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PERSONAL COOLING UNIT USING PHASE CHANGE MATERIAL

TECHNICAL FIELD

The present invention relates to personal cooling devices.

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BACKGROUND

In indoor spaces of office buildings and the like, it is usual to seek to improve the comfort of persons within the building by the use of air-conditioning apparatus. The air-conditioning system is installed within the walls of the building and ducts are provided to
10 release cooled or heated air at particular locations, usually the rooms or offices of the building. It is difficult to control, with any precision, the temperature of the air in an individual office using such systems.

Personalised heating or cooling units which could partially address the individual needs of
15 persons within the building are known. For example, it is known to provide small electric fans which can provide a localised cooling effect due to wind chill (convective heat loss). However, in hot and humid environments, to supply sufficient cooling for thermal comfort, the fan may need to be operated at speeds such that excessive draft is induced.

20 An alternative type of personalised heating or cooling device is described in US patent 6,481,213. The apparatus therein described incorporates an inlet fan which draws air towards a heat exchanger. The heat exchanger is in thermal contact with and is cooled by a heat pump in the form of a thermoelectric device. The heat removed from the air by the heat pump is delivered to a thermal store heat exchanger to be absorbed by a thermal mass
25 in the form of ice. Rather than reject the heat from the input air, and waste heat from the heat pumping process, to the surrounding local environment, the heat is at least partially stored in the thermal mass as latent heat due to melting of the ice.

Whilst overcoming some of the disadvantages of the prior art, the device described in US
30 6,481,213 has several disadvantages of its own:

- Prior to use, the device must be "re-charged" by freezing the ice, and this may

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require the use of a timer such that the re-charging process is commenced sufficiently early relative to the time of intended use. The device therefore may not be suitable in situations where the demand is difficult to predict beforehand.

- If a number of devices in, for example, an office space is set to charge at the end of a working day, this would result in simultaneous rejection of heat into the space from the devices, possibly causing discomfort to anyone remaining in the office at the scheduled charge time.
- The ice must be insulated, for example by polystyrene which consumes space, or by a high R-value material such as polyurethane/silicone which adds substantial cost.

There is a need to provide a personal cooling device which alleviates one or more of the above disadvantages, or at least provides a useful alternative.

15 SUMMARY OF THE INVENTION

The present invention provides, in a first aspect, a personal cooling unit, comprising:

an air inlet for receiving input air;

at least one heat pump having a first surface and a second surface, and being configured to extract heat from the input air at the first surface to generate cooled output air and to transport heat to the second surface;

a phase change material in thermal contact with the second surface of the heat pump; and

means for conveying the cooled output air to the exterior of the unit;

wherein the phase change material undergoes a temperature-driven phase change from a first phase to a second phase, so that when at least a portion of the phase change material is in the first phase, the phase change material absorbs heat from the second surface until all of the phase change material has changed to the second phase; and

wherein the phase change material has a phase transition temperature which is at least about 28°C.

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The present invention also provides an air-conditioning method, comprising steps of:

determining an expected ambient air temperature range for a specified location over a specified time period;

selecting, on the basis of the expected ambient air temperature range, a phase change
5 material having a phase transition temperature which is higher than a maximum of the expected ambient air temperature range; and

providing a personal cooling unit comprising:

an air inlet for receiving input air;

at least one heat pump having a first surface and a second surface, the second
10 surface being in thermal contact with the phase change material, the heat pump being configured to extract heat from the input air at the first surface to generate cooled output air and to transport heat to the second surface; and

means for conveying the cooled output air to the exterior of the unit;

wherein the phase change material undergoes a temperature-driven phase change from
15 a first phase to a second phase, so that when at least a portion of the phase change material is in the first phase, the phase change material absorbs heat from the second surface until all of the phase change material has changed to the second phase.

The present applicant has surprisingly found that phase change materials with a relatively
20 high (greater than 28°C) transition temperature, as opposed to the low transition temperatures of the prior art, are particularly effective in providing cooling of localised spaces such as those around persons in an office or home environment. By using a phase change material with a phase transition temperature (for example, melting temperature) above an expected ambient air temperature, it is possible to provide a cooling unit which
25 automatically recharges when not in use. That is, the phase change material begins passively undergoing the reverse phase change from the second phase to the first phase once the heat pump is switched off and the phase change material is exposed to ambient air at a temperature below its transition temperature. The need for a timing mechanism, and for pre-charging the unit, is thereby obviated.

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In certain embodiments, the phase change material is selected on the basis of an expected

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ambient air temperature range for a predetermined location over a predetermined time period, the phase change material having a phase transition temperature which is higher than a maximum of the expected ambient air temperature range.

- 5 Phase change materials having a transition temperature around 28°C or more may be particularly suitable when the unit is to be used as supplementary cooling in a space which is already air-conditioned, for example, while materials with even higher transition temperatures (above 40°C or more, for example) may be useful when the unit is to be the primary source of localised cooling.

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The heat pump may be a thermoelectric device, for example a Peltier module. In other embodiments, the heat pump may be a device which transports heat by means of thermotunnelling or the electro-calorific effect.

- 15 In certain embodiments, a suitable phase change material comprises a paraffin wax and has a melting point temperature of about 40°C. However, other phase change materials having a melting temperature greater than 40°C may be used. In other embodiments, the phase change material may comprise a paraffin wax having a melting point temperature of greater than about 28°C. Paraffin waxes are preferred due to their ease of containment,
20 non-toxicity and non-causticity.

In certain embodiments, the unit includes a filtering system for at least partially removing moisture and/or contaminants from the input air. The filtering system may be located adjacent the air inlet, for example. The filtering system may include one or more of a
25 dehumidification component, a particulate matter filtration component, or a gas filtration component. The filtering system may be partly or fully removable. For example, individual components of the filtering system may be individually removable, and may be user-maintainable.

- 30 The unit may include an air sanitisation system for at least partially removing or killing microbial contaminants. The air sanitisation system may be in fluid communication with

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the air inlet and/or an air outlet of the unit. For example, the air sanitisation system may include one or more of: a UV-C light source; a photocatalytic component, such as a photocatalytic coating which may be applied to internal surfaces of the unit; or a negative ion generator.

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In one embodiment, the vessel containing the phase change material at least partly surrounds the or each heat pump. The or each heat pump may be concentric with the vessel.

- 10 In some embodiments, the unit further includes a heat exchanger in thermal contact with the first surface of the or each heat pump. The heat exchanger may comprise a plurality of planar members, which may form, for example, a honeycomb structure.

- 15 The vessel preferably comprises at least one heat sink in thermal contact with the second surface of the or each heat pump. The or each heat sink may comprise a plurality of fins.

- 20 If the unit includes a heat exchanger as described above, the heat exchanger may be polygonal in cross-section, for example having rectangular or hexagonal cross-section, with each side of the heat exchanger being in thermal contact with a first surface of one of the heat pumps.

The unit, in some embodiments, further comprises means for adjusting the voltage across the or each heat pump.

25 **BRIEF DESCRIPTION OF THE DRAWINGS**

Some embodiments of the invention will now be described, by way of non-limiting example only, with reference to the accompanying figures in which:

- 30 Figure 1 is a schematic block diagram of a personal cooling unit according to an embodiment of the invention;

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Figure 2 shows an exploded and partially cut-away view of a personal cooling unit according to another embodiment of the invention;

Figure 3 is a front perspective view of an alternative embodiment of a personal cooling
5 unit;

Figure 4 is a rear perspective view of the personal cooling unit of Figure 3;

Figure 5 is a perspective view of a phase change material-containing vessel for use with
10 the cooling unit of Figures 3 and 4;

Figure 6 is a schematic sectional view of the phase change material-containing vessel of Figure 5; and

15 Figure 7 shows a further alternative embodiment of a personal cooling unit.

DETAILED DESCRIPTION

Referring initially to Figure 1, there is shown in schematic form a personal cooling unit 10 having a housing 12 which houses components including a filtering system 30, a heat
20 exchanger 40, a heat pump 50, vessel containing phase change material 60, an air sanitisation system 75, and fan 15. Defined within the housing 12 is a channel 35 delimited by inlet 20 and outlet 80 for flow and cooling of air therebetween in a manner which will be described below.

25 The unit 10 accepts input air 90 at ambient temperature at inlet 20. The input air passes through a filtering system 30, which in a presently preferred embodiment is located adjacent the inlet 20 and in fluid communication therewith. Other locations of the filtering system 30 are possible. The filtering system 30, depending on its particular configuration, may perform a number of functions including, without limitation, dehumidification,
30 particulate matter filtration, or gas filtration.

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For example, the filtering system 30 may dehumidify input air using a dehumidification component which comprises at least one desiccant bed or desiccant impregnated honeycomb structure of any suitable type known in the art. The dehumidification component may be removable by a user of the unit 10, and able to be regenerated by heating in a microwave oven to expel the absorbed moisture, for example.

Alternatively, or in addition, the filtering system may comprise a particulate matter filtration component. The particulate matter filtration component may comprise a single stage (MERV 13) air filter; a double stage air filter (MERV 8 pre-filter and MERV 13 final filter); or an electrostatic filtration module.

As a further alternative, the filtering system 30 may comprise a gas filtration component, such as a molecular sieve or activated carbon honeycomb structure, for removing volatile organic compounds (VOCs) and odour-causing gases.

The filtering system 30 may be partly or fully removable. For example, individual components (as mentioned above) of the filtering system may be individually removable, and may be user-maintainable.

The filtered input air flows along channel 35 in the direction indicated by the arrows. The channel 35 is in thermal contact with heat exchanger 40. Heat exchanger 40 is in thermal contact with a first surface of heat pump 50, and a second surface of heat pump 50 is in turn in thermal contact with the phase change material 60. Phase change material 60 has a melting temperature which is higher than the ambient air temperature. As input air flows along the channel 35, heat is drawn therefrom by heat exchanger 40 / heat pump 50 and into phase change material 60. The cooled air is drawn by the action of fan 15 through an air sanitisation system 75 to the outlet 80 such that cooled, sanitised output air 95 exits the unit 10. Exemplary configurations of heat exchanger 40 and heat pump 50 for achieving the cooling action will be described below.

The air sanitisation system 75 serves to at least partially remove or kill any microbial

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contaminants which may be present in input air 90, and may take a number of forms. For example, the air sanitisation system may include one or more of: a UV-C light source for irradiating bacteria and viruses; a photocatalytic component, such as a photocatalytic coating which may be applied to internal surfaces of the unit, for example an internal surface of channel 35; or a negative ion generator. Although shown adjacent the outlet 80 of the unit 10, it will be appreciated that the sanitisation system 75 may instead be located near inlet 20, or may extend along the channel 35. For example, a series of UV-C light sources may be placed along channel 35, and/or a titanium dioxide or other photocatalytic coating may be applied along the length of the channel 35.

It will be appreciated that, while depicted as substantially linear in Figure 1, the channel 35 may take any number of forms, and may follow a path which is curved or serpentine in at least some portions, for example.

Turning now to Figure 2, there is shown a personal cooling unit, generally indicated by 100, comprising a vessel 110 containing a phase change material that has a melting temperature above the ambient air temperature. The phase change material used in the presently described embodiments is a paraffin wax, although it will be appreciated that in other embodiments, different phase change materials may be used.

The vessel 110 is concentric with a heat exchanger in the form of a honeycomb structure 102, and is also concentric with thermoelectric heat pumps (Peltier modules) 104. The Peltier modules each have a first surface 105 which is in thermal contact with the heat exchanger 102, and a second surface 106 which is in thermal contact with one of the heat sinks 112. The heat sinks 112 include a plurality of extrusions in the form of fins, and are immersed in, and therefore in thermal contact with, the phase change material in the vessel 110.

The heat exchanger 102 particularly shown in Figure 1 is of substantially rectangular cross-section, and is in thermal contact with one of four Peltier modules 104 at each of its faces. It will also be appreciated by the skilled person that other cross-sectional shapes for

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the heat exchanger 102 may be chosen. For example, the heat exchanger 102 could have a hexagonal cross-section, in which case six Peltier modules could be employed, one for each side of the hexagon.

- 5 The cooling unit 100 includes means for conveying cooled output air to its exterior, in the form of a fan 115. After input air is received at ambient temperature at an air inlet (not shown) and cooled on passage through heat exchanger 102, fan 115 moves the cooled output air towards controller/vent 120 where it is dispersed through diffuser 130.
- 10 The operation of the cooling unit is controlled by the controller/vent unit 120. Controller 120 may have a number of functions including powering the unit on and off, adjusting the speed of fan 115 (via fan speed knob 122), and adjusting the voltage across Peltier modules 104, and hence the amount of heat drawn from the input air (via voltage knob 124). Power to the cooling unit will generally be supplied by mains power, but in some
- 15 circumstances could be supplied by a generator or battery. If mains power is used, then a regulated power supply including a rectifier may be used in order to supply an adjustable DC voltage to the Peltier modules 104.

The Peltier modules 104 are configured such that their inward-facing (first) surfaces 105
20 are the "cold" side, and the outward-facing (second) surfaces 106 are the "hot side". The difference between the temperatures of the two sides is sufficient to produce a "cold" side temperature which is less than the ambient air temperature, and a "hot" side temperature which is greater than or equal to the melting temperature of the phase change material. A Peltier module 104 will thus extract heat at its first surface 105 from input air which is at
25 ambient temperature, and transport it to its second surface 106 and then (via the heat sink 112) to the phase change material where it will be stored.

The cooling unit preferably includes a condensate pan 140 to catch any water droplets which might form, for example on days of high humidity.

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The cooling unit 100 shown in Figure 2 is suitable for installation at an office workstation,

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for example with the controller/vent unit 120 lying above a desk surface 150 and the remainder of the cooling unit 100 lying below the desk surface and out of view once the unit 100 is installed. For example, the controller/vent unit 120 may have formed in its lower surface a channel or bore (not shown) for receiving an annular projection 126 of a plate 128. During installation, a circular aperture sized to accommodate projection 126 may be formed in the desk surface 150. The components which are to remain below desk surface 150 may be assembled, and once complete, the projection 126 fitted to controller/vent unit 120 such that the desk surface 150 is effectively sandwiched between the controller/vent unit 120 and the plate 128.

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Referring now to Figures 3 and 4, there is shown an alternative embodiment of a personal cooling unit 200 which is portable and which can be placed directly on a desktop without installation, for example.

15 The cooling unit 200 includes a heat exchanger 202 which is seated under a vessel 210 containing a phase change material. The unit may be connected to a rechargeable battery (not shown) which provides power to the Peltier modules 204 by means of terminals 240 seated in the top of the unit's casing.

20 The upper surface of heat exchanger 202 is in thermal contact with a first surface of one or more Peltier modules 204 (Figure 6), and the second, upper surfaces of Peltier modules 204 are in thermal contact with the vessel 210.

Figures 5 (in which the phase change material has been omitted for clarity) and 6 depict the internal structure of the vessel 210 of cooling unit 200. The vessel 210 contains a paraffin wax, which is shown (during phase change) partly in solid (218) and liquid (219) form. The vessel 210 includes a heat sink, generally indicated by reference numeral 212. The heat sink 212 includes two plates 214 and 215 having substantially L-shaped cross section, which sit one on top of the other so that the short limbs of the respective 'L' shapes form the ends of the heat sink 212, and fins 213 extend upwardly between the two ends and penetrate through the upper surface of the paraffin. The plates 214 and 215 and

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extrusions (fins) 213 are preferably formed of a highly thermally conductive material such as aluminium.

The double-walled configuration shown in Figure 6, in which a relatively thick layer of aluminium is presented at the base of the vessel 210, has been found to be particularly advantageous in directing heat from the upper (hot) surfaces of Peltier modules 204 to the solid paraffin 218. In particular, the extruded profile of the fins 213 presents an increased surface area such that more of the solid paraffin 218 is in contact with the heated aluminium. In the absence of fins 213, the unmelted paraffin 218 tends to remain buoyant, and thus out of thermal contact with the hot surface of Peltier modules 204, thereby decreasing the effectiveness of the cooling unit 200. By contrast, when fins 213 penetrating through the upper surface of the paraffin are installed, relatively thin sections of solid paraffin 218 sink towards the base of the vessel 210 through the liquid paraffin 219, so that solid paraffin 218 is continually fed towards the hot surface of Peltier modules 204 by gravity.

Turning now to Figure 7, there is shown a further embodiment of a personal cooling unit 300. The unit 300 has a housing 312 which contains a tank 360 of a phase change material which is in thermal contact with a heat pump (not shown), the heat pump being interposed between the tank 360 and a heat exchanger 340. The heat pump may be in the form of a series of Peltier modules, as described above for example. The heat exchanger 340 comprises a series of cooling fins and is located near the bottom of the housing. In use, input air is drawn through intake 320 and subsequently through a filtering system located at 330 and then through heat exchanger 340 by operation of a centrifugal fan 315. The filtering system 330 may comprise any of the components mentioned above.

The unit 300 includes an output channel generally indicated by dotted outline at 372. Output channel 372 may include an air sanitisation system 375, for example along the lines of air sanitisation system 75 discussed previously. Cooled and sanitised output air is expelled from outlets 380, which may be connected to respective ducts for conveying cooled air to different respective locations. For example, each outlet 380 may be connected

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to a duct which terminates at a controller/vent unit similar to controller/vent unit 120 discussed previously, respective controller/vent units 120 being located at different locations.

- 5 In certain embodiments, the unit 300 includes insulation 365, for example a column of an insulating material having dimensions to suit those of the tank 360, the housing 312 and the output channel 372, interposed between the phase change material tank 360 and the output channel 372 to reduce or substantially prevent transfer of heat from the tank 360 to the cooled air in output channel 372. The unit 300 may also include a fan power control
10 dial 314 (for controlling the speed of fan 315) and a cooling power control dial 316 (for controlling the operation of the heat pump, for example by adjusting the voltage across the Peltier modules).

The filtering system 330 may be housed in a removable tray 332 located adjacent to the
15 intake 320, the tray having a recessed handle 335 for ease of removal. The tray 332 may be removably mounted in the housing 312 in any suitable manner known in the art, for example by means of guide rails configured to mate with corresponding channels or grooves in the housing 312.

- 20 Many modifications of the embodiments described above will be apparent to those skilled in the art without departing from the scope of the present invention. For example, while the phase change material employed in the embodiments presently described is a paraffin wax having a melting temperature of about 40°C, it will be appreciated that other phase change materials having the required thermal characteristics can be used in other embodiments.
25 For example, if the personal cooling unit 100 is to be used to provide supplementary cooling in a space which is already air-conditioned, a phase change material with a lower melting temperature, of about 28°C or more, could be used. A phase change material having a melting temperature of this order is advantageous as it requires a lower voltage to be applied across the thermoelectric heat pump in order to achieve the desired cooling. In
30 addition, while the heat sinks described above employ extrusions in the form of substantially planar fins, it may be advantageous in some circumstances to replace the fins

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with elongate members such as pins or spikes.

An exemplary class of alternative phase change materials includes encapsulated hydrated salts. An exemplary hydrated salt is hydrated sodium sulphate which has a melting
5 temperature of about 32°C. The encapsulated hydrated salt may be submerged in a bath.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps
10 but not the exclusion of any other integer or step or group of integers or steps.

The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived
15 from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

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CLAIMS

1. A personal cooling unit, comprising:
 - an air inlet for receiving input air;
 - 5 at least one heat pump having a first surface and a second surface, and being configured to extract heat from the input air at the first surface to generate cooled output air and to transport heat to the second surface;
 - a phase change material in thermal contact with the second surface of the heat pump; and
 - 10 means for conveying the cooled output air to the exterior of the unit;
 - wherein the phase change material undergoes a temperature-driven phase change from a first phase to a second phase, so that when at least a portion of the phase change material is in the first phase, the phase change material absorbs heat from the second surface until all of the phase change material has changed to the
 - 15 second phase; and
 - wherein the phase change material has a phase transition temperature which is at least about 28°C.
2. A personal cooling unit according to claim 1, wherein the phase change material is
20 selected on the basis of an expected ambient air temperature range for a predetermined location over a predetermined time period, the phase change material having a phase transition temperature which is higher than a maximum of the expected ambient air temperature range.
- 25 3. A personal cooling unit according to claim 1 or claim 2, wherein the phase transition temperature is at least about 40°C.
4. A personal cooling unit according to any one of the preceding claims, wherein the phase change material comprises paraffin wax.
- 30 5. A personal cooling unit according to any one of the preceding claims, comprising a

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filtering system for at least partially removing moisture and/or contaminants from the input air.

- 5 6. A personal cooling unit according to claim 5, comprising one or more of a dehumidification component, a particulate matter filtration component, or a gas filtration component.
7. A personal cooling unit according to claim 5 or claim 6, wherein the filtering system is partly or fully removable.
- 10 8. A personal cooling unit according to any one of the preceding claims, comprising an air sanitisation system for at least partially removing or killing microbial contaminants.
- 15 9. A personal cooling unit according to claim 8, wherein the air sanitisation system is in fluid communication with the air inlet and/or an air outlet of the unit.
- 20 10. A personal cooling unit according to claim 8 or claim 9, wherein the air sanitisation system comprises one or more of: a UV-C light source; a photocatalytic component; or a negative ion generator.
- 25 11. A personal cooling unit according to any one of the preceding claims, wherein the vessel containing the phase change material at least partly surrounds the or each heat pump.
12. A personal cooling unit according to claim 11, wherein the or each heat pump is concentric with the vessel.
- 30 13. A personal cooling unit according to any one of the preceding claims, further including a heat exchanger in thermal contact with the first surface of the or each heat pump.

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14. A personal cooling unit according to claim 13, wherein the heat exchanger comprises a plurality of planar members.
- 5 15. A personal cooling unit according to claim 14, wherein the planar members form a honeycomb structure.
16. A personal cooling unit according to any one of the preceding claims, wherein the vessel comprises at least one heat sink in thermal contact with the second surface of
10 the or each heat pump.
17. A personal cooling unit according to claim 16, wherein the or each heat sink comprises a plurality of extrusions.
- 15 18. A personal cooling unit according to claim 13 when appended to claim 12, wherein the heat exchanger is polygonal in cross-section, and each side of the heat exchanger is in thermal contact with a first surface of one of the heat pumps.
19. A personal cooling unit according to any one of the preceding claims, further
20 comprising means for adjusting the voltage across the or each heat pump.
20. An air-conditioning method, comprising steps of:
- determining an expected ambient air temperature range for a specified location over a specified time period;
- 25 selecting, on the basis of the expected ambient air temperature range, a phase change material having a phase transition temperature which is higher than a maximum of the expected ambient air temperature range; and
- providing a personal cooling unit comprising:
- an air inlet for receiving input air;
- 30 at least one heat pump having a first surface and a second surface, the second surface being in thermal contact with the phase change material,

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the heat pump being configured to extract heat from the input air at the first surface to generate cooled output air and to transport heat to the second surface; and

means for conveying the cooled output air to the exterior of the unit;

5 wherein the phase change material undergoes a temperature-driven phase change from a first phase to a second phase, so that when at least a portion of the phase change material is in the first phase, the phase change material absorbs heat from the second surface until all of the phase change material has changed to the second phase.

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