(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 510 816 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
17.10.2012 Bulletin 2012/42

(51) Int Cl.:
A41D 13/005 *(2006.01)*

(21) Application number: **12164308.4**

(22) Date of filing: **16.04.2012**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **14.04.2011 US 201113087160**

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(54) Personal cooling apparatus

(57) A wearable personal cooling apparatus includes an outer layer (201), which comprises fabric proportioned and configured to closely envelop a human torso, a primary air plenum (204) proximate the outer layer (201), and an inner layer (202) proximate the outer layer (201) and in communication with the primary air plenum (204). The inner layer is configured to distribute air from the primary air plenum (204) throughout an inner surface of the inner layer. A secondary air plenum (210) is arranged within the inner layer and in communication with the primary air plenum (204). The secondary air plenum (210) comprises a first end proximate the primary air plenum (204) and a second end, and is configured to direct air from the first end to the second end.

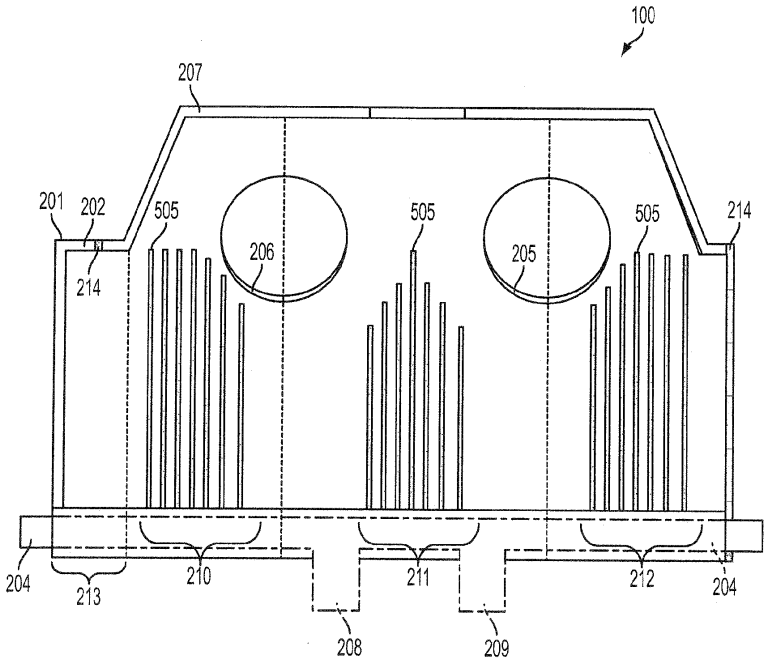

FIG. 4

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Description

BACKGROUND OF THE INVENTION

[0001] Generally, the present invention is directed to a personal cooling apparatus, and more particularly, example embodiments of the present invention are directed to a personal cooling vest configured to enhance sensible and latent heat transfer from a user wearing the vest.

[0002] Heat stress is a symptom of excessive heat exposure which may lead to loss of the ability to function effectively (e.g., disruption of cognitive thought), to unconsciousness, and to critical or full body failure. There are numerous occupations where an excessively hot environment or particularly strenuous task affects the ability for persons to perform effectively. Military personnel in particular are affected in hot environments due to additional clothing and personal protection which are generally employed. Conventional systems for personal cooling involve complex liquid circulation systems which typically aim to exchange heat with a wearer through complex tubing. Other systems employ ice-packs or other precooled means.

BRIEF DESCRIPTION OF THE INVENTION

[0003] According to an example embodiment of the present invention, a wearable personal cooling apparatus includes an outer layer, wherein the outer layer comprises fabric proportioned and configured to envelop a human torso, a primary air plenum proximate the outer layer, an inner layer proximate the outer layer and in communication with the primary air plenum. The inner layer is configured to distribute air from the primary air plenum throughout an inner surface of the inner layer, and a secondary air plenum is arranged within the inner layer and in communication with the primary air plenum. The secondary air plenum includes a first end proximate the primary air plenum and a second end. The secondary air plenum is configured to direct air from the first end to the second end.

[0004] According to an additional example embodiment of the present invention, a wearable personal cooling apparatus includes an outer layer, wherein the outer layer includes fabric proportioned and configured to envelop a human torso. The outer layer further includes a neck cutout proximate a neck portion of the human torso, wherein the outer layer further includes first and second arm cutouts proximate first and second arm portions of the human torso. The outer layer further includes a neck exit vent arranged within the neck cutout, and the outer layer further includes first and second arm exit vents arranged within the first and second arm cutouts. The apparatus further includes a primary air plenum proximate the outer layer and arranged proximate a waist portion of the human torso, an inner layer proximate the outer layer and in communication with the primary air plenum. The inner layer is configured to distribute air from the primary air plenum throughout an inner surface of the inner layer. The inner surface of the inner layer is proximate an outer surface of the human torso, and a secondary air plenum is arranged within the inner layer and in communication with the primary air plenum. The secondary air plenum includes a first end proximate the primary air plenum and a second end proximate a chest area of the human torso, and the secondary air plenum is configured to direct air from the first end to the second end.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 depicts a personal cooling vest, according to an example embodiment;

FIG. 2 depicts a personal cooling vest, according to an example embodiment;

FIG. 3 depicts a personal cooling vest, according to an example embodiment;

FIG. 4 depicts a personal cooling vest, according to an example embodiment;

FIG. 5A depicts a cut-away of fabric forming a portion of a personal cooling vest, according to an example embodiment;

FIG. 5B depicts a cut-away of fabric forming a portion of a personal cooling vest, according to an example embodiment;

FIG. 6 depicts a primary air plenum of a personal cooling vest, according to an example embodiment;

FIG. 7 depicts a fan apparatus for use with a personal cooling vest, according to an example embodiment;

FIG. 8 depicts a personal cooling vest, according to an example embodiment; and

FIG. 9 depicts a personal cooling vest, according to an example embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0006] Example embodiments of the present invention provide a personal cooling vest which greatly enhances the transfer of heat from a user to effectively reduce the user's core temperature. In this manner, the user benefits

through increased ability to withstand hot environments. Further benefits include a more distributed pattern of pressure impinging upon a user when wearing addition material, armor, backpacks, etc upon the vest. According to example embodiments, the personal cooling vest augments sensible and latent heat transfer for better personal cooling. Sensible heat transfer occurs if supply air is below the user's skin surface temperature. Latent heat transfer occurs by evaporating perspiration from the user's body.

[0007] Turning to FIG. 1, the personal cooling vest 100 is designed to receive ambient air supplied by a fan, or to receive conditioned air supplied by an external cooling device through a supply opening near the waistline 101. The ambient or conditioned air enters a primary plenum at the waistline 101 and flows upwards across the torso. The primary plenum consists of a number of vent holes distributing the air at an optimal velocity. The air flow then enters a matrix material that surrounds the torso. The air moves through two different mediums to cool the user. The stretchable outer vest material 201 holds the matrix close to the users body so that the air may not channel, but rather be forced to travel through the intended plenums. Most of the air will travel up through the matrix, causing the air to be turbulent and direct it to the user's body with added turbulence. The resultant turbulent air flow increases sensible heat transfer from the body due to the higher coefficient of thermal convection and introduces dry air to the user's body providing greater latent heat transfer. The process air warms as it moves up a user's body resulting in an increase of its dew point. As the dew point increases, so does the air's potential water content. For example, increasing from 20°C to 30°C increases the potential water content from 17.148 g/m^3 to 30.078 g/m^3 equivalent to a 75% increase in water content. This expanded capability allows the cooling apparatus to govern itself. For example, even if the surrounding air is at 100% relative humidity, or fully saturated with water, as it warms it is enabled to accept vaporized perspiration from the user. The air exits past the user's body at a neck portion 103 and under the user's arms at portions 102, 104. This exit air is directed to increase the cooling area, thus further enhancing cooling. All of these components reside within the stretchable vest that holds the aforementioned matrix against the user's body, not allowing the air to channel to the exit without proper cooling flow.

[0008] FIG. 2 depicts an alternate configuration of the personal cooling vest 100, according to an example embodiment. As depicted, waste heat is recycled in a closed fashion. Thus, the closed system shares all of the above components, further including a seal configured to prohibit air from leaving the vest at the underarm portions 102, 104. Although not illustrated in FIGS. 1-2, it should be appreciated that additional sealing functionality may be provided by a waist-band draw-string or other means to prohibit leakage in the waist area of the vest 100. The exit air is collected at the user's neck through portion 103 and recycled through supporting cooling systems. Capturing this air allows some cooling systems to achieve higher efficiency. Furthermore, the vest may be worn beneath sealed garments configured to protect a user from the external environment, such as a HAZMAT suit. Thus, capturing and recirculating this air facilitates cooling while limiting or prohibiting external air from entering the vest 100. Thus, the personal cooling vest 100 may provide enhanced cooling thereby allowing a user to survive hostile environments (e.g., nuclear-biological-contamination areas) where completely closed systems should be employed.

[0009] As described above, example embodiments provide personal cooling vests which are configured to enhance both latent and sensible heat transfer through use of a matrix configured to promote turbulent air flow proximate a user's skin / torso. It should be noted, however, that warm air, as well as ambient temperature air, may be circulated to provide personal heating in some applications, for example, applications where a user is in a cold environment.

[0010] Hereinafter a more detailed description of the componentry and construction of the vest 100 is provided.

[0011] FIG. 3 depicts the personal cooling vest 100, according to an example embodiment. As illustrated, the vest 100 includes the primary air plenum 204 arranged within a primary chamber 203. The primary chamber 203 may be a sewn or bonded chamber comprised primarily of a flexible, stretchable outer vest material 201, proximate a matrix material 202. The vest 100 further includes exit vents 205, 206, 207 arranged within the underarm and neck portions.

[0012] Turning to FIG. 4, a view of the interior portion of the vest 100, which would be proximate a user's torso when wearing the vest, is provided. As illustrated, the vest 100 includes first, second, and third secondary air plenums 210, 211, 212 arranged within the matrix 202. Studies have shown that for a given core temperature, the back and chest have higher sweating rates as compared to other portions of a user's torso. Therefore, the secondary air plenums 210-212 are configured to deliver air more readily to these portions of a user's body. Thus, the effectiveness of the cooling/evaporative air flow is greatly enhanced due to impingement heat transfer, which generates high convection coefficients, because the bodies fluid boundary is disrupted by the perpendicular impinging jets. The secondary air plenums 210, 211, and 212 are fed air from the primary plenum 204. Each secondary air plenum 210, 211, and 212 comprises a plurality of plenum-portions 505. The plenum portions 505 are configured to transmit air more readily than the surrounding matrix 202. For example, the plenum portions 505 may comprise fabric less dense than the surrounding matrix, tubes, tube-like pockets, or any suitable means to increase airflow relative to the surrounding fabric of the matrix 202.

[0013] With regards to supply air, ports 208 and 209

are arranged on the primary plenum 204, and configured to receive supply air from an external source.

[0014] With regards to maintaining air flow from the supply air throughout the matrix 202 to the exit vents 205, 206, and 207, flap 213 comprising sealing zipper 214 arranged on the vest 100. The sealing zipper 214 may be a zipper configured to limit and/or reduce the flow of air there-through. Further, the flap 213 provides further closure/sealing to reduce the loss of internal air and promote internal circulation of the air. An alternate design may include a fully closed vest with expansion folds, allowing the user to pull the garment over their head and avoid zipping.

[0015] Turning to FIGS. 5A-5B, the particular arrangement of layers within the vest 100 are illustrated. As shown the primary plenum 204 comprises a plurality of apertures 507 configured to distribute air supplied to the plenum 204 relatively evenly throughout the matrix 202. These apertures 507 may be arranged equidistant or relatively equidistant. Further, the matrix 202 includes a plurality of layers configured to distribute the supplied air to a torso of a user.

[0016] Generally, a first layer 502 is arranged to be proximate a user's skin. The layer 502 may comprise any fabric allowing air to flow and pass there-through. The first layer 502 is configured to disrupt localized air-flow in such a manner that any laminar flow is converted to more turbulent airflow. This turbulent flow is transmitted to the user such that localized turbulence is impingent on a user's torso. The secondary air plenums' portions 505 are arranged within the matrix 202 proximate the first layer 502. Air plenums' portions 505 are configured at a substantially optimal distance from the users body to enhance impingment heat transfer and user comfort. Finally, the outer, stretchable layer 201 is arranged proximate the matrix 202. The layer 201 is arranged at a waistline 101 of the vest to surround the primary plenum 204, and affixed to the matrix 202 within the interior of the vest 100. Furthermore, a waist-band and/or waist-tie 509 may further facilitate positioning of the matrix 202 against a user's torso. As the layer 201 is generally or substantially impermeable with regards to air, air supplied from the primary plenum 204 is directed upwards through the matrix 202 and secondary plenums.

[0017] FIG. 6 depicts the primary air plenum 204 of the personal cooling vest 100, according to an example embodiment. As shown the plenum 204 may be tubular and may be arranged to wrap around a user's waist when arranged within the vest 100. Upon vest closure, a first end 601 is configured to mate and/or seal with a second end 602. This may be facilitated through interlocking means, sliding means, or any other suitable means to secure the first end 601 to the second end 602 and maintain airflow therein. If the apparel is designed as a pull over, this interlocking means may be a sliding mechanism as well to enable donning the garment.

[0018] FIG. 7 depicts a fan apparatus for use with the personal cooling vest, according to an example embodiment. The fan apparatus 700 is configured to provide airflow to the primary plenum 204 through ports 708-709. The fan apparatus 700 includes a housing 701 defining a fan assembly 702 and the ports 708-709. The fan apparatus 700 may further include heat exchangers 703 and thermo-electric modules 704. Thus, the fan apparatus 700 may reduce a temperature of air entering the fan assembly 702 before exiting the ports 708-709. Alternatively, the fan apparatus 700 may supply ambient air without conditioning. In other alternatives, conditioned air may be provided to the primary plenum 204 from entirely external means, for example, from an umbilical line or piping providing conditioned or heated air from a vehicle, air-conditioning /filtration system, or any other suitable means.

[0019] To better understand the form-fitting nature of exemplary personal cooling vests, FIGS. 8-9 provide stylized views of the same. It is noted that according to some example embodiments, an adjustment means 901, 902 may be provided to reduce the proximity of the matrix 202 and a user's torso. The adjustment means 901, 902 may comprise pleats and/or additional zippers. Furthermore, a drawstring, elastic band, or waistline adjustment means 509 may be provided within or proximate chamber 203 to further enhance the form-fitting nature of the vest 100. Moreover, additional cushioning or positioning material 903 may be arranged within a lumbar or back portion of the vest 100 to position the matrix 202 proximate a user's skin to reduce uninterrupted air flow and further reduce process air channeling.

[0020] Although particularly described above as encompassing a personal cooling vest, it is readily appreciated that the matrix and plenum combinations described above are applicable to any number of garments. For example, short trousers may be arranged with a turbulence matrix and plenum to facilitate cooling / heating of lower extremities of a user. Furthermore, a cap or hood may be arranged with a turbulence matrix and plenum to facilitate cooling /heating of a user's cranial areas. Moreover, any combination of hood, vest, short trousers may be combined as a complete personal cooling / heating temperature regulation system. In such combinations a primary plenum may be provided for each portion, or a main plenum may supply air for all portions, for example, through mating of respective turbulence matrices of each portion. Therefore, example embodiments should not be limited to personal cooling vests alone, but are extensible to any suitable personal garment.

[0021] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the in-

vention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

Claims

1. A wearable temperature regulation apparatus (100), comprising:

   an outer layer (201), wherein the outer layer comprises fabric proportioned and configured to envelop a portion of a user's body;
   a primary air plenum (204) proximate the outer layer (201);
   an inner layer (502) proximate the outer layer (201) and in communication with the primary air plenum (204), wherein the inner layer (502) is configured to distribute air from the primary air plenum (204) throughout an inner surface of the inner layer; and
   a secondary air plenum (210) arranged within the inner layer (502) and in communication with the primary air plenum (204), wherein the secondary air plenum (210) comprises a first end proximate the primary air plenum (204) and a second end, and wherein the secondary air plenum (210) is configured to direct air from the first end to the second end.

2. The apparatus of claim 1 configured as a wearable personal cooling apparatus, which:

   said outer layer (201), comprises fabric proportioned and configured to closely envelop a human torso.

3. The apparatus of claim 2, wherein the outer layer (201) comprises a neck cutout proximate a neck portion of the human torso, wherein the outer layer (201) further comprises first and second arm cutouts proximate first and second arm portions of the human torso, wherein the outer layer (201) further comprises a neck exit vent (207) arranged within the neck cutout, and wherein the outer layer (201) further comprises first and second arm exit vents (205,206) arranged within the first and second arm cutouts;
   wherein the primary air plenum (204) is arranged proximate a waist portion of the human torso;
   wherein the inner surface of the inner layer is proximate an outer surface of the human torso; and
   second end of the secondary air plenum (210) is proximate a chest area of the human torso.

4. The apparatus of claim 1, 2 or 3, further comprising a zipper closure (214) arranged on the outer layer (201), wherein the zipper closure (214) is configured to allow separation and closure of the apparatus.

5. The apparatus of any preceding claim, wherein the primary air plenum (204) comprises at least one inlet port (208,209) configured to receive air exterior to the apparatus.

6. The apparatus of claim 5, wherein the inlet port (208,209) penetrates the outer layer (201).

7. The apparatus of claim 5 or 6, further comprising a fan apparatus (700) proximate the at least one inlet port (208,209), wherein the fan apparatus (700) is configured to force the air exterior to the personal cooling apparatus to flow through the primary air plenum (204).

8. The apparatus of claim 5, 6 or 7, wherein the primary air plenum (204) further comprises a plurality of apertures (507) arranged there-through, wherein the plurality of apertures (507) are proximate the inner layer (502), the plurality of apertures (507) optionally being of a uniform size and of a uniform separation.

9. The apparatus of any preceding claim, wherein the inner layer (502) comprises a turbulence matrix (202).

10. The apparatus of claim 8, wherein the turbulence matrix (202) is configured to disrupt laminar air flow and promote turbulent air flow, the turbulence matrix for example comprising a plurality of individual fibers arranged in a matrix-like pattern.

11. The apparatus of any preceding claim, further comprising a plenum chamber (203) surrounding the primary air plenum (204) and formed of the outer layer (201).

12. The apparatus of claim 11, further comprising an adjustment means (509) arranged within the plenum chamber (203).

13. The apparatus of claim 12, wherein the adjustment means is a drawstring or elastic band (509).

14. The apparatus of any preceding claim, further comprising first and second adjustment means (901,903), wherein the first and second adjustment means are configured to reduce the proportions of the outer layer (201).

15. The apparatus of claim 14, wherein the first and second adjustment means are zippered-pleats (901,902) in the outer layer (201).

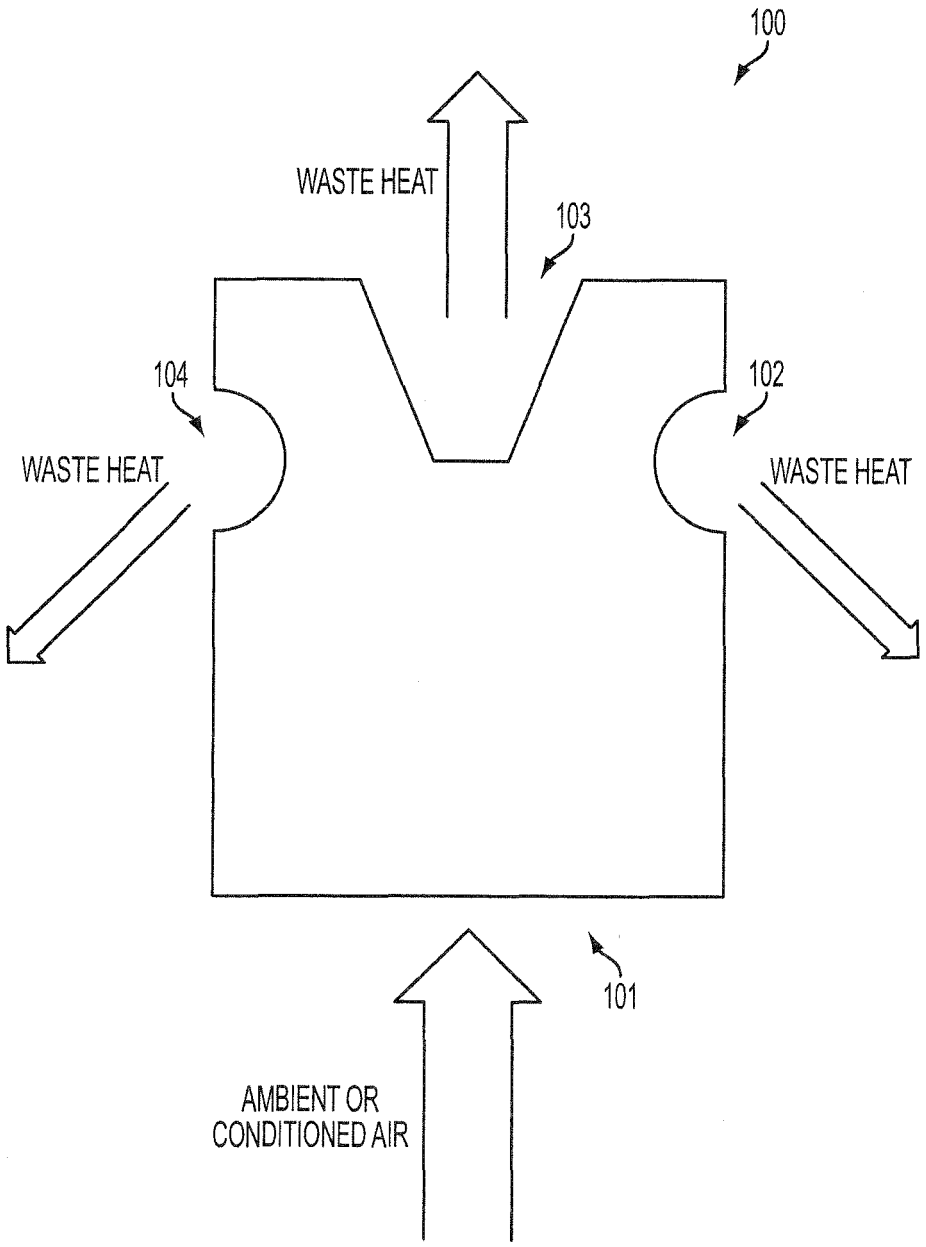
100
WASTE HEAT
103
104
102
WASTE HEAT
WASTE HEAT
101
AMBIENT OR
CONDITIONED AIR

FIG. 1

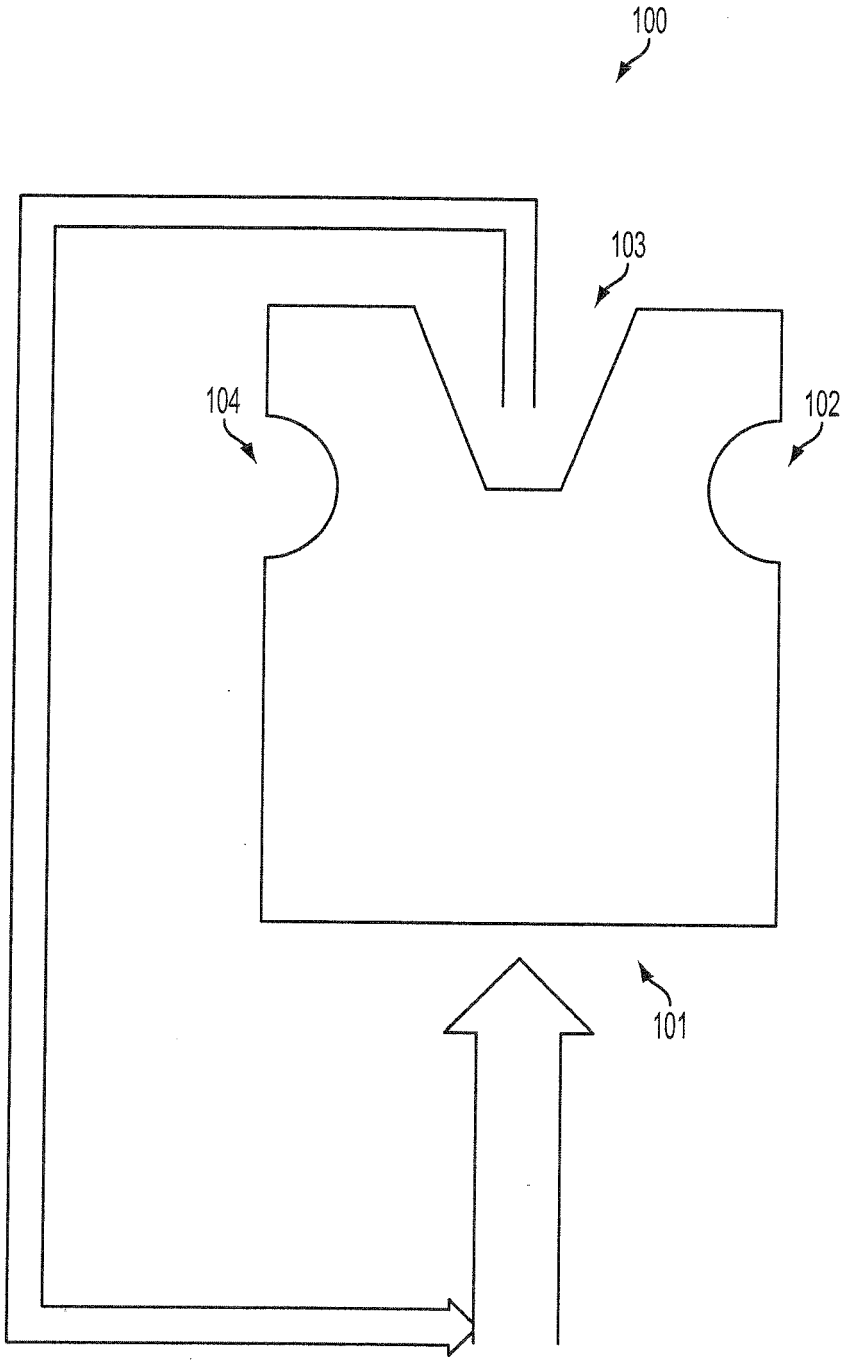

FIG. 2

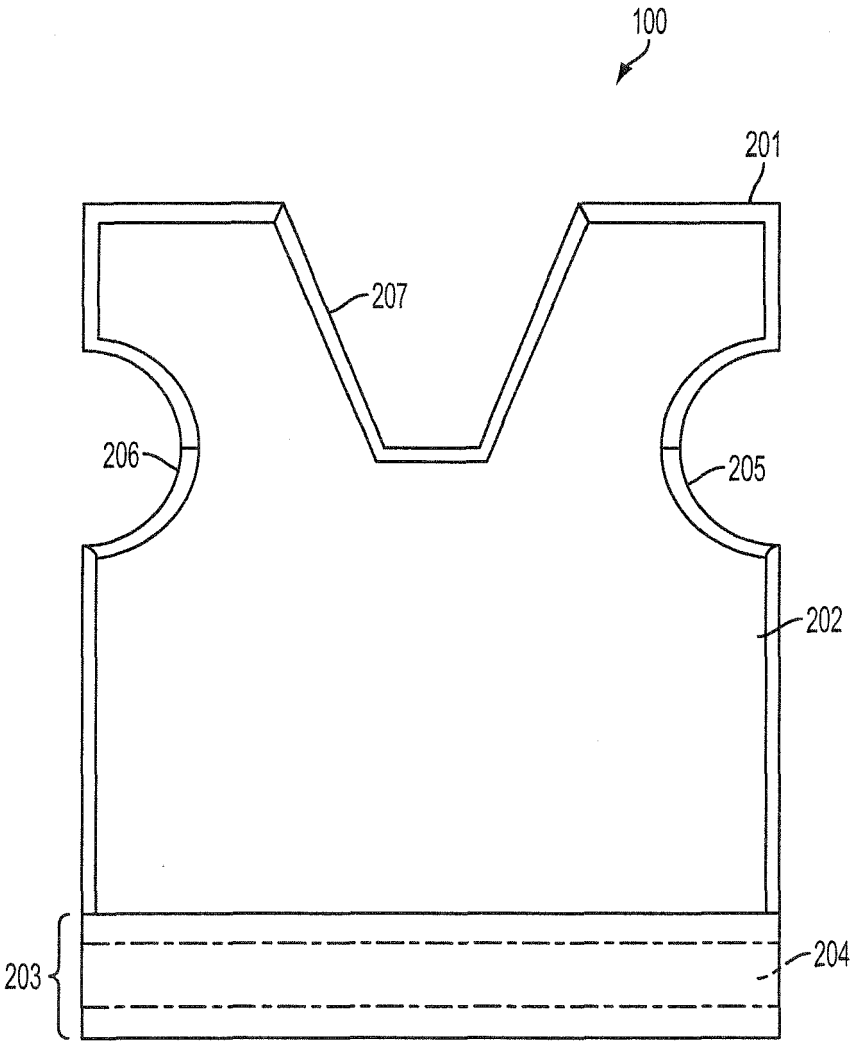

FIG. 3

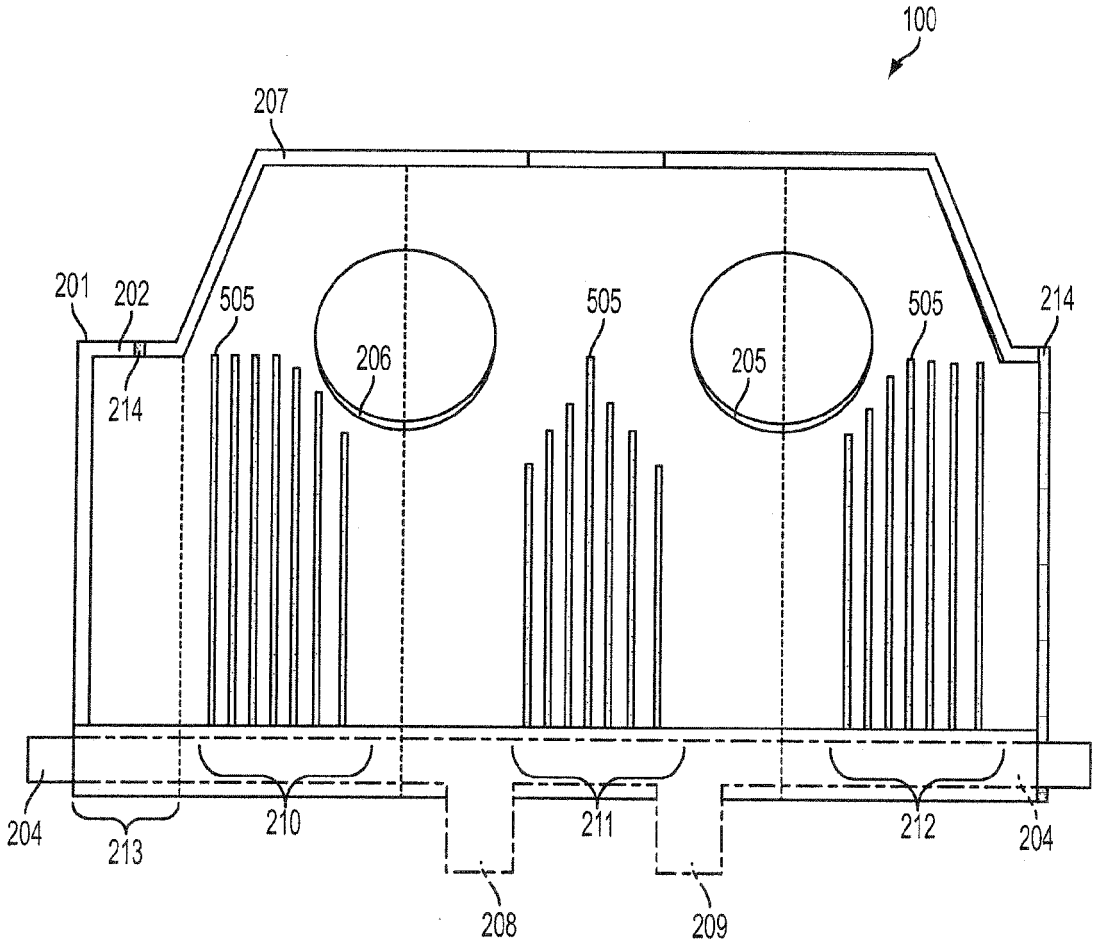
100
207
201
202
214
505
206
505
205
505
214
204
213
210
211
212
204
208
209

FIG. 4

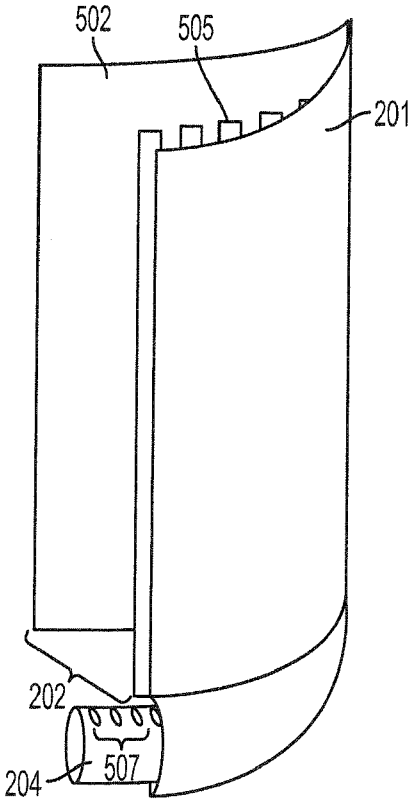

FIG. 5A

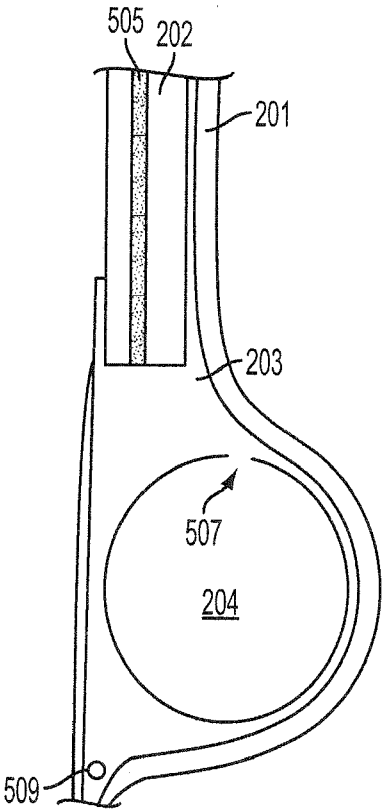

FIG. 5B

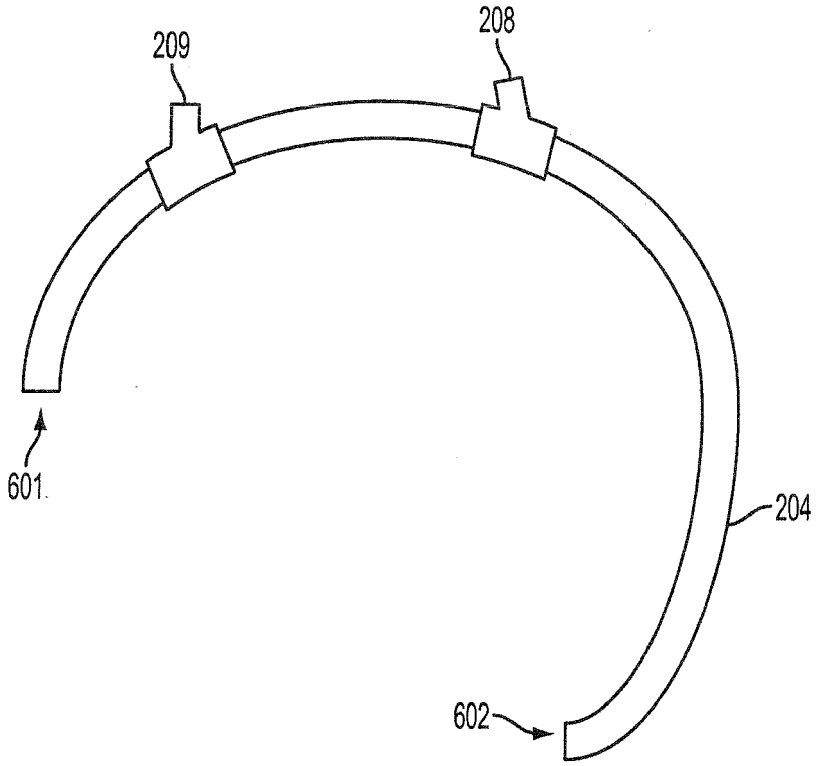

FIG. 6

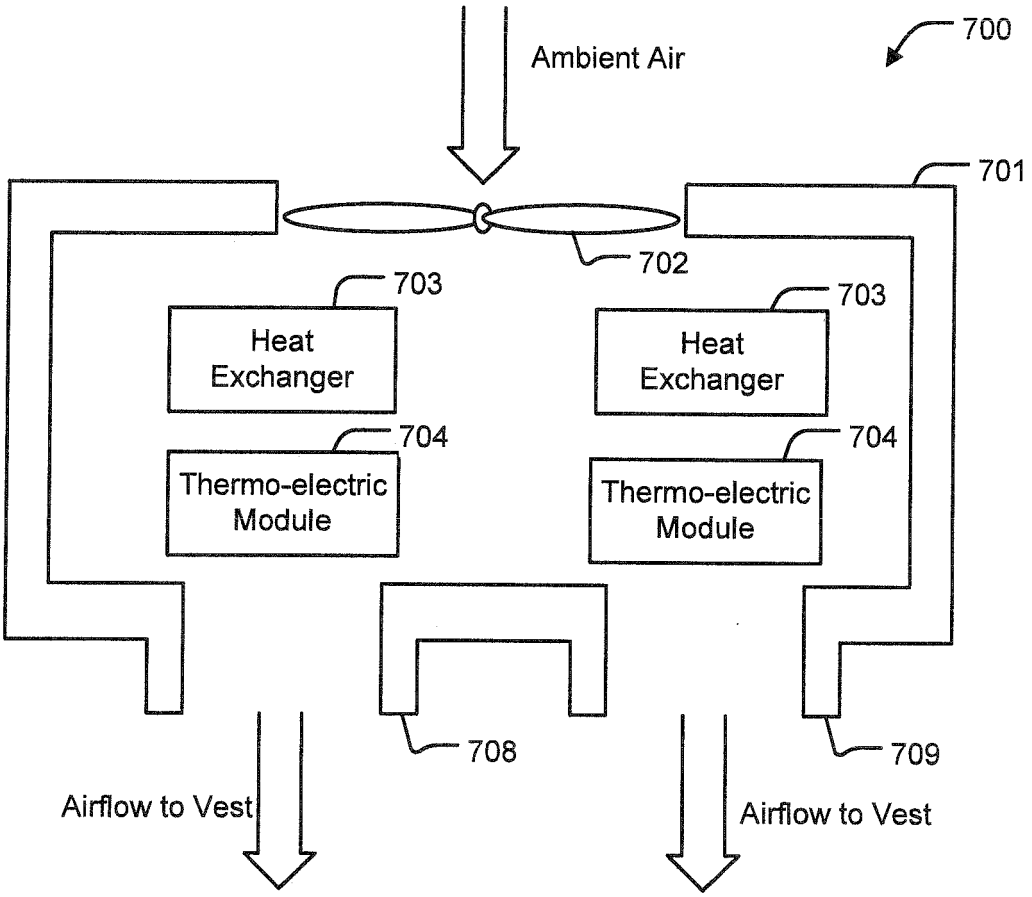
Ambient Air
700
701
702
703
Heat Exchanger
703
Heat Exchanger
704
Thermo-electric Module
704
Thermo-electric Module
708
709
Airflow to Vest
Airflow to Vest

FIG. 7

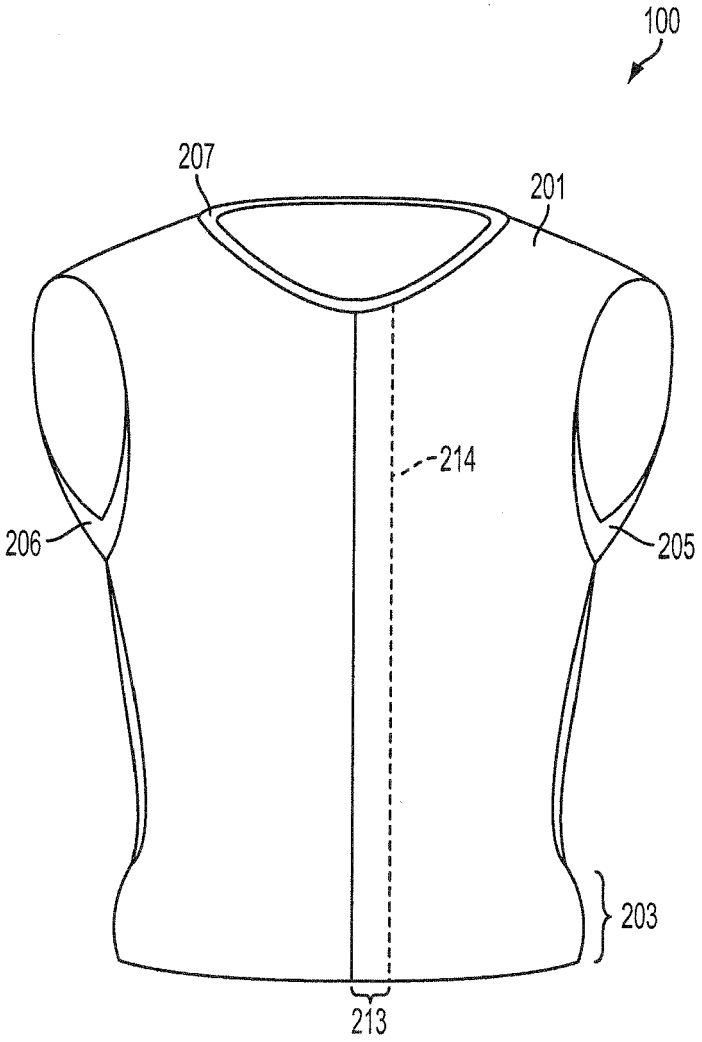

FIG. 8

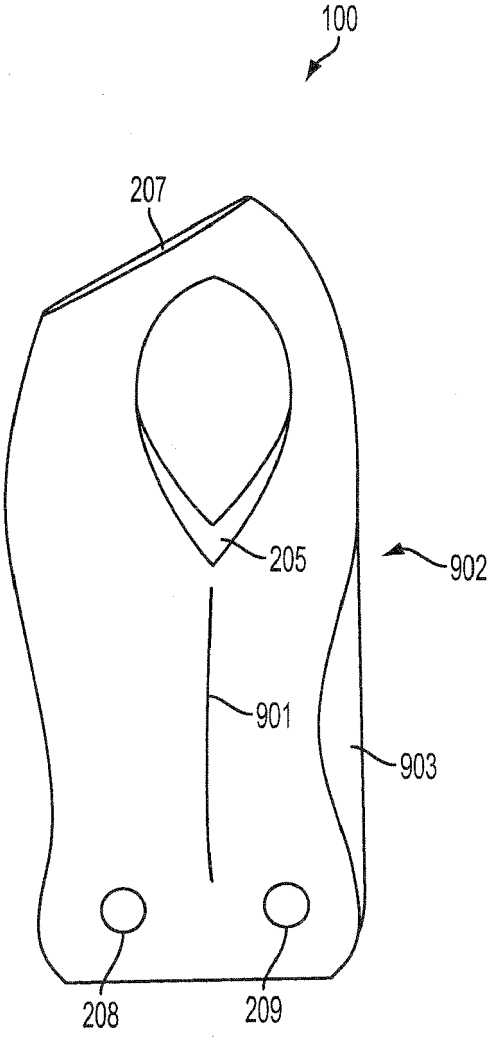

FIG. 9