

Jan. 24, 1956

V. STARK

2,731,808

REFRIGERATED CLOTHING

Filed April 22, 1955

3 Sheets-Sheet 1

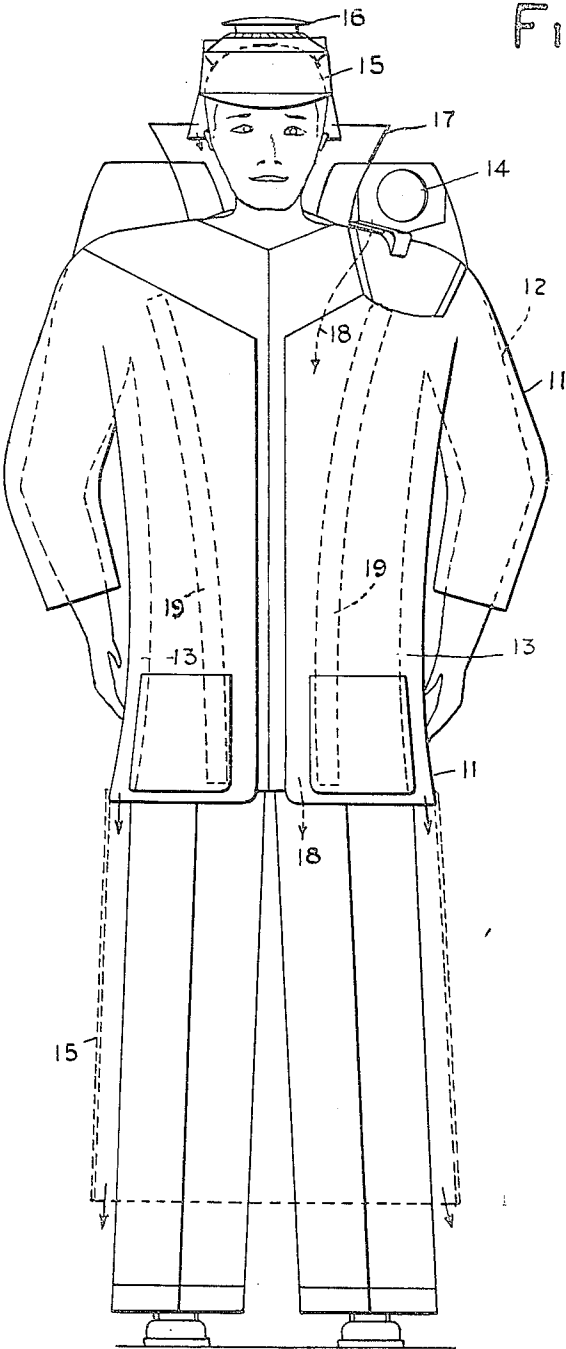
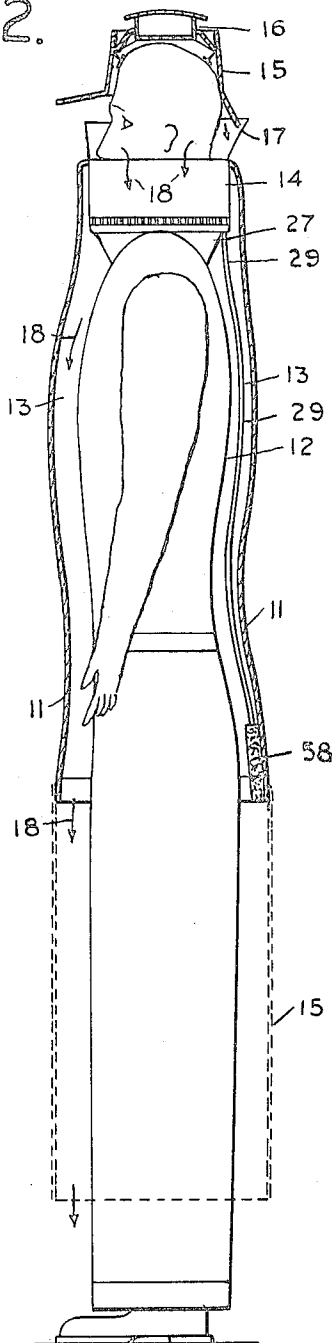


FIG. 1.

FIG. 2.



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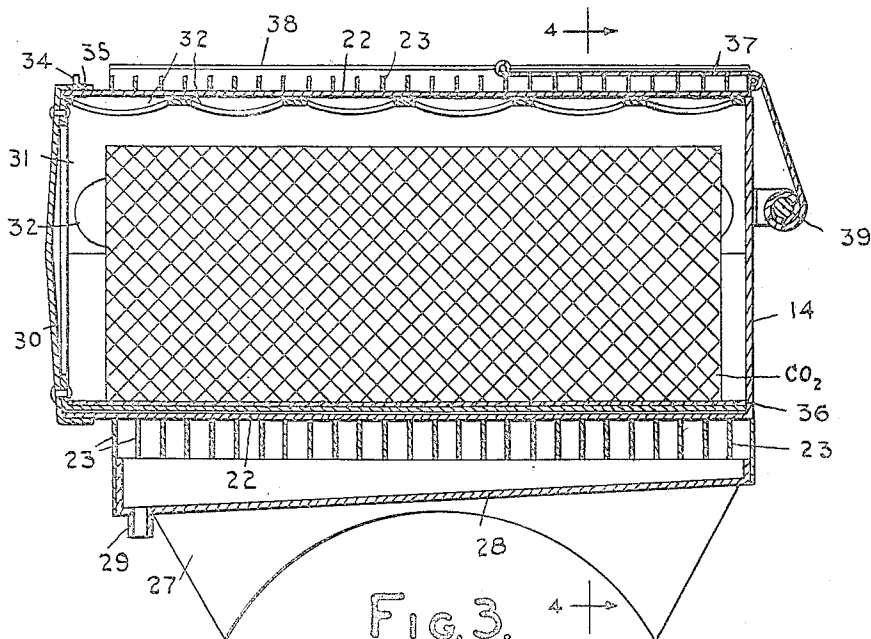


FIG. 4.

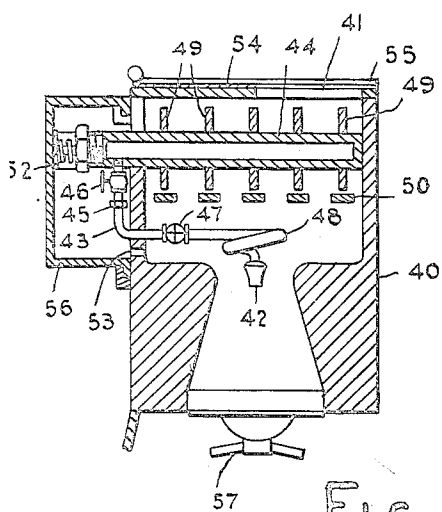
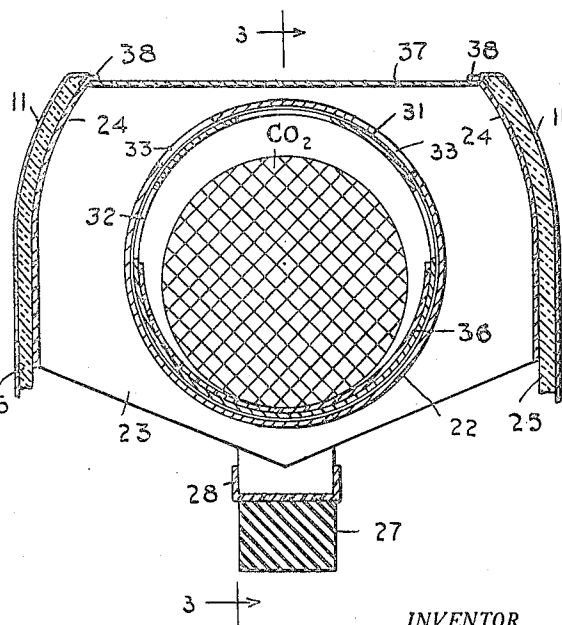


FIG. 5.



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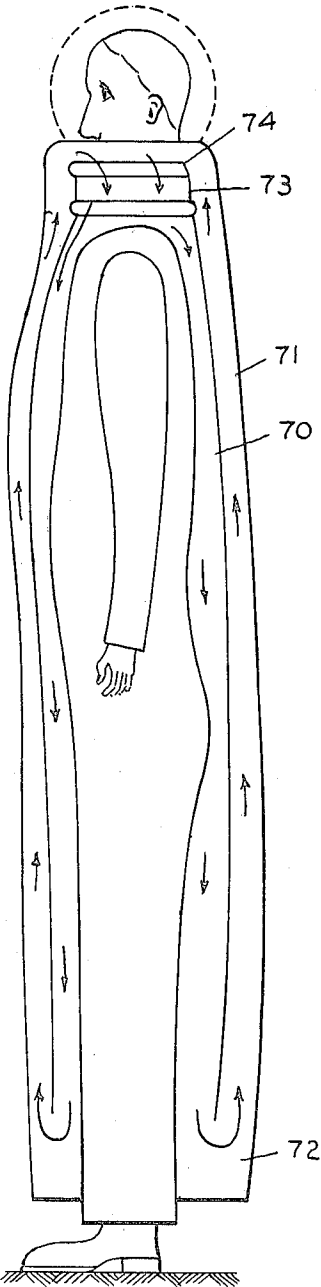
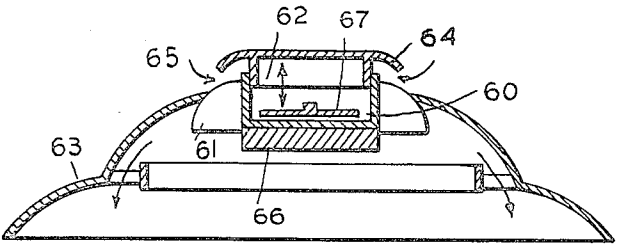
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FIG. 7.

FIG. 6.



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REFRIGERATED CLOTHING

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Application April 22, 1955, Serial No. 503,313

11 Claims. (Cl. 62—9)

This invention relates to refrigerated clothing and means for creating bodily comfort, and is a substitute for and in part a continuation of my application Serial No. 399,950, filed December 23, 1953, now abandoned.

The object of this invention is to obtain by a system including proper refrigerated clothing around the human body an intermediate environment of comfort even if the ambient temperature and/or vapor pressure or sun radiation may make otherwise the human body feel uncomfortable or may result in exhaustion or death.

The invention aims to promote sustained bodily comfort by maintaining thermal equilibrium in the body within the range corresponding to comfortable mean skin temperature.

The invention consists in creating an intermediate environment between the human body and a properly designed clothing of adequate material provided with a refrigeration system consisting of a refrigerant, such as a replaceable Dry Ice charge carried in a special container, combined with heat transfer elements, which cools the ambient air and results in the creation of an airflow by gravity difference between the cooled air and the ambient air; and the invention further comprises a system of conducting and distributing such an air flow in the intermediate environment, which airflow will carry away the heat dissipated by the human body and the evaporated water from sweat.

This system will operate as follows:

The container filled with solid CO² (−109.6° F. at 14.7 p. s. i. a.) will have cold metallic surfaces 40–60° F., for instance. The ambient air will be cooled when in contact with the cold metallic surfaces of the finned container. The cooled air is heavier than the warmer ambient air and will tend to flow to the ground by gravity difference between both. In this way, a downwards air flow is "created" by such gravity difference between the air column in the colder intermediate environment (separated by the insulated garment) and the warmer ambient air. The volume of the air flow and its velocity will depend on the temperature of cooling and the friction losses and the velocity will depend also on the cross section of passage available. The latent heat of sublimation or latent heat of vaporization of the CO² will basically supply the main refrigeration of the air. The CO² vapor produced may be released from the container into the air flow and the sensible heat of the cold CO² vapor will supply additional refrigeration.

For increase in air flow (but not indispensable to the system) the following can be provided in addition to above: The CO² vapor released may be discharged into the incoming cooled air passing through an ejector, and will have a suction effect which will increase the volume of air passing through the cooler. The pressure drop through the nozzle will reduce the temperature of the CO² vapor which has been heated before in the cooling coil.

The metallic container partially filled with CO² may be provided with a relief valve which can be set at a certain maximum pressure. If the production of the CO²

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vapor in the container is higher than the volume of the vapor which is allowed to be released through the regulating valve, the pressure in the container will increase but not above the maximum pressure at which the relief valve is set. The temperature of the container filled with solid CO² depends upon the inside pressure and can, therefore, be regulated by setting the relief valve on one side and the flow regulating shut-off valve on the other side.

The human body dissipates the generated heat in form of radiation, conduction, convection and evaporation. The cooled air and CO² vapor flow will absorb the heat generated by the human body and dissipated through radiation and convection, and the temperature of the air will gradually increase as it flows downwards.

The temperature of the air after being cooled by the finned container will drop sharply, for instance, from 100° F. ambient temperature to 50° F. around the fins.

The cooled air cannot hold as much moisture as the incoming warm air can, therefore, along with the drop in temperature condensation occurs and this mostly along the container fins. The container is preferably inclined with provision for collection of moisture which is conducted by plastic tubes to a water absorbing sponge element which is removably incorporated in the lining of the clothing.

The air after being cooled to low temperatures by the finned container will be gradually heated by the heat dissipated by the body when flowing downwards. However, as the temperature rises the moisture absorption capacity of the air increases. This makes the system of greater interest as it not only reduces the temperature of the body environment but, at the same time, it also increases the absorption capacity of the humidity dissipated by the body allowing a larger margin of comfort feeling.

In short, my invention comprises properly designed clothing of suitable material and refrigeration means utilizing solid carbon dioxide (Dry Ice) or other refrigerant charged in a finned container, and provisions for maintaining a flow of cooled ambient air in the intermediate environment of the human body, together with control devices for regulating the temperature and flow into the air, thereby allowing to obtain selected temperatures in such environment and increasing its humidity absorption capacity.

I prefer to use solid carbon dioxide as a refrigerant material, as it volatilizes under atmospheric pressure at −109.6° F., and the vapor is heavier than air at the same temperature, forming therewith a cold mixture which tends to flow to the ground. The latent heat of sublimation of solid CO² is 246 B. t. u. per lb., which, added to its sensible heat of CO² cold vapor of approximately 34 B. t. u./lb. makes available about 280 B. t. u. per lb. for refrigerating the ambient air in the intermediate environment of my system. The CO² vapor released in the environment and thereafter in the ambient air has the advantage of being an inert gas, therefore not inflammable, and also a gas which is non-toxic and harmless to human beings. The introduction of CO² vapor in the air flow also tends to reduce the vapor pressure of the mixture.

A preferred design of garment and air cooling and circulating means operating according to my system are shown in the accompanying drawings, together with a modification thereof, and the features comprised in my invention are set forth in the appended claims.

In the drawings, wherein like reference characters designate like parts in the several views:

Figure 1 is a front view of a manikin wearing a garment partly broken away at one shoulder to disclose cooling means according to my invention;

Figure 2 is a side view of the same manikin, comprising a vertical mid-section through the outer garment expos-

ing the cooling means and the refrigerant container and vapor and air mixer in side elevation;

Figure 3 is a vertical longitudinal section of the refrigerant container on the line 3—3 of Fig. 4;

Figure 4 is a vertical cross section of the refrigerant container and air mixer on the line 4—4 of Fig. 3, Figs. 3 and 4 being drawn to a larger scale than Figs. 1 and 2;

Figure 5 is a vertical section longitudinally of the axis of the modified form of container;

Figure 6 is a cross-sectional view of a head cover containing a receptacle for a refrigerating medium; and

Figure 7 is a diagram illustrating a further modification of my invention.

In the embodiment of the invention shown in Figures 1 to 4, inclusive, a loosely fitting insulating coat or cloak, preferably of light foam plastic, 11, of conventional style is worn by a manikin 12, the loose fit of the garment below the shoulders providing an encircling space 13 around the body of the wearer, and a refrigerating device 14 providing the desired environment within said space, the ribs 19 causing the insulating garment to be spaced away from the body and facilitating the circulation of the downwards moving airflow. Preferably the refrigerating device is supported by the shoulders of the wearer, as shown in Figure 1. An insulating cap or helmet 15 may be worn on the wearer's head and provided with a small refrigerant container 16, or a refrigerating system may be installed at top part of existing headwear, such as a colonial helmet, by providing the finned container filled with refrigerant charge to cool the air, and providing open spacing between the head and the helmet to allow the downwards air flow around the head and continuing along the neck to which it may be conducted by a proper fabric extension of the hat.

A hood 17 may be secured to the garment about the collar for additional protection from the sun radiation while receiving the flow of refrigerated air from the head, and to provide a conduit for atmospheric air to enter the garment at the neckline; and pants or a skirt 15 may be secured to the lower part of the garment for extending the intermediate environment to afford additional protection and comfort.

The refrigerating means 14, 16 cool the air in immediate contact therewith which then flows downwards around the wearer between his body and the insulating garment, as indicated by the arrows 18 in Figures 1 and 2, escaping from beneath the lower part of the garment in this form of the invention.

The preferred form of refrigerating means 14 shown in Figures 3 and 4, comprises a cylindrical container 22 provided with a number of fins 23 on its exterior which are welded or otherwise secured at their lateral edges to side walls 24 extending from end to end of the container and covered with insulation 25 between their outer faces and the encompassing portions of the garment 11 into which they are fitted. The insulation 25 may extend downwards within the garment as far as desired but for comfort it need not extend much below the shoulders.

The container is supported by a shoulder pad 27 to which it is secured at its ends. Between the shoulder pad and the under side of the container, beneath the lower edges of the fins 23, a trough 28 is provided to collect moisture from the air which may condense on the fins. A drip pipe 29 at one end of the trough leads to a sponge 58 in an aperture in the garment 11 to receive this moisture and protect the wearer's clothing.

One end of the container 14 is closed and the opposite end is covered by a removable cap 30 which is secured to one end of a horizontal cylinder 31, the other end of which is open to receive the charge of solid carbon dioxide, and which fits loosely within the cylinder 22. The upper half of this cylinder 31 is provided with orifices 32, which register with similar orifices 33 in the upper part of the outer cylinder 22 when the cylinder 31 is

rotated, so as to change the heat transfer factors. A pin 34, working in a slot 35 in the edge of the cover 30 secures the latter in position. A sheet of insulation 36 may cover the lower half of the cylinders and normally supports the solid carbon dioxide charge to protect it from direct contact with the metal of the container.

A sliding flexible cover 37 running lengthwise on tracks 38 extending along the top edges of the side walls 24, and one end of which is rolled upon the shaft 39, may be manually adjusted lengthwise to uncover a greater or lesser area of the top opening into the refrigerating device 14 and expose a larger or smaller number of the fins 23 to the flow of air therethrough, thereby affording a measure of control over the refrigeration process.

The refrigerating device illustrated in Figure 5 comprises a casing 40 which is provided with an opening 41 in its top through which air can enter, and an interior space leading to one or more ejector passages in which one or more expansion nozzles 42 may be arranged to assist in drawing air through the device when in operation. The valved outlet tube 43 leads to the nozzle 42 from the pressure changer 44 which contains the solid CO₂ charge, a removable connection 45 being provided for replacing the refrigerant charge. The relief valve 52, a shut-off valve 46 and a pressure regulating valve 47 are also provided in the outlet pipe for controlling the flow of vaporized CO₂ to the expansion nozzles. A coil 48 is also provided for further cooling the air and heating the CO₂ vapor before expansion and refrigeration in the nozzle 42. The CO₂ vapor is released through the shut-off and regulating valve and thence through the pressure regulator. The CO₂ vapor passes eventually through the nozzle placed in the ejector passage and commingles with the ambient air drawn in thereby. The excess CO₂ vapor released by the relief valve will be introduced in the air flow by proper openings 53 in the wall of the casing.

Control of the air refrigeration can also be obtained by varying the surface of passage and the surface of heat transfer of the pressure chamber containing the charge by means of a regulating device in the top wall of the casing above the pressure chamber, such as the valve 54 made of insulating material and slidable on a suitable track 55 for covering more or less the upper surface of the pressure chamber. In this way not only the capacity of the air passage can be varied, but also the surface of heat transfer as more or less fins and exposed parts of the pressure chamber are uncovered, thus regulating both the volume of air flow and also its cooling.

A removable cap 56 is provided to cover and insulate the regulating valves and the exposed part of the cylinder 44. A collector and distributing pipes 57 may be provided for circulating the mixture of cooled air and CO₂ vapor as desired.

The casing 40 in the form of device illustrated in Figure 5 is either insulated or it is placed in a compartment made of insulating material with openings at top and bottom between the garment 11 and the body of the wearer, allowing the entering air to be cooled and flow downwards in the intermediate environment from the ejector passage.

By extending the high pressure refrigeration system illustrated in Figure 5 to discharge within the cover of the head, a supply of cool vapor may be obtained for absorbing the heat losses of the neck and head. In such a case, the flow has to be upward from the container, and CO₂ vapor under pressure can readily be distributed to the desired upper part.

Preferably another finned container charged with Dry Ice may be placed as shown in Figure 6 at the upper part of the headcover so as to provide a flow of cooler air around the head similar to the system provided for the trunk. Figure 6 shows a container 60 with fins 61 and a removable cover 62 in the crown of a helmet 63. The vertically sliding cover 62 is provided with extension

rim 64 which, by changing position, may increase or decrease the air passage 65 to the fins 61, the head of the wearer being protected by an insulating pad 66. The cooling capacity and the cooling temperature can also be varied by introducing in the container 60 an insulating element 67 made out of plastic to be located at the bottom of such a container which will reduce the heat transfer and therefore the cooling effect. One or more of these removable elements 67 can be used for the above variation.

The entire refrigeration apparatus can be put conveniently on the back of the person along the shoulder line or above the shoulders, preferably in one container above each, and covered in a fashionable way by a proper collar. The clothing or the suit, preferably both, covers the apparatus and distributes the flow along and around the body. Between the cooling apparatus and the body of the wearer a heavy insulation will preferably be provided. The size of the container and apparatus, the charge of CO₂, and the garment, will be designed so as to suit the existing ambient conditions and the conditions desired and to keep the weight at a minimum.

The clothing forming the separation from the ambient atmosphere can be made of any suitable insulating material. The outside part of the clothing can be made to better reflect the sunshine radiation with proper means, such as metal powder evaporated into cloth, or adhering to the surface of coated cloth, or mixed with plastic or coated on cloth or metals in continual layers such as aluminum foil, or lamé, or metal ribbons wrapped around yarn. However, the inside of the cloth can be made in a different way in order to increase the absorption of the heat diffused by radiation from the body. The introduction of CO₂ in the intermediate environment will change the radiation conditions as CO₂ gas has different emissivity and radiation absorption than the air and this will increase the radiation dissipation of the body. In addition to the increase in the quantity of moisture absorption as indicated above, an apparatus for dehydration of the air flow can be introduced after the cooling unit in order to reduce further the vapor pressure in the intermediate environment.

This invention will not only create an intermediate environment temperature lower than the ambient one, thus changing the proportion of heat dissipation by evaporation on one side and convection and radiation on the other side, but also will activate the heat dissipation by convection (forced circulation) and evaporation by increasing the velocity of the surrounding intermediate air flow.

The effect of air movement increases the cooling power of air and results in a more pleasant feeling at higher temperatures. The convection heat transfer will more than double if the air velocity be increased from 10 feet/min. to 50 feet/min. The evaporative dissipation of heat is also increased with higher velocity of the air and will vary with the square root of the air velocity. The heat absorbed by the air and CO₂ flow in the intermediate environment will correspond only to the heat dissipated by the body in form of radiation and convection. Such heat dissipation by radiation and convection is nil when the ambient temperature is equal to the mean skin temperature (when all heat dissipation is made only through perspiration and evaporation) and increase with the temperature differential. Therefore, the heating of the air and CO₂ flow in the intermediate environment space will depend on the temperature selected for such flow for comfort conditions.

The temperature increase of the flow and the outlet temperature from the intermediate space will also depend on the volume of air passed through, the initial temperature (atmospheric temperature), the amount of refrigeration and also the velocity of such flow. As illustrated above, both the air volume and refrigeration can be set as desired considering the conditions selected and

the atmospheric conditions. All of the above factors will determine the consumption of Dry Ice and therefore the charge of Dry Ice that is necessary and its duration. Tests made with an insulating jacket embodying my invention, having a weight of approximately 4 lbs. including refrigeration equipment, have shown that the temperature in the intermediate environment can be regulated to 10°–40° F. below the ambient temperature, and the refrigeration capacity may be regulated for a low of approximately 100 B. t. u./h. to a high rate of approximately 900 B. t. u./h., the volume of air and the speed increasing with higher cooling rates.

For special purposes, such as polluted ambiances and even atomic warfare, special garments with double intermediate environments in a closed system can be made as illustrated by Fig. 7. In such a case there will be two closures surrounding the body, properly separated and insulated, one 70 adjacent to the body with a downward flow of cooled air, and an outer enclosure 71, with an upward flow of air, the air being gradually warmed by the heat dissipated by the body. The system will be closed at the bottom 72 of the garment so that the warmed air will not be let out of the system but will flow upward in the second enclosure 71 adjacent to the inner one. The warm air will then be cooled at the top of the system by the finned container 73 filled with Dry Ice or other refrigerant charge, and thereafter the air will flow into enclosure 70. The system will be closed at the top by a suitable collar 74 and at the bottom by the downward extension of the outer garment so that the ambient air eventually polluted will not be let into the system but will allow the reducing of the temperature around the body, which otherwise may increase above permissible limits by the body heat dissipation.

The system may be completed with a reserve of pure air under pressure to be released in the environment and a back pressure valve for release of the circulating air to ambient if desired.

Other refrigerants than Dry Ice can be used with the above system, such as liquid nitrogen, liquid oxygen, liquid air, ice, hydrogen peroxide and eutectic solution, etc., with proper adaptation and modification thereof.

This invention can also be applied to cover and cool only specific parts of the human body such as arms, legs, etc., increasing the heat dissipation in such parts and obtaining a feeling of pleasantness for the whole body.

The invention can be applied also for creation of intermediate environment for a larger covering or surrounding of the human body other than clothing, such as blankets, ponchos, etc. with proper adaptations, and which are comprised within the word "garments" as used in the claims.

From the foregoing it is evident that the invention proposes to create an intermediate environment between the human body and the outside ambient which will have the following effects:

1. Decrease the ambient temperature to an operating temperature of comfort.
2. Decrease the vapor pressure of the ambient air flow increasing its capacity for moisture absorption and thereby the dissipation possibilities of sweat.
3. Change the proportions of heat dissipation by evaporation on one side and radiation and convection on the other side by change of environmental conditions to differ from ambient conditions.
4. Increase the transfer through convection and evaporation by increasing the velocity of the air flow.
5. Regulate the system to the desired conditions.

The invention would have a large use not only in desert and tropical climates, but also in industries where work is done in hot environments, including furnaces, rolling mills, glass works, boiler rooms, cement works, and in the armed forces, protection for fire extinguishing, polluted ambiances.

I claim the following as my invention:

1. A portable system of maintaining a protective and comfort promoting intermediate environment between a human body and the ambient atmosphere comprising a suitable body encompassing garment providing space at least in part surrounding the body upon which it is adapted to be worn and having passages from top to bottom for circulation of a mixture of air and vapor, cooling means associated with a top passage in said garment arranged for causing thermal circulation of the atmosphere within the intermediate environment, a source of vaporizable refrigerant for said cooling means, and control means associated therewith for accommodating the system to changing conditions of thermolysis.

2. A portable system of maintaining a protective and comfort promoting intermediate environment between a human body and the ambient atmosphere as set forth in claim 1 wherein the system comprises inner and outer circulation spaces surrounding the body and a connecting passage from one to the other at the bottom permitting circulation downwards in the inner and upwards in the outer space.

3. A portable system of maintaining a protective and comfort promoting intermediate environment between a human body and the ambient atmosphere comprising a suitable body encompassing garment providing space at least in part surrounding the body upon which it is adapted to be worn and having passages from top to bottom for circulation of air and vapor, cooling and atmospheric humidity condensing means associated with a top passage in said garment arranged for trapping moisture in the entering air and causing thermal circulation of the atmosphere within the intermediate environment, a source of vaporizable refrigerant for said cooling and condensing means, and control means associated therewith for accommodating the system to changing conditions of thermolysis.

4. A portable system of maintaining a protective and comfort promoting intermediate environment between parts of a human body and the ambient atmosphere comprising suitable body encompassing means including a garment and headcover providing space surrounding the parts of the body upon which it is adapted to be worn and having vertical passages for circulation of air and vapor, cooling means therefor in said garment and head cover associated with a top passage in said body encompassing means and arranged for causing thermal circulation of the atmosphere within said intermediate environment, a refillable finned container providing a source of replaceable vaporizable refrigerant for said cooling means, and vaporization regulating and flow control means associated therewith for accommodating the system to changing conditions of thermolysis by varying the temperature, humidity, volume and velocity of flow of air-vapor mixture and rate of absorption thereby of the heat dissipated by the body.

5. A portable system of maintaining a protective and comfort promoting intermediate environment between a human body and the ambient atmosphere comprising a suitable body encompassing garment providing space at least in part surrounding the body upon which it is adapted to be worn and having passages from top to bottom for circulation of air and vapor, cooling and atmospheric humidity condensing means associated with a top passage in said garment arranged for trapping moisture in the entering air and causing thermal circulation of the atmosphere within the intermediate environment, removing trapped moisture from the air and thus increasing its humidity absorption capacity when it is gradually heated in passing said environment, a refillable container of vaporizable refrigerant for said cooling and condensing means, and control means associated therewith for accommodating the system to meet changing conditions of thermolysis.

6. A portable system of maintaining a protective and comfort promoting intermediate environment between a human body and the ambient atmosphere as set forth in claim 5 wherein the system comprises two intermediate environments one with inner and one with outer circulation spaces surrounding the body and a connecting passage from one to the other at the bottom permitting circulation downwards of the cooled air in the inner space and circulation upwards of the warmed air in the outer space.

7. A refrigeration apparatus comprising a loose garment having vertically disposed inner spacing means between it and the body of the wearer providing passages for air forming an intermediate environment for said body, in combination with a closed metallic container provided with heat transfer fins and adapted to be filled with a replaceable Dry Ice charge and placed in the upper part of said garment, thereby creating a cooled air flow by gravity in said intermediate environment and absorbing moisture from the body collected in said intermediate environment.

8. An apparatus as set forth in claim 7 wherein the finned container is provided with a regulating device consisting of an insulating support for the solid Dry Ice which is removably and adjustably positioned inside the finned container with provisions to move one with respect to the other to vary the heat transfer from the Dry Ice in the container to the metallic outside surface thereof and the fins thereon.

9. Apparatus as set forth in claim 7 provided with a control valve to regulate the refrigeration effect by variation and setting of the release of the CO² vapor so as to obtain more or less heat absorption from the latent heat of sublimation, and a safety relief valve on the container set at a desired pressure so that when production of CO² vapor exceeds the release volume, the safety valve will open and the excess vapor will be introduced in the air flow.

10. Apparatus as set forth in claim 7 provided with a nozzle for CO² vapor and with a cooperating pressure regulator to increase the cooling effect by pressure drop of CO² vapor, combined with an ejector for suction of ambient air and increase in the volume of air passing through the cooler, and provided with an additional heat transfer element, in the form of a coil filled with released CO² vapor at low temperature, allowing further cooling of the air and heating of the CO² vapor before the expansion in the nozzle and consequent reduction of the temperature of the CO² vapor.

11. An apparatus as set forth in claim 7 provided with a regulating device consisting of a slidable cover which is adjustable with respect to an air passage affecting flow past the finned container thereby allowing regulation of the heat transfer between the latter and the air to be cooled, and means controlling the amount of exposed surface of heat transfer of the Dry Ice charge regulating thereby the cooling effect of the temperature of the air after passing the container and also the volume of airflow in the intermediate environment and amount of moisture absorbed thereby.

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