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(71) Applicants: **NANYANG POLYTECHNIC** [SG/SG]; 180 Ang Mo Kio Avenue 8, Singapore 569830 (SG). **JURONG HEALTH SERVICES** [SG/SG]; Ng Teng Fong General Hospital, 1 Jurong East Street 21, Singapore 609606 (SG).

(72) Inventors: **TAN, Seng Sing**; Block 273B, Bishan Street 24, Natura Loft, #29-108, Singapore 572273 (SG). **LIM, Eng Koon**; 2F Glasgow Road, Singapore 549371 (SG). **NG, Chin Tiong**; Block 248, Choa Chu Kang Avenue 2, #14-486, Singapore 680248 (SG).

(74) Agent: **ALLEN & GLEDHILL LLP**; One Marina Boulevard, #28-00, Singapore 018989 (SG).

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(54) **Title**: A PORTABLE WHOLE-BODY EVAPORATIVE COOLING SYSTEM FOR EXERCISE-INDUCED HYPERTHERMIA

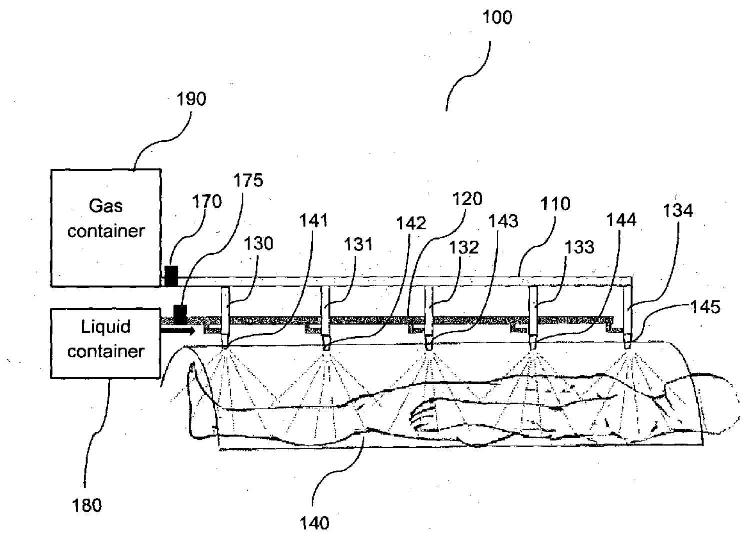


Figure 1

(57) Abstract: This invention relates to a portable evaporative cooling system. The portable evaporative cooling system includes a cover, a first conduit, a second conduit and a number of nozzles. The first conduit is for conveying dry gas while the second conduit is for conveying liquid. Each of the nozzles includes a base with a first inlet in fluid communication with the first conduit, a second inlet in fluid communication with the second conduit, and an outlet. The base defines a first passageway extending between the first inlet and the outlet and a second passageway extending between the second inlet and a tip of the outlet. Further the nozzles are fitted on the cover with the outlet extending through apertures of the cover.

WO 2015/195044 A1

A Portable Whole-Body Evaporative Cooling System For Exercise-Induced Hyperthermia

Field of the Invention

This invention relates to a cooling system for treating heat related illnesses. Particularly, this invention relates to an evaporative cooling system that is portable. More particularly, this invention relates to a portable evaporative cooling system for treating heat related illnesses effectively.

Prior Art

There is an increase in number of cases of Exertional heat illness (EHI). This occurs mainly in active individuals pushing to their physical limits, resulting in overheating from generation of heat faster than what the body can dissipate. In mass endurance events, runners with heat illnesses are typically treated with ice packs or cooled with ice water in the pre-hospital setting, before the more definitive methods of cooling by immersion in ice water or Body Cooling Units (BCUs) in the hospitals. It was reported in a half marathon (21-km run) in Singapore, a field-deployed BCU was used for cooling hyperthermia patients. Seventy-two thousand runners participated in the event, which was held in an ambient temperature of 30°C with relative humidity of 85%. In the event, there were 7 hyperthermia patients, and 3 patients with heatstroke were hypotensive. After the diagnosis of heatstroke or heat exhaustion, initial resuscitation was commenced immediately, and the patients were transferred to the BCU for evaporative cooling. The evaporative cooling method had been demonstrated to be effective in the treatment of heat injuries. The cooling therapy would be terminated once the rectal temperature falls below 39°C to avoid hypothermia. Casualties would subsequently be transferred to a tertiary care center for further management.

In most severe situations, EHI need to be assessed and appropriately cared to prevent possible serious consequences or fatalities. The most serious of these illnesses is exertional heat stroke (EHS), a condition marked by an elevated core body temperature greater than 40°C and central nervous system dysfunction. Heat stroke in distance runners is increasing in frequency. Because the most critical predictor outcome after EHS is the amount of time that core body temperature remains above a critical threshold, athletic trainers should, whenever possible, implement the most effective cooling required immediately. Other classic heat stroke involve passive thermal exposure, normally affecting the elderly in a non-air-conditioned environment or young being abandoned in vehicles during hot weather. Induced hypothermia, where the body temperature is purposely lower by a few degrees centigrade, is gaining attention for treating heat stroke patient, as well as beneficial therapy for treatment during and after conditions of hypoxia and ischemia. If cooling is delayed, the benefits decrease as function of time. For example, therapeutic hypothermia resulted in 16% improvement in survival of patients following cardiac arrest, despite the cooling being mild, only 4°C below normal body temperature.

Given the time-critical nature of such life threatening emergencies and many of these injuries occur outside of the hospital, the time required to achieve cooling becomes a critical parameter.

Current typical cooling methods for induced hypothermia can be divided into two categories: devices that cool the body from outside and devices that are invasive to reduce the core body temperature within the patient. Current external cooling devices, such as Flex.Pad by EmCools, ArcticGel by Medivance, cooling blankets or ice bags, which are much simpler to implement, relatively inexpensive and do not pose many of the risk associated with the more invasive internal cooling, especially for patients outside the hospital. However, such approach is slow. In general, the range of time to achieve 4°C of cooling for these devices spans from more than 2 hours to almost 7 hours.

Internal cooling has the best ability to cool locally more rapidly with the use of Peltier cooler but current devices are more invasive, costly and are still not able to provide rapid cooling within the 5-min interval. Cardiopulmonary bypass and recirculating coolants such as Alsius CoolGard 3000 system and Philips InnerCool system can achieve the cooling rate but are currently extremely invasive and require a highly skilled team to implement. Nurses and physicians recognize the limitations of external methods in that they are clinically inefficient, labour intensive and limit access to critically ill patients.

In light of the above, those skilled in the art are striving to provide an effective and portable cooling system for treating heat related illnesses.

Summary of the Invention

The above and other problems are solved and an advance in the art is made by a portable evaporative cooling system in accordance with this invention. A first advantage of a portable evaporative cooling system in accordance with this invention is that the portable evaporative cooling system requires a few components and can be easily used when required. A second advantage of a portable evaporative cooling system in accordance with this invention is that the portable evaporative cooling system is that no electrical power supply is required to work the system. A third advantage of a portable evaporative cooling system in accordance with this invention is that the portable evaporative cooling system includes a few components and hence is portable. This means that the portable evaporative cooling system can be carried to remote areas.

In accordance with embodiments of this invention, a portable evaporative cooling system is configured in the following manner. The portable evaporative cooling system comprises a cover, a first conduit, a second conduit and a number of nozzles. The first conduit is for conveying dry gas while the second conduit is for conveying liquid. Each of the nozzles includes a base with a first inlet in fluid communication with the first conduit, a second inlet in fluid communication with the second conduit, and an outlet. The base defines a first passageway extending between the first inlet and the outlet and a second passageway extending between the second inlet and a tip of the outlet. The nozzles are fitted on the cover with the outlet extending through apertures of the cover.

In accordance with an embodiment, the evaporating cooling system further includes a retractable frame and a blanket coupled to the retractable frame such that when the retractable frame is unfolded, the blanket is support on the retractable frame.

In accordance with an embodiment, the cover comprises an inflatable tube along a perimeter of the cover configured such that when inflated, forms an arc along a width of the cover.

In accordance with an embodiment, the evaporating cooling system further comprises a control valve provided along the first conduit to control the flow of the gas. Another control valve is provided along the second conduit to regulate the flow of liquid.

In accordance with an embodiment, the evaporating cooling system further comprises a number of tube couplings for connecting each of the first inlet of the nozzles with the first conduit, and each of the second inlet of the nozzles with the second conduit.

In accordance with an embodiment, a container containing compressed gas in fluid communication with said first conduit is provided. In accordance with another embodiment, a container containing liquidised gas in fluid communication with the first conduit is provided.

In yet another embodiment, a container containing room temperature water in fluid communication with the second conduit is provided.

In accordance with an embodiment, a kit bag comprising a bag, a portable evaporating cooling system, a gas container with compressed gas and a bottle of liquid is provided. The portable evaporating cooling system, gas container and bottle of liquid are housed in the bag.

Brief Description of the Drawings

The above and other features and advantages in accordance with this invention are described in the following detailed description and are shown in the following drawings:

Figure 1 illustrating a perspective view of a portable evaporative cooling system in accordance with an embodiment of this invention;

Figure 2 illustrating connections between the nozzle, first conduit and the second conduit in accordance with an embodiment of this invention; and

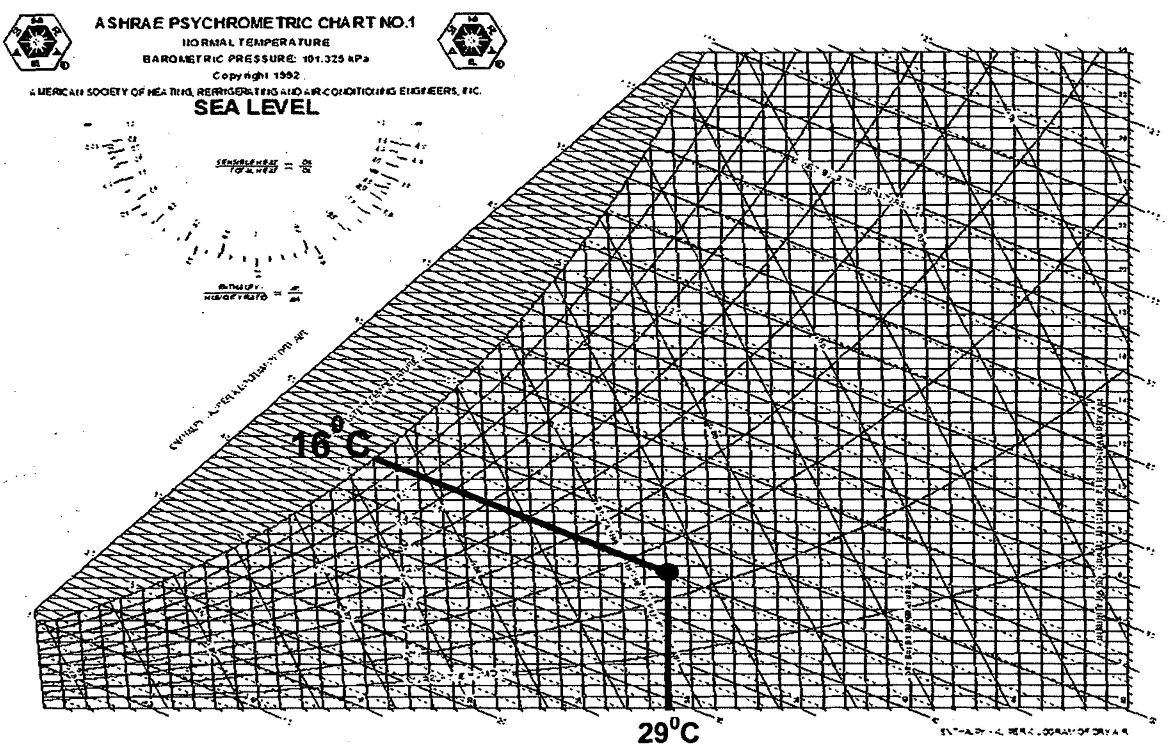
Figure 3 illustrating a perspective view of a frame in accordance with an embodiment of this invention.

Detailed Description

This invention relates to a cooling system for treating heat related illnesses. Particularly, this invention relates to an evaporative cooling system that is portable. More particularly, this invention relates to a portable evaporative cooling system for treating heat related illnesses effectively.

Heat exhaustion patient has a body temperature of as high as 40°C. It is important to cool the body as fast as possible, preferably within 5 minutes, before causing complication arises. Ideally, the body temperature has to be brought down to less than 39°C within 30 minutes at a rate not less than 0.15°C/min. However, using current approaches such as ice packs or gel pads to cool the body is not fast enough and using ice-water immersion to quench the body could have adverse effects. Most existing systems available for evaporative cooling are not portable. The main objective is to improve the management of a heat stroke patient by initiating an early effective cooling procedure.

Based on the psychrometry theory in the thermodynamics, it is known that the evaporating rate of water could be moderated by the air flow rate over a damp surface as well as the relative humidity of the circulating air. Like the cooling tower, heat energy removed from water through the evaporating process could result in a reasonable decrease in the water temperature. Besides manipulating the flow rate, we could also supply air or gas with a lower humidity to improve the evaporating cooling effect. Our preliminary study shows that sprinkling of water at 22.7°C can cool to 18.8°C on a path of airflow at room conditions. The water of the same temperature can be further lower to approximately 16°C by the evaporative cooling using a dryer-air flow concept. If the circulating air supply has a lower relative humidity, more water could be evaporated into the circulating air. With higher flow rate of supply air, more heat will be removed through the evaporation process. Referring to the psychrometric properties of air-vapour mixture, the relative humidity depends very much on the air-supply temperature and its relative humidity. Referring to the psychrometric chart below, an appropriated dryness of air flow, say a relative humidity of 25%, the air of even as high as 29°C can achieve an effective cooling effect of 16°C by the evaporative cooling based on the wet-bulb temperature reading from the chart. Hence, better control over the dry air supply temperature or velocity would in turn optimise the evaporation rate of the water, resulting cooler mists.



A portable evaporative cooling system is provided to create cooled mists from unpressurised room-temperature water through the use compressed gas or liquidised gas connected to rows of atomisers attached to a foldable frame or a lightweight blanket. The portable evaporative cooling system uses atomisers together with a method of supplying continuous flow of dehumidified air to create massive cooling-mist flow over heat exhaustion patients. Further details of the portable evaporative cooling system will be described below.

Figure 1 shows a portable evaporative cooling system 100. The portable evaporative cooling system 100 includes a first conduit 110, a second conduit 120, a number of nozzles 130-134, and a cover 140. A liquid container 180 is connected to the second conduit 120 for supplying liquid. A gas container 190 is connected to the first conduit 110 for supplying gas.

Compressed gas kept in an insulated, portable, refillable carrying gas container 190 may be used for consistent supply of pressurised gas. Alternatively, liquidised gas could be used. When the liquidised gas evaporates, the latent heat absorbed cools the whole system. This means that the supply gas for patient delivery will be cooler. A valve control on the portable gas container 190 may be provided to enable a user to adjust an appropriate gas flow rates. This consumes no external electricity power. The pressurised gas with very low relative humidity exists through rows of atomiser nozzles, creating a high velocity of gas flow through a narrow channel in the nozzles, resulted a relatively lower static pressure near the exit. Gas container 190 is in fluid communication with the nozzles 130-134 via first conduit 110. A first control valve 170 is provided between the first conduit 110 and the gas container 190 to regulate the flow of the gas being supplied to the nozzles 130-134.

Liquid container 180 is any container for holding liquid such as a small water container, water bottle, water bag, or pail. Liquid container 180 is in fluid communication with the nozzles 130-134 via second conduit 120. A second control valve 175 is provided between the second conduit 120 and the liquid container 180 to regulate the flow of the liquid being supplied to the nozzles 130-134.

First conduit 110 and second conduit 120 are flexible tubing for conveying gas and liquid respectively. Figure 2 shows a magnified view of a nozzle 130. As shown in figure 2, each of the nozzles 130-134 includes a base 200 having a first inlet 210, a second inlet 220, and an outlet 230. A first passageway 240 and a second passageway 250 are defined within the base 200. The first inlet 210 is in fluid communication with the first passageway 240 and is adaptable to connect to one end of first conduit 110 to receive gas supply from gas container 190. The second inlet 220 is in fluid communication with the second passageway 250 and is adaptable to connect to one end of the second conduit 120 to receive liquid supply from the liquid container 180. Tube couplings are provided to connect the first inlet 210 with the first conduit 110, and second inlet 250 with the second conduit 120. The outlet 230 extends through the aperture 141.

The first passageway 240 extends between the first inlet 210 and outlet 230. The second passageway 250 extends between the second inlet 220 and the tip 231 of the outlet 230. The first passageway 240 has a narrower radius compared to the second passageway 250. As shown in figure 2, the second passageway 250 extends to the tip 231 of outlet 230. As gas is directed out from the tip 231 of the outlet 230, fluid is drawn from the liquid container 180 to the nozzles 130-134 and sprinkle out through the outlet 230 of nozzles 130-134. Hence, a water pump is not required to push the liquid from the liquid container 180 to the nozzles 130-134. In particular, a higher velocity of gas flowing out from outlet 230 results in a lower static pressure in the second passageway 250. The relatively lower static pressure in the second passageway 250 will draw or extract liquid from the liquid container 180 and dispense out of the outlet 230 without an electrical pump. In other words, nozzles 130-134 function as an atomiser nozzle to dispense gas and liquid.

Advantageously, the high velocity flow rate at the outlet 230 will also draw in the surrounding air and amplify the flow rate. Higher flow rate and lower relative humidity of air and gas will stimulate the evaporation effect to promote an effective whole-body cooling through phase-change

The use of compressed air or liquidised gas to create a high velocity flow of dry gas removes the need of an external electrical power source, unlike other techniques which involved fans and dehumidifier to create flow of dehumidified air. This provides a continuous flow of relatively-low-humidity air or dry gas over sprinkling of water mists to promote an effective whole-body cooling through phase-change.

The cover 140 is adapted to cover and/or isolate the patient. This shields the patient from direct sunlight and isolates the patient from the surrounding environment. The cover 140 is a flexible sheet of material which includes apertures 141-145 adapted to fit the nozzles 130-134 with at least the outlets extending therethrough. The apertures 141-145 are distributed on the surface of the flexible sheet. The cover 140 has a length and a width. When not in use, the cover 140 is folded and stored in a kit bag. When required, the cover 140 is unfolded forming an arc along the width. As shown in figure 1, the apertures are distributed along the length of the cover 140 and at the top of the arc. However, one skilled in the art will recognise that other arrangement may be implemented without departing from the invention. In order for the cover to form an arc along the width, a frame as shown in figure 3 may be provided. The frame includes flexible rods 310-312 having a length longer than the width of the cover such that when the flexible rods are fitted along the width of the cover 140, the cover 140 forms an arc. A pair of rods is fitted along the sides of the cover 140. Alternatively, a retractable frame may be provided. After unfolding of the retractable frame, the cover 140 may be supported on the retractable frame. In yet another embodiment, the cover 140 may include inflatable tube arranged along the perimeter of the cover such that when inflated, the cover forms an arc along the width of the cover 140. One skilled in the art will recognise that other methods may be provided to form an arc along the width of the cover 140 without departing from the invention as long as an arc is form along the width of the cover. This is required so that the cover is not in contact with the patient. This allows the right amount of cooled mist to be delivered to achieve an optimal cooling effect for the patient lying below. Without the need to soak the whole body of the patient, a bedside monitoring system can be attached to the patient to continue monitoring the other essential parameters. The rate of cooling can be closely monitored to control the cooling therapy. Further, since the cover is not in contact with the patient, the mists will be effectively cooled before reaching the patient lying below the system.

The first control valve 170 may be provided at the first conduit 110 to control the velocity of the gas supply from the gas container 190. The second control valve 175 may be provided at the second conduit 120 to control the velocity of the liquid supply from the liquid container 190. Although figure 1 shows only two control valves, one skilled in the art will recognise that more than two control valves may be used without departing from the invention. This allows optimising the evaporative cooling effect with only a small amount of water being used. In other words, by controlling the flow rate of the gas supply and regulating the flow of the liquid supply, the ratio of the gas and liquid to be dispensed from the nozzles 130-134 can be manipulated to improve the evaporating process. This optimizes the effectiveness of the cooling process with a right amount of cooled mist to be delivered to the patient. Unlike other techniques which have patients completely soaked in water, other electronic measuring devices could be attached co-currently on the patients together with this invention to continue monitoring the other essential parameters, as well as monitoring the effect of the evaporative cooling.

In a typical setup, the portable evaporative cooling system consists of only a portable compressed or liquidised gas container for supplying gas and a small liquid container connected to rows of atomiser nozzles attached to a foldable frame or a light-weight blanket. Minimal setup procedure is required since the cooling system include a few components. Hence, the system can be easily deployed when required. Since the portable evaporative cooling system has to be portable, the total weight of the system is preferably as light as possible. When the cover is unfolded, the length of the cover should be long enough to cover most part of the body and the width should be wide enough to form an arc to a certain height to accommodate a heat stroke patient in it and the row of nozzles shall be positioned just above the patient lying under the cover. When not in used, the cooling system can be packed into a portable kit such as like a backpack that can be easily carried by an individual.

The portable evaporative cooling system can be deployed in an ambulance or helicopter during standbys. When the ambulance is being deployed, the cooling system can be delivered together with patient on the stretcher in ambulance or helicopter.

The above is a description of exemplary embodiments of a portable cooling system in accordance with this invention. It is foreseeable that those skilled in the art can and will design alternative apparatus or device based on this disclosure that infringe upon this invention as set forth in the following claims.

Claims

1. A portable evaporative cooling system comprising:

a cover;

a first conduit for conveying dry gas;

a second conduit for conveying liquid;

a plurality of nozzles, each of said plurality of nozzles having a base with a first inlet in fluid communication with said first conduit, a second inlet in fluid communication with said second conduit, and an outlet, said base defining a first passageway extending between said first inlet and said outlet and a second passageway extending between said second inlet and a tip of said outlet, and wherein said plurality of nozzles are fitted on said cover with said outlet extending through apertures of said cover.

2. The evaporating cooling system according to claim 1 wherein said cover comprises:

a retractable frame; and

a blanket coupled to said retractable frame such that when said frame is unfolded said blanket is support on said retractable frame.

3. The evaporating cooling system according to claim 1 wherein said cover comprises:

an inflatable tube along a perimeter of said cover configured such that when inflated, forms an arc along a width of said cover.

4. The evaporating cooling system according to claim 1 further comprising a control valve provided along said first conduit to control the flow of the gas.

5. The evaporating cooling system according to claim 4 further comprising another control valve provided along said second conduit to regulate the flow of liquid.

6. The evaporating cooling system according to claim 1 further comprising a plurality of tube couplings for connecting each of said first inlet of said plurality of nozzles with said first conduit, and each of said second inlet of said plurality of nozzles with said second conduit.

7. The evaporating cooling system according to claim 1 further comprises a container containing compressed gas in fluid communication with said first conduit.

8. The evaporating cooling system according to claim 1 further comprises a container containing liquidised gas in fluid communication with said first conduit.

9. The evaporating cooling system according to claim 1 comprises a container containing room temperature water in fluid communication with said second conduit.

10. A kit bag comprising a bag, a portable evaporating cooling system according to claim 1, a gas container with compressed gas and a bottle of liquid, said portable evaporating cooling system, gas container and bottle of liquid are housed in said bag.

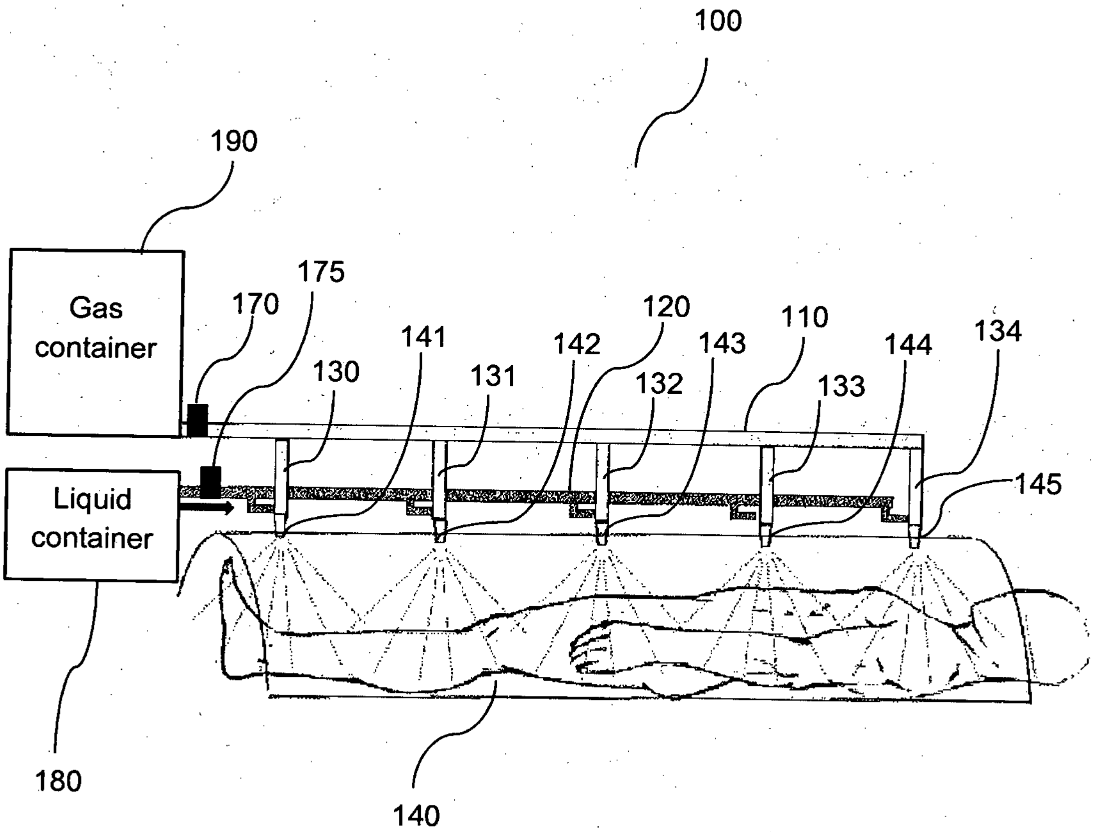

100
190
Gas container
175
170
120
110
141
143
134
142
144
130
131
132
133
145
Liquid container
180
140

Figure 1

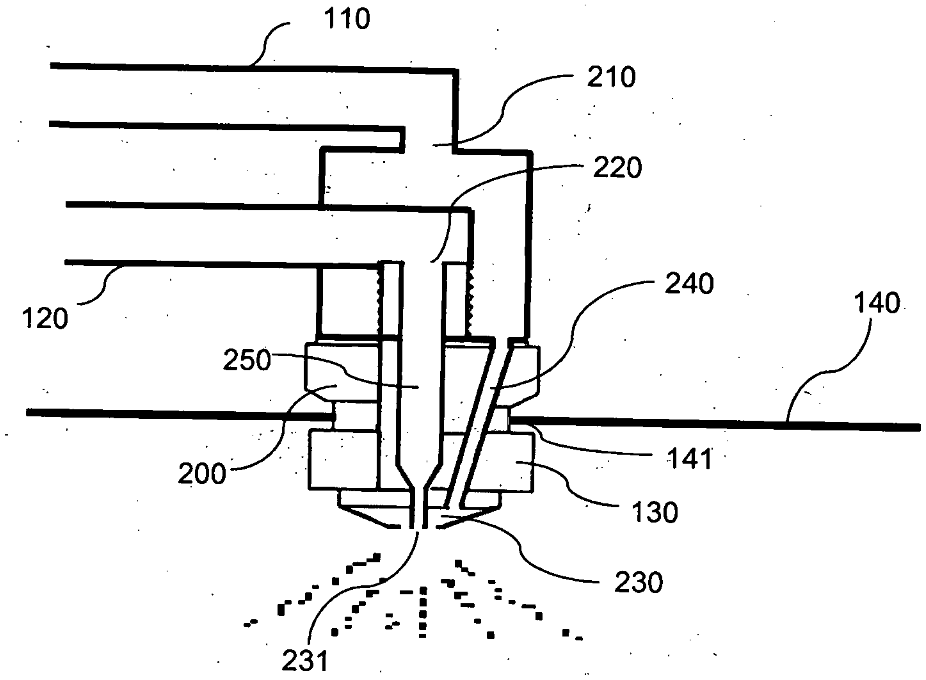


Figure 2

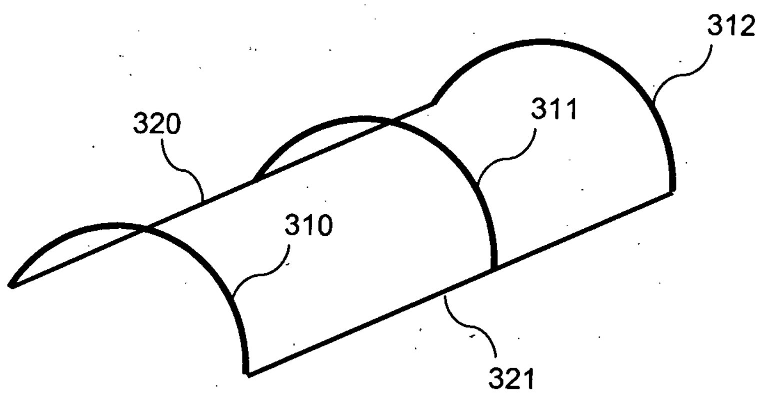


Figure 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2014/000288

A. CLASSIFICATION OF SUBJECT MATTER

F28D 5/00(2006.01)i, B05B 1/28(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F28D 5/00; H05B 3/34; F28D 20/00; A61F 7/12; A61F 7/00; C01B 21/04; B05B 1/28

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: evaporative cooling system, cover, conduit, nozzle, blanket, tube, kit, and bag

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	EP 1604950 A1 (MAYEKAWA MFG. CO., LTD.) 14 December 2005 See paragraphs [0067]-[0069]; and figure 1.	1,3-10
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Y	US 2008-0093356 A1 (PIZZI, GIAN VITTORIO) 24 April 2008 See paragraph [0018]; and figure 3.	10
A	US 5,405,371 A (AUGUSTINE et al.) 11 April 1995 See column 4, line 55 - column 5, line 34; and figures 1-2.	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 March 2015 (16.03.2015)	**17 March 2015 (17.03.2015)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. ++82 42 472 7140

Authorized officer
HAN, Joong Sub
Telephone No. +82-42-481-5606

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