedreht werden kann, um Bereiche der Pervaporationsmatrix selektiv zu bedecken oder freizulegen.

## Revendications

**1.** Un réceptacle refroidi par pervaporation, comprenant:

un réceptacle comprenant une ou plusieurs parois ; dans lequel au moins une partie de ladite ou de lesdites parois comprend une matrice pervaporative (503), ladite matrice comprenant une matière poreuse hydrophobe, dans laquelle ladite matrice permet le passage de petites quantités de molécules d'une vapeur liquide volatile dans la matrice, dont l'évaporation refroidit le réceptacle et
une couche externe (505) directement adjacente à au moins une partie du réceptacle, étant **caractérisée en ce que** ladite couche comprend une matière déshydratante ou absorbante, absorbant la moisissure ou autre substance résultant de la pervaporation, et ladite couche externe étant jetable ou séparément régénérable telle que par séchage dans un four.

**2.** Un réceptacle refroidi par pervaporation selon la revendication 1, dans lequel la matrice comprend en outre une fine matière poreuse hydrophobe ou oléophobe laminée ou déposée sur la matière hydrophobe poreuse.

**3.** Un réceptacle refroidi par pervaporation selon la revendication 2, dans lequel la matrice est orientée vers le réceptacle de telle manière que la couche de matière hydrophobe poreuse donne sur l'intérieur du réceptacle.

**4.** Un réceptacle refroidi par pervaporation selon la revendication 1, dans lequel au moins 10 % de la surface de l'une ou de plusieurs parois comprend ladite matrice.

**5.** Un réceptacle refroidi par pervaporation selon la revendication 1, comprenant en outre une base (502) fixée à ladite ou lesdites parois.

**6.** Un réceptacle refroidi par pervaporation selon la revendication 1, dans lequel la matrice comprend une couche interne comprenant une matière poreuse hydrophobe élevée placée entre deux couches externes de matière poreuse hydrophobe.

**7.** Un réceptacle refroidi par pervaporation selon la revendication 6, dans lequel la couche interne a une taille de pore et une épaisseur moins importante que celle des couches externes.

**8.** Un réceptacle refroidi par pervaporation selon la revendication 6, dans lequel la couche interne comprend un PTFE et la couche externe comprend du polyéthylène.

**9.** Un réceptacle refroidi par pervaporation selon la revendication 1, dans lequel le réceptacle comprend en outre une pluralité de rainures de support (508, 514).

**10.** Un réceptacle refroidi par pervaporation selon la revendication 1, dans lequel la matrice (503) est constituée d'un creux ou de particules élargies qui sont fusionnées ou collées ensemble pour réduire la conductibilité thermique de la matrice et la perte de l'efficacité du refroidissement pervaporatif.

**11.** Un réceptacle refroidi par pervaporation selon la revendication 1, comprenant en outre un manchon isolant (518) encerclant au moins une partie de l'une ou de plusieurs parois.

**12.** Un réceptacle refroidi par pervaporation selon la revendication 11, dans lequel le manchon isolant (518) comprend une matière poreuse.

**13.** Un réceptacle refroidi par pervaporation selon la revendication 11, dans lequel le manchon isolant (518) est généralement tubulaire et a une ou plusieurs ouverture(s) dans la paroi, par lequel le manchon peut être tourné vers le container pour sélectivement couvrir ou exposer des parties de ladite matrice pervaporative.

FIG. 1A

FIG. 1B

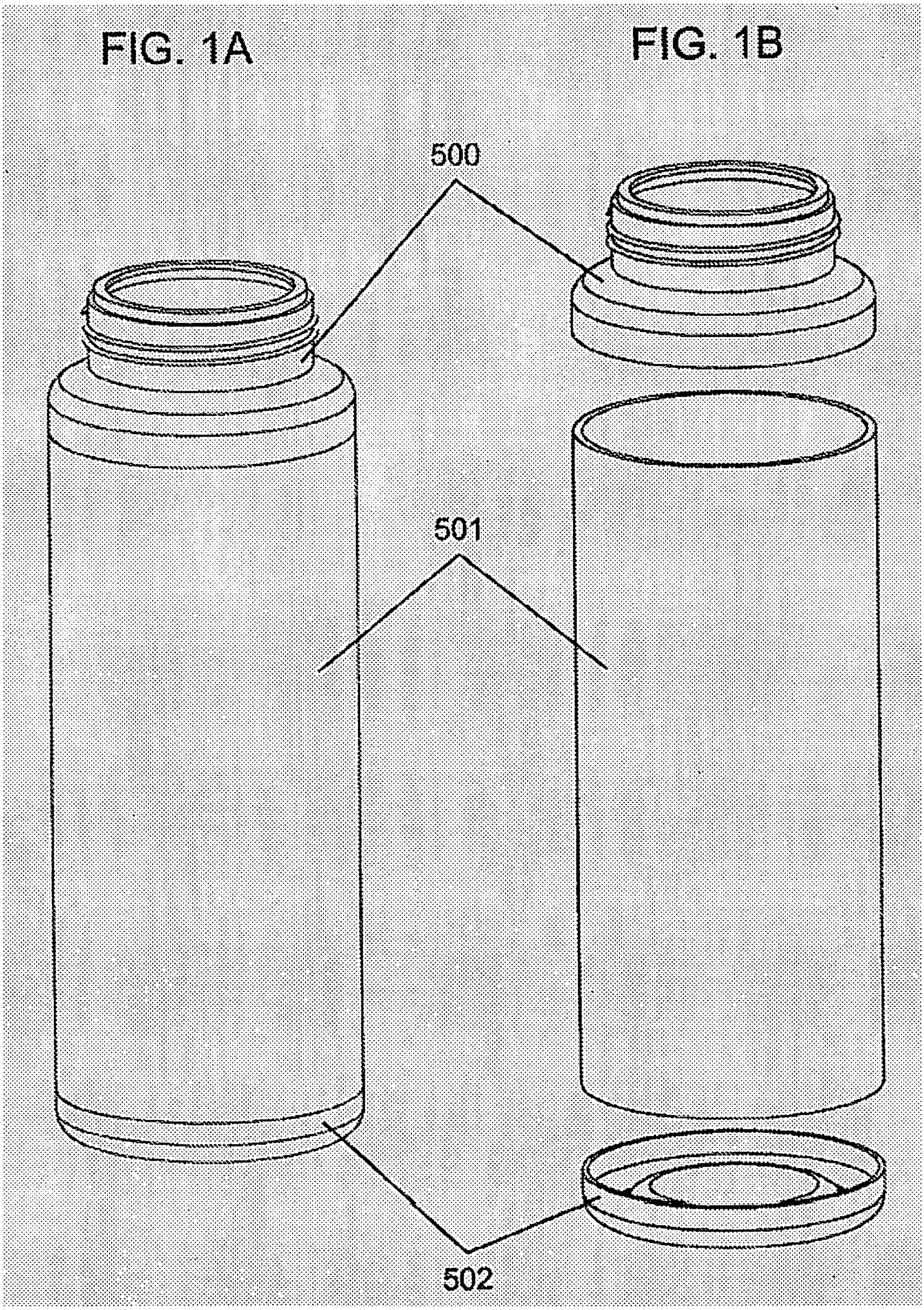


FIG. 2

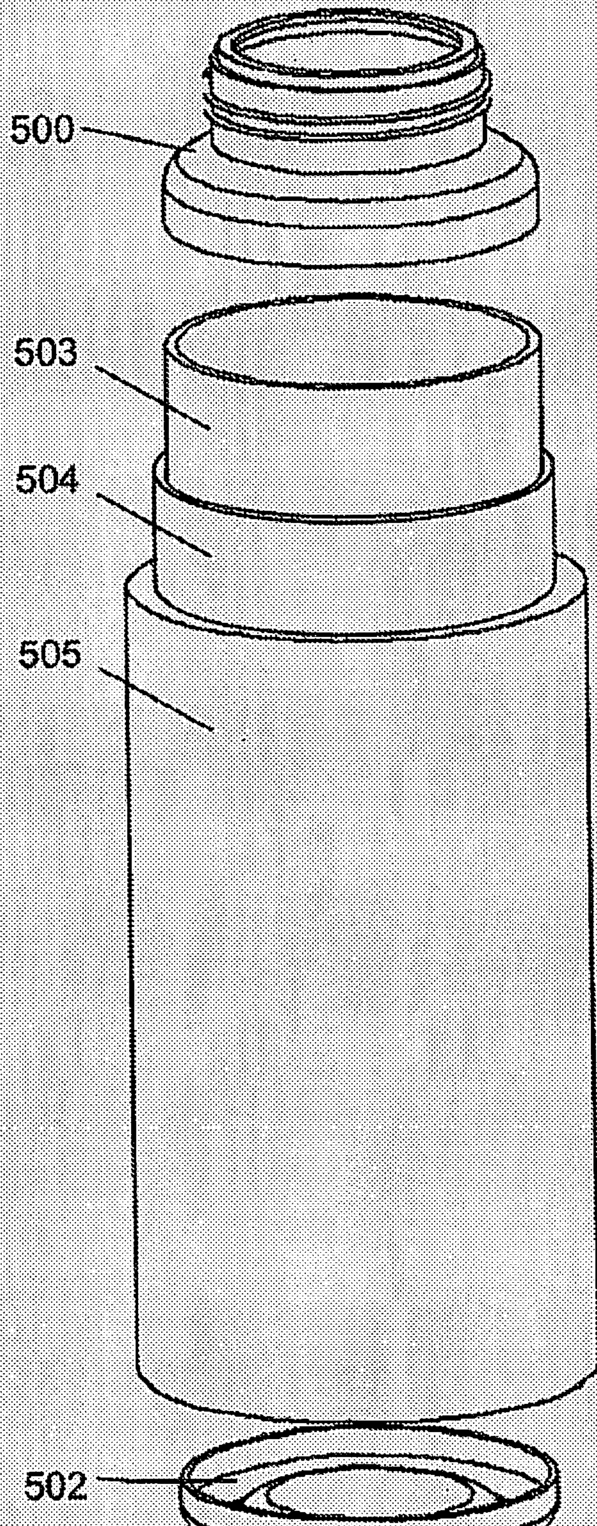


FIG. 3A

FIG. 3B

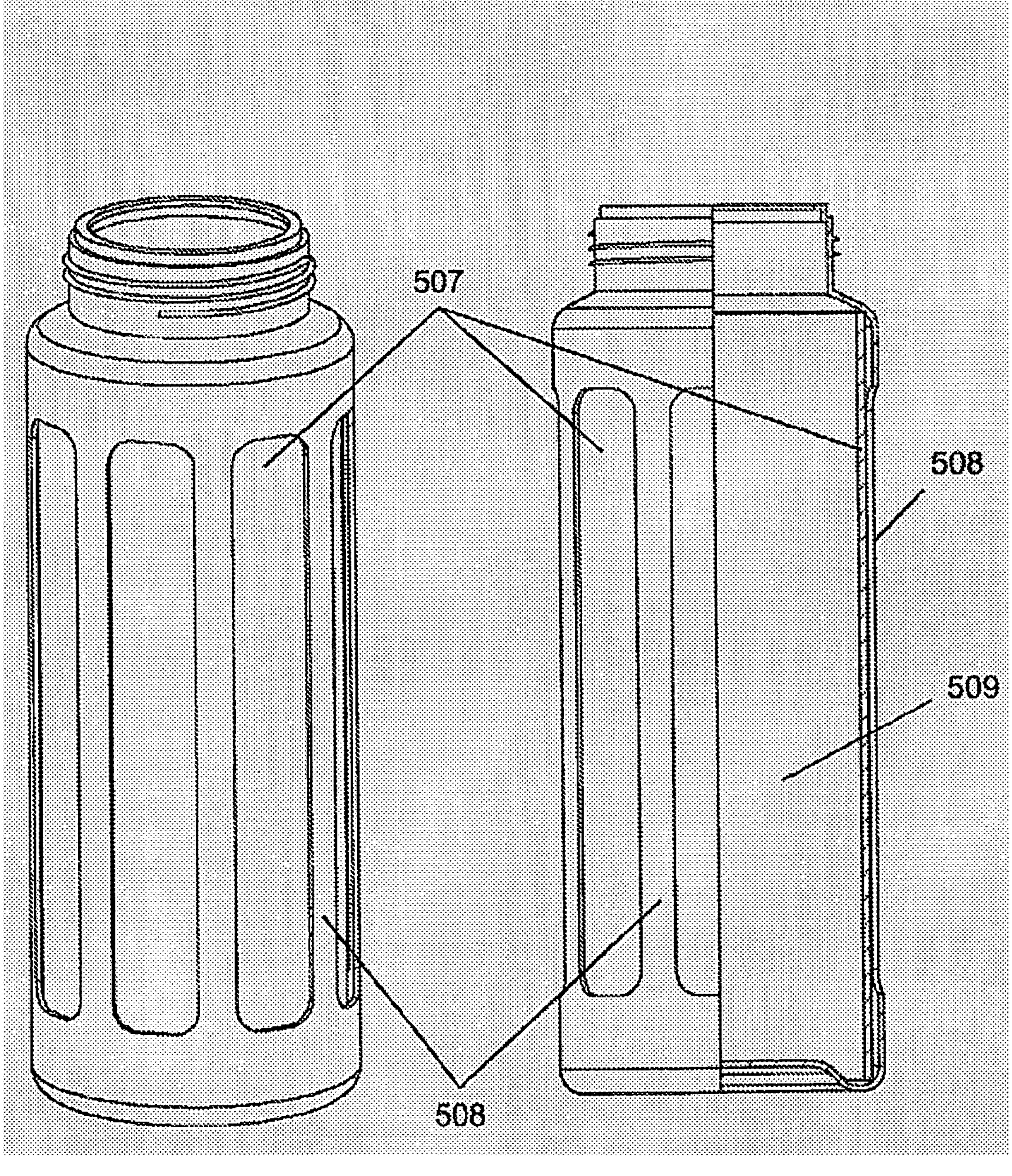


FIG. 3C

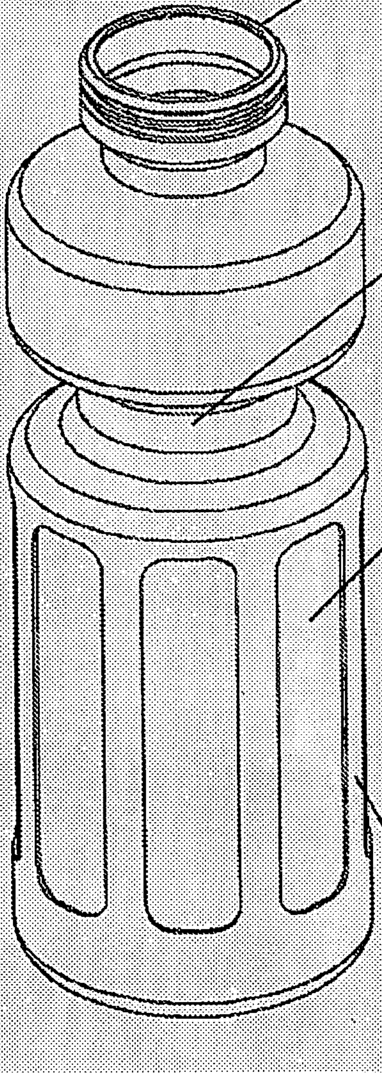


FIG. 3D

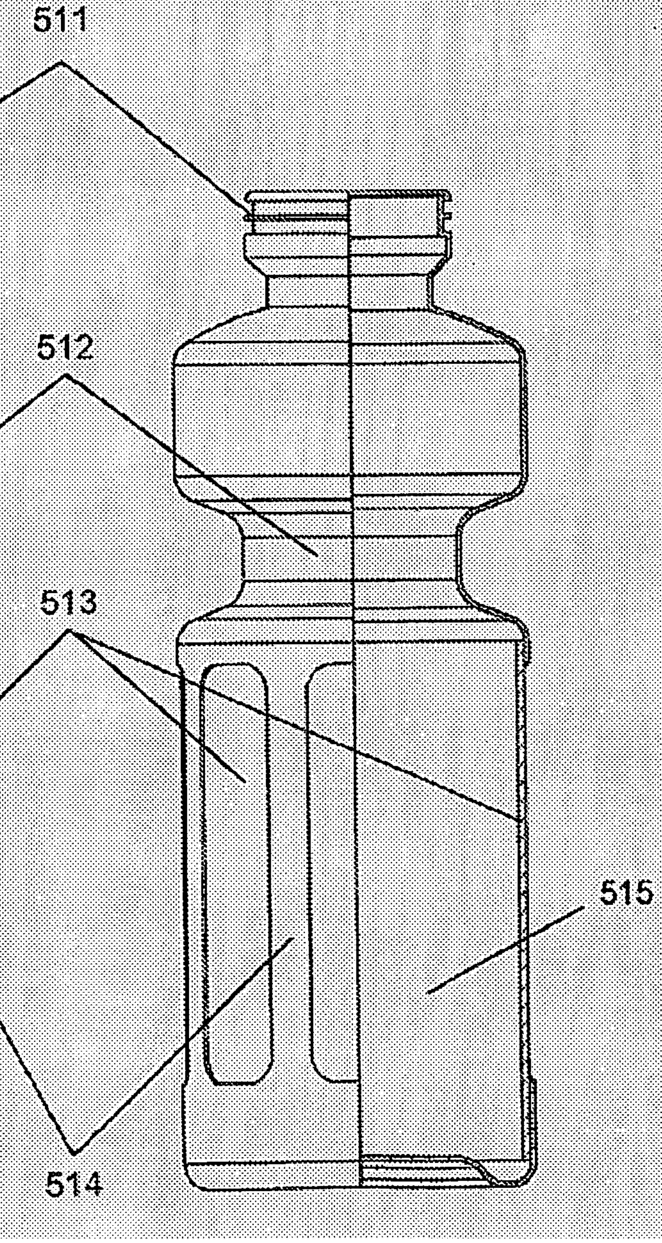


FIG. 4

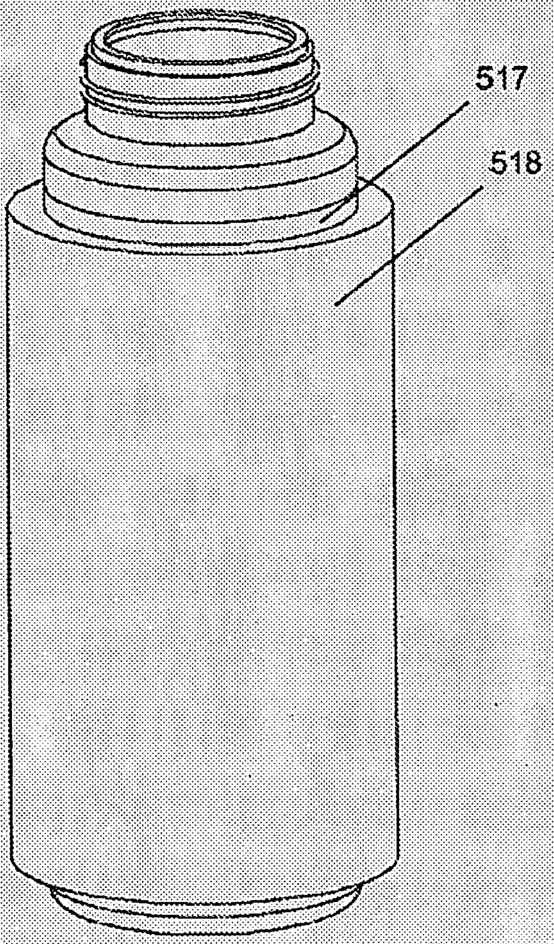


FIG. 5

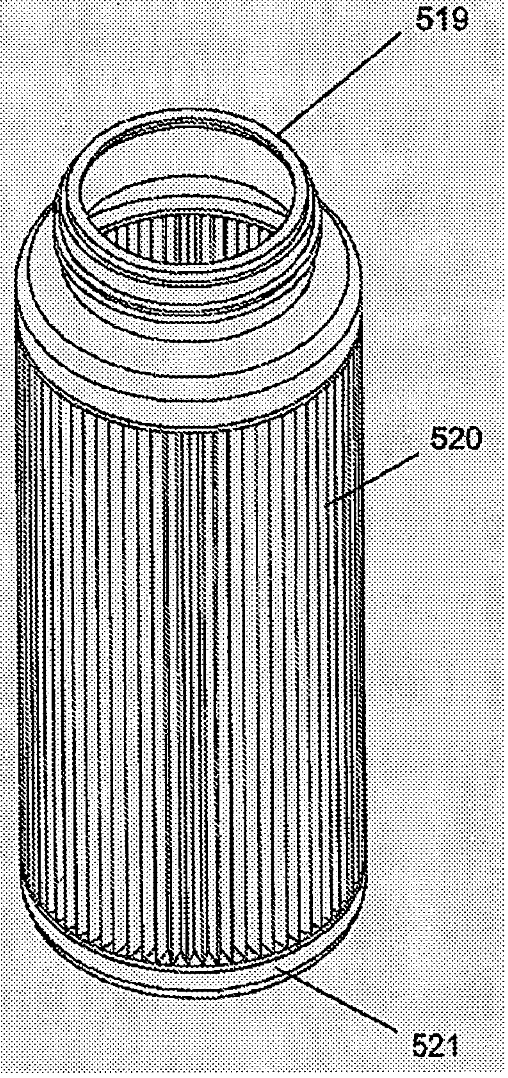


FIG. 6A

FIG. 6B

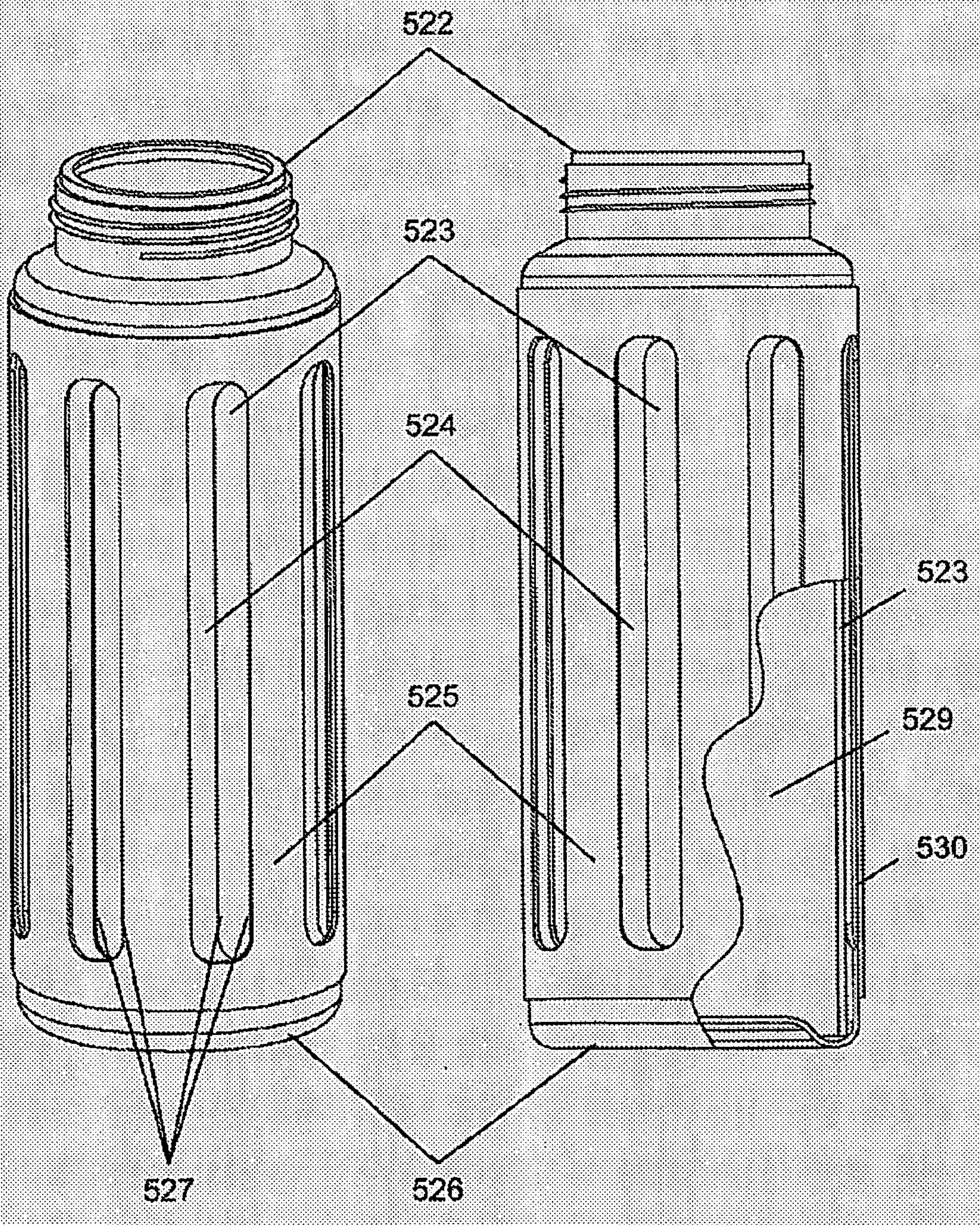


FIG. 7

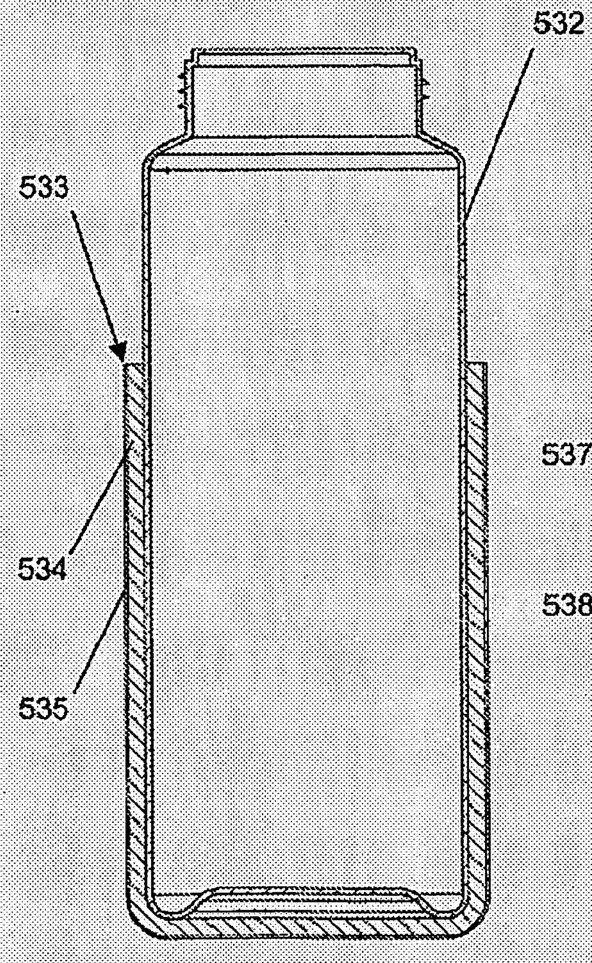


FIG. 8

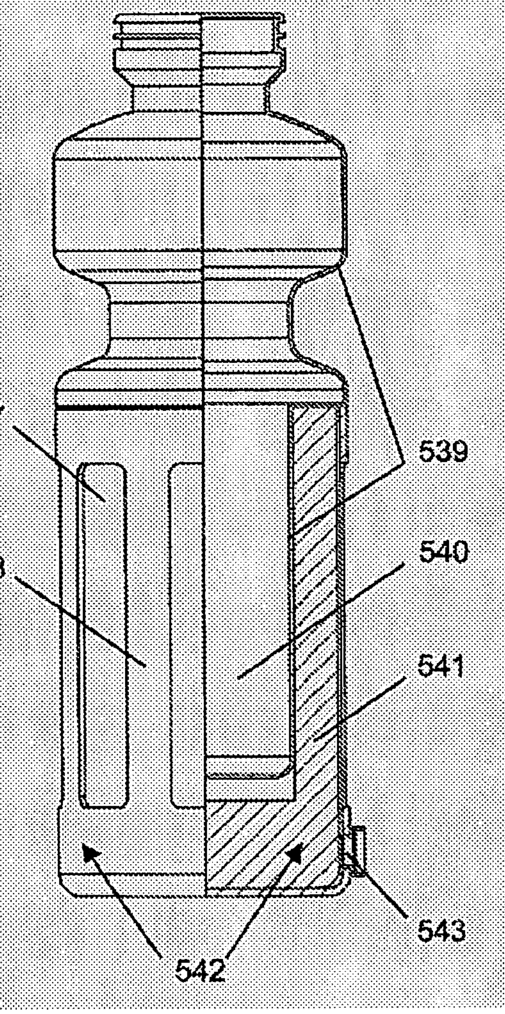


FIG. 9

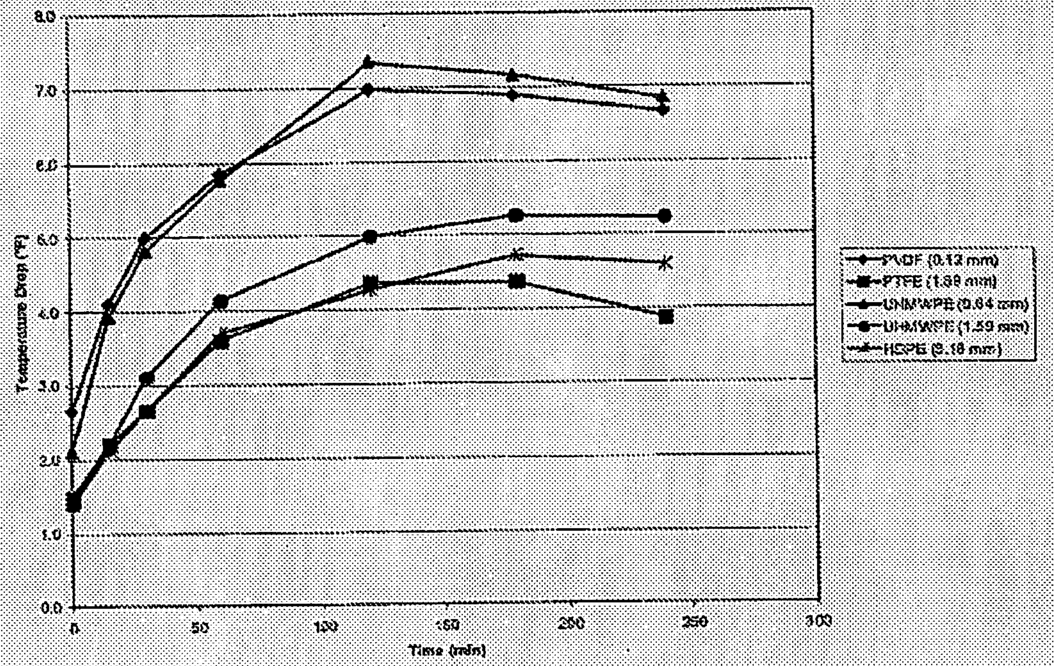
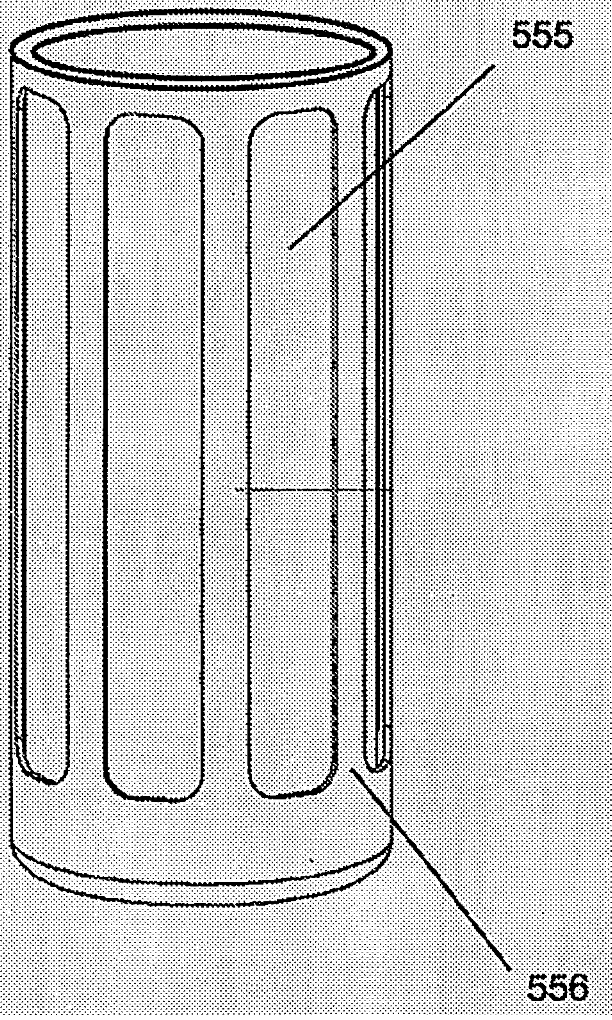

8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Temperature Drop (°F)
0
50
100
150
200
250
300
Time (min)
PVDF (0.13 mm)
PTFE (1.59 mm)
UHMWPE (0.64 mm)
UHMWPE (1.59 mm)
HSPE (3.18 mm)

FIG. 10



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