March 29, 1966 A. P. SHLOSINGER 3,242,979

LIQUID AND GAS COOLED GARMENT

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Fig. 1

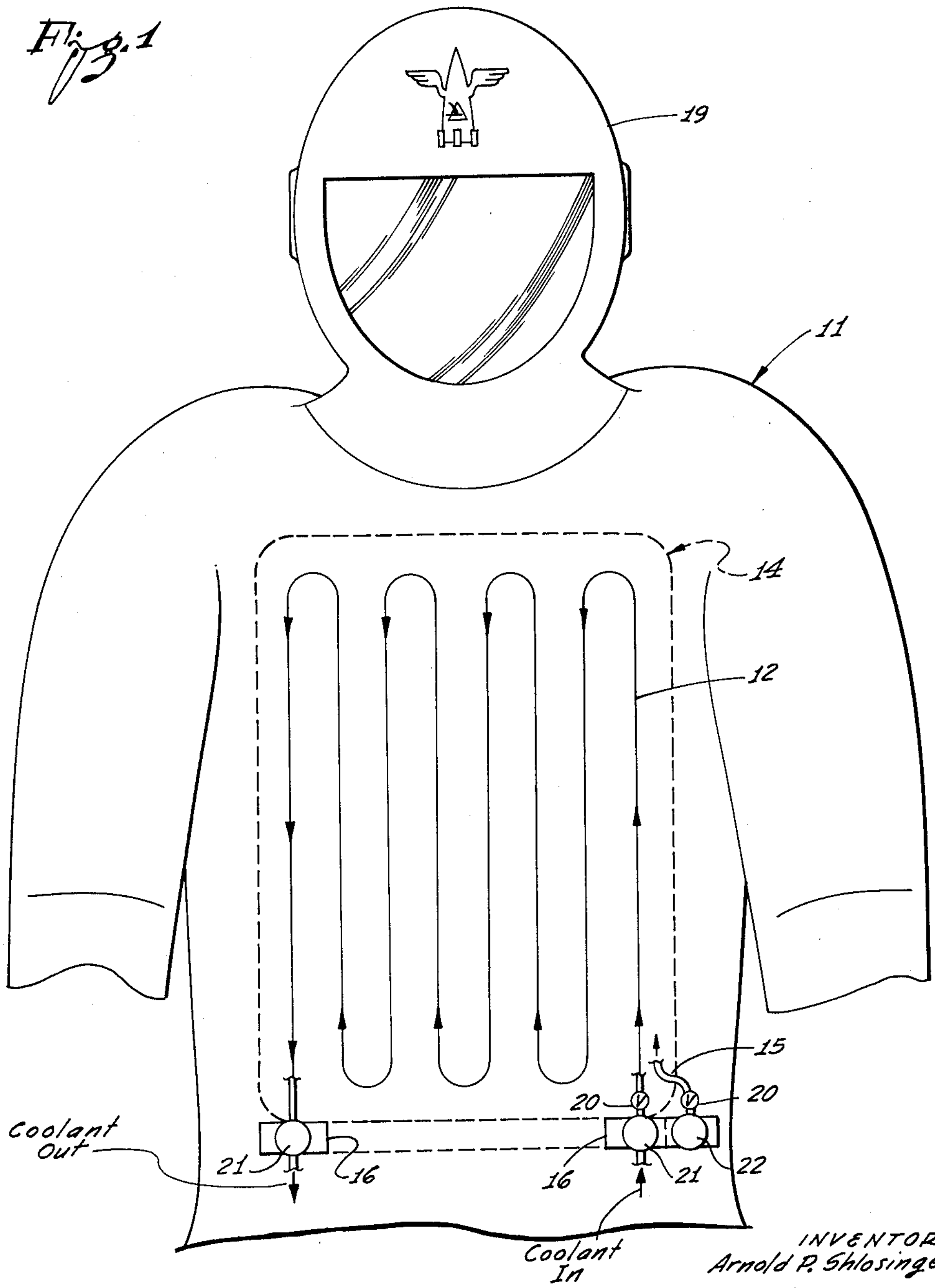


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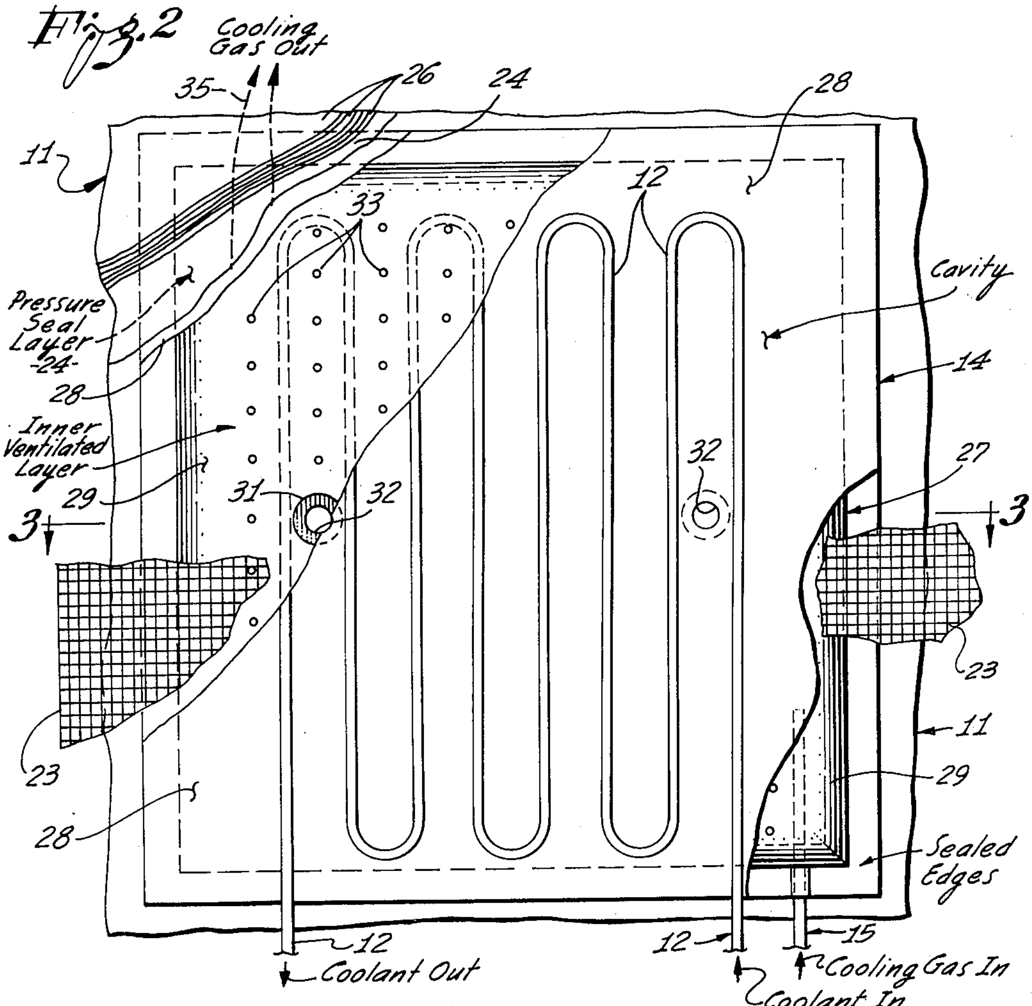
Fig. 2



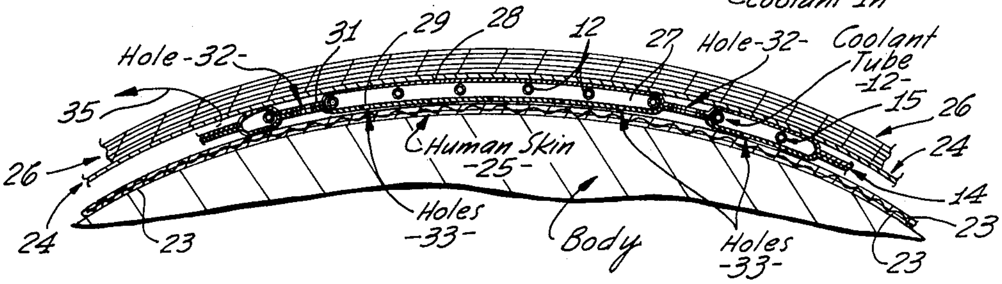




Fig. 3

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# 3,242,979
# LIQUID AND GAS COOLED GARMENT

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5 Claims. (Cl. 165—46)

This invention pertains to heat transfer apparatus and more particularly to a garment adapted to maintain a desirable thermal balance of a space worker wearing the garment.

The optimum temperature range for human beings constitutes a very narrow band in the broad spectrum of potential temperatures associated with space flight and environs.

To maintain a person in a survivable and comfortable thermal environment within a pressure suit, heat generated as a result of his metabolism and heat reaching the body from the external environment must be removed from the proximity of his skin. The heat generated by metabolic action is emitted in two distinctly different forms. The first is sensible heat, i.e., thermal energy which can be removed from the skin by conduction, convection and radiation. The second is water vapor, containing a fraction of the metabolic heat of evaporation. This vapor can be removed by flushing with a circulating gas.

In order to minimize the effects of the wide band of external environments which are possible in space operations, the concept used will, to the highest practical degree, thermally isolate the man from the effects of the external environment by the use of materials with a high thermal insulating value between the external and internal garment surfaces. With this concept established, the problem essentially reduces itself to controlled removal of the metabolic heat.

Existing pressure suit assemblies utilize circulating gas (oxygen) as the primary or only means of removing heat from the proximity of the skin. This circulating gas removes sensible heat by convective cooling to the low temperature gas and removes latent heat by flushing of evaporated body perspiration. Due to the low heat transfer coefficients, low density, and relatively low heat capacity associated with circulating gas at the pressure commonly used (3½ to 5 p.s.i.a., for example), the convective transfer of sensible heat is small. In such systems, primary reliance for removal of the body metabolic heat must therefore be placed upon the evaporation of perspiration, i.e., the latent heat removal method of thermal control. When the majority of heat removal has to be by evaporation of perspiration, too much sweating is involved, and thus an excessive amount of body moisture is removed, together with excessive deposits of salts accumulated in the space garment. Increasing the pressure of the circulating gas would improve heat transfer, but would greatly degrade the mobility of the space worker, thus further reducing his mobility already limited by the space suit.

An object of the present invention is to provide a garment, especially useful in space, in which sensible body heat emitted by a wearer of the garment is removed from the proximity of the wearer's skin primarily by radiation (and to a lesser degree conduction and convection) and with a minimum amount of heat removed by evaporation of body perspiration or latent heat.

Another object is to provide a garment, especially useful in space, adapted to effectively remove the sensible heat generated by a human body at a rate and at an environmental temperature level providing physical comfort for the space worker.



Another object is to provide a garment, especially useful in space, adapted to maintain the partial pressure of water vapor near the space worker's skin at a level permitting the inherent temperature regulation of the human body by evaporation of body moisture to function normally.

Another object is to provide a garment, especially useful in space, adapted to minimize the amount of external heat absorbed by the garment.

In contrast to the conventional systems mentioned above, the present invention described herein envisions shifting the primary method of heat transfer from the latent heat of vaporization to sensible heat transfer. The transfer of the major portion of the generated metabolic heat as sensible heat from the space worker's skin to a heat sink is primarily accomplished by thermal radiation to a garment layer or "wall" (spaced away from the skin) which is maintained at a temperature level of approximately 48° F. This "cooled wall" is spaced away from the skin by a porous spacer material, thus permitting a passageway between the "cooled wall" and the skin for a circulating gas, which will remove evaporated body perspiration. The porous spacer material will also permit some conduction of sensible heat from the skin to the "cooled wall" with only a slight degradation in thermal radiation heat transfer, but will prevent chilling and discomfort by preventing contact between human skin and the "cooled wall." Radiation and conduction heat transfer from the skin to the wall, through which a cool liquid is circulated, is the primary method of thermal control. However, the present system will not entirely eliminate the latent method of heat control, hence not disturb the natural body thermo-regulatory mechanism, but will permit reduction of the reliance upon this method to a minimum.

Briefly, the present invention comprises a space garment embodying a plurality of cooling panels through which both gas and liquid are circulated. The panels are spaced from the body by spacer material of appreciable thickness and low heat conducting abilitiy. The panels include conduit means through which the cooling liquid flows and also define a plenum chamber from which gas (preferably pure dry oxygen) discharges and contacts the skin. The liquid cooling portion of the panels functions to remove sensible body heat while the circulating gas is utilized to remove body heat in the form of latent heat of evaporated perspiration.

Although the characteristic features of the present invention are particularly pointed out in the appended claims, the invention itself, and also the manner in which it may be carried out, will be better understood by referring to the following description taken in connection with the accompanying drawings forming a part of this application and in which:

FIGURE 1 is a schematic view of a portion of a space worker's garment as disclosed herein.

FIGURE 2 is an enlarged fragmentary cut-away elevational view of the chest section of the garment of FIGURE 1.

FIGURE 3 is a sectional view of the chest section of FIGURE 2 as viewed along the line 3—3 of the latter figure, as if no parts were cut away.

Referring to the drawings, FIGURE 1 shows a portion of a preferred embodiment of a space garment 11 as disclosed herein. The specific construction of the garment, also the operation thereof, will be described in detail in connection with FIGURES 2 and 3.

FIGURE 1 and FIGURE 2 schematically illustrate liquid-carrying tubing 12 comprising a component of a cooling panel 44. Although only one panel is shown in FIGURE 1 and FIGURE 2, it will be understood that other panels adapted to cover arm, leg and back portions, etc., may be added to the garment **11** as desired or required. Also entering the panel **14**, in addition to the ends of tubing **12**, is a tube **15** which conveys a dry gas, such as oxygen, thereto.

The tubing **12** carries liquid such as water at a low temperature, the ends of the tubing **12** terminating in a compartmented manifold **16**. Refrigerated liquid and processed oxygen are supplied through the tubes **12** and **15**, respectively. The manifold **16** includes quick connect and disconnect means **21** and **22** for supply lines (not shown) transporting liquid and gas to and from the manifold **16**. Also, individually operable valves **20** are provided, permitting controlling the ingress of fluid to the tubes **12** and **15**.

Referring to FIGURES 2 and 3, the specific construction of the garment **11**, including a typical panel **14**, is shown. The inside of the garment **11** constitutes a double layer of extremely porous nylon netting **23** or the like. The layers of netting **23, 23** are randomly positioned, one on top of the other in juxtaposed relation, in a manner allowing maximum circulation of oxygen therethrough for a purpose that will be apparent presently. The double layers of netting **23** are located next to the skin **25** of a person wearing the garment **11**. The panels **14** are located adjacent to material **23**. In turn, the panels **14** are completely covered by a sealing member **24** fabricated of a material impervious to gas. The member **24** is shaped to conform to a human body having a fluid tight relation around the ankles and wrists of a wearer, but spaces will exist between the outside of the panel **14** and the member **24**, since the two are not bonded together in any manner. Therefore, it will be apparent that the member **24**, when in position on a human body, defines a chamber completely surrounding the wearer thereof adapted to receive and confine a circulating gas therein. The member **24** may be constructed of vinyl plastic material or the like. Surrounding the member **24** is a plurality of layers of aluminized mylar or aluminum foil **26** shaped to be secured to the outer surface of the member **24**. The layers of foil **26** provide good thermal insulating qualities.

The panel **14** includes an envelope **27** consisting of two sheets of vinyl film **28** and **29** of substantially the same size and shape. The edges of the sheets **28** and **29** have a sealed relation except at positions where the tubes **12** and **15** enter and leave the envelope, while at these locations the sheets **28** and **29** have a sealed relation with respect to the tubes **12** and **15**. The tubes **12** and **15** are constructed of vinyl-plastic material and are extremely flexible. The tubing **12** is secured between the sheets **28** and **29**, preferably by cementing to the inner layer **29**, and has a serpentine configuration substantially as shown in FIGURES 2 and 3.

The sheets **28** and **29** also have a sealed relation at certain locations between the portions of the tube **12** as indicated by the numeral **31**, and in the center of these places a hole **32** (approximately ¼-inch in diameter) is provided which goes entirely through the panel **14**. A plurality of substantially smaller apertures **33** is provided in the inner sheet **29**, through which oxygen is fed from the envelope **27**. It will now be apparent that the sheets **28** and **29**, sealed in the above manner, provide a plenum chamber from which oxygen is discharged through the apertures **33** toward the skin **25**. The holes **32** provide means for the egress of humid gas (oxygen) after it has absorbed moisture from the skin **25**.

The tube **12**, and inner sheet **29** of the envelope **27**, are spaced from the skin **25** approximately one-sixteenth (1/16) to one-eight (⅛) of an inch by the net members **23, 23**. Cooling liquid enters the liquid portion of the manifold **16**, flows through the tubing **12** and returns to another segment of the manifold. Liquid flowing through the tubing **12** at a temperature of approximately 48° F., effectively absorbs sensible heat generated by a person



wearing the garment **11**. The tubing **12**, being spaced from the skin **25**, receives the major part of heat transfer from the body to the liquid flowing through the tube **12** by radiation, although some is transferred by conduction.

The cooling gas tube **15** enters the plenum chamber defined by the sheets **28** and **29** and carries dry oxygen from a standard pressure supply of approximately 3½ to 5 p.s.i.a. This oxygen escapes from the aforementioned plenum chamber via the apertures **33** to pass through the coarse netting **23** and contact the skin **25**. In so doing it absorbs latent heat of water vapor in the form of evaporated body moisture. After contacting all portions of the skin **25**, the oxygen then circulates back through the netting **23, 23** and through the cooling panel **14** at the several holes **32**. It then passes between the outer panel layer **28** and sealing member **24** of the suit **11**, as shown by the arrows **35**, to a desired exit area which may be located anywhere at an edge of the garment. In a particular instance, the humidified oxygen may be directed through the neck portion of the garment and into a helmet **19** to be used for breathing. A gas outlet tube (not shown) from the helmet **19** will then return the used oxygen and exhaled gases to a regenerating unit contained in a back pack, for example, for contaminant removal, temperature control and recirculating supply back to the inlet manifold **16** of the suit. The back pack (not shown) is conventional and will contain the cooling liquid supply and return system also.

Thus it will be seen that a full-pressure space worker's garment is disclosed which enables a person to more efficiently perform his duties and also makes possible the other objects of the invention. The same cooling means as described and claimed herein may also obviously be adapted to other types of body covering.

While in order to comply with the statute, the invention has been described in language more or less specific as to the structural features, it is to be understood that the invention is not limited to the specific features shown, but that the method and means herein disclosed comprise several forms of putting the invention into effect, and the invention is therefore claimed in any of its forms or modifications within the legitimate and valid scope of the appended claims.

I claim:

**1.** In a heat exchange equipment adapted to maintain body temperature within a predetermined range, the combination comprising: a pair of sheet members of approximately equal size and shape fabricated of a material that is impervious to gas; the edges of said sheet members being sealed together to provide an assembly defining a fluid chamber; a plurality of spaced apertures provided in one of said sheet members; a plurality of aligned apertures in said sheet members; said sheet members having a sealed relation adjacent said aligned apertures whereby fluid passages are provided between the outer surfaces of said assembly; conduit means secured in said chamber; porous material secured to the outside of said one sheet member; means adapted to maintain said assembly and porous material in close proximity to the body of an animal with said porous material adjacent the animal's skin; first means allowing ingress and egress of a first fluid to and from said conduit means and second means allowing ingress and egress of a second fluid to and from said chamber.

**2.** In heat exchange equipment usuable in maintaining body temperature within a predetermined range, the combination comprising: at least one pair of sheet members of approximately equal size and shape fabricated of a material that is impervious to gas; the edges of said sheet members being sealed together to provide an assembly defining a fluid chamber; a plurality of first apertures provided in one of said sheet members; continuous conduit means secured in said chamber; the ends of said conduit means extending from said chamber in fluid tight relation; a plurality of second apertures provided in said sheet members; said second apertures being aligned and portions of said sheet members immediately adjacent said second apertures being sealed together to provide fluid communication from one side of said assembly to the other; porous material approximately the same size and shape as said sheet members; means adapted to maintain said assembly and porous material in close proximity to the body of an animal with said porous material adjacent the animal's skin; first means allowing and controlling ingress and egress of liquid to and from said conduit means and second means allowing and controlling ingress and egress of a gaseous medium to enter and leave said chamber.

**3.** A garment especially useful in space adapted to maintain body temperature of a person wearing the garment within a predetermined range comprising: at least one pair of sheet members of substantially the same size and shape fabricated of material impervious to gas; the edges of said pair of sheet members being secured together in fluid tight relation to provide an assembly defining a plenum chamber therebetween; a plurality of minor apertures formed in one of said sheet members; continuous conduit means secured in said chamber with the ends there of extending from said chamber in fluid tight relation; porous means secured to the outer surface of said one sheet member; a plurality of major apertures in said sheet members; said major apertures being aligned at such time as said pair of sheet members are in their assembled relation; said sheet members having a sealed relation adjacent said major apertures whereby fluid passages are provided from one side of said assembly to the other; a covering fabricated of a material impervious to gas shaped to snugly fit a wearer thereof defining a fluid tight chamber around the wearer of said covering; said covering adapted to maintain said assembly and porous material in near contacting relation with respect to the skin of a wearer of said covering with said porous material immediately adjacent the wearer's skin; and control means allowing ingress and egress of a first fluid and a second fluid to and from said conduit means and chamber, respectively.

**4.** A garment as set forth in claim **3**: in which said first fluid is a liquid and said second fluid is a gas.

**5.** A garment as set forth in claim **4**: in which said control means includes a pair of non-continuous conduit means first ends of which terminate inside of said chamber; the other ends of said non-continuous conduit means terminating in a manifold; and values associated with said continuous and non-continuous conduit means functioning to control the flow of fluid therethrough.

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