United States Patent

Chi et al.

[15] **3,688,762**

[45] **Sept. 5, 1972**

[54] **THERMAL CONTROL GARMENT**

[72] Inventors: **John W. H. Chi; Robert Flaherty,** both of Pittsburgh, Pa.

[73] Assignee: **Westinghouse Electric Corporation,** Pittsburgh, Pa.

[22] Filed: **March 2, 1971**

[21] Appl. No.: **120,281**

[52] **U.S. Cl.** **126/204**

[51] **Int. Cl.** **F24j 1/00**

[58] **Field of Search** 126/204, 263; 165/46

[56] **References Cited**

UNITED STATES PATENTS

3,402,708	9/1968	Grega	126/204
3,450,127	6/1969	Harwood, Jr.	126/204
3,599,625	8/1971	Curtis	126/204

Primary Examiner—Charles J. Myhre
Attorney—A. T. Stratton and Z. L. Dermer

[57] **ABSTRACT**

A thermal control garment is disclosed for controlling body heat losses over an extended period of time in a hostile environment. The garment utilizes a self-contained heat source which is thermally coupled to an evaporator unit having a suitable working fluid contained therein. A network of capillary tubing is interwoven throughout the garment, with the ends thereof connected to the input and output sections of the evaporator unit, respectively, so as to permit the distribution of heat from the heat-source-evaporator to the various parts of the garment; especially those parts covering the body extremities. The capillary pumped loop contains no moving parts and the life of the system is dependent solely on the life of the heat source, which can be of the exothermic chemical reaction or radioisotopic variety.

7 Claims, 5 Drawing Figures

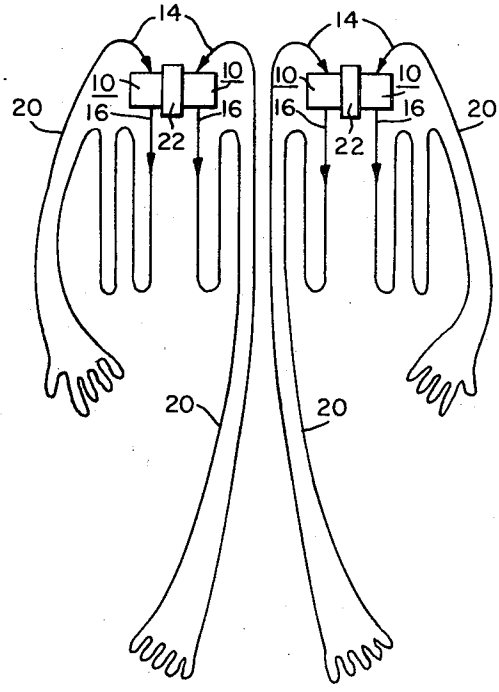
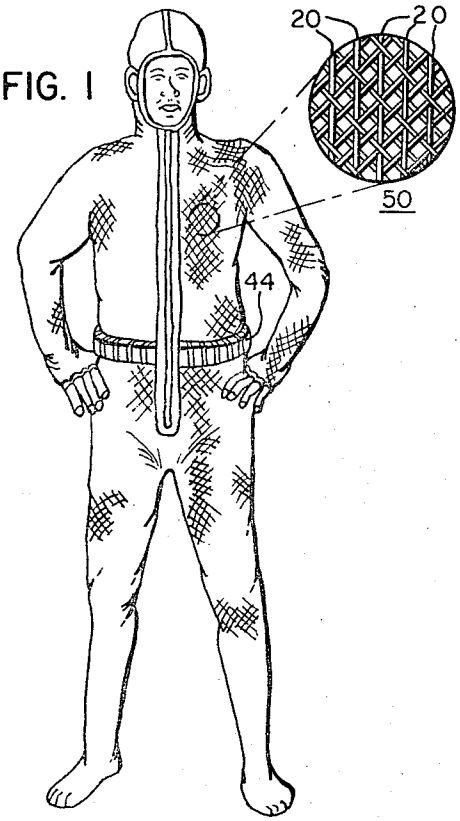


FIG. 1



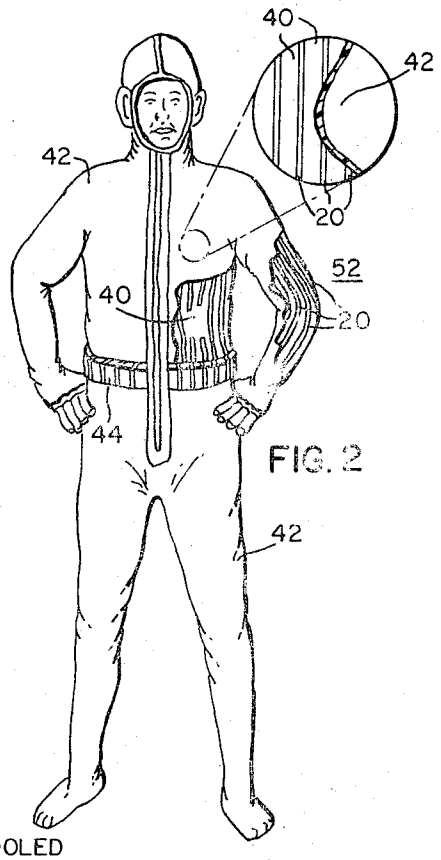


FIG. 2

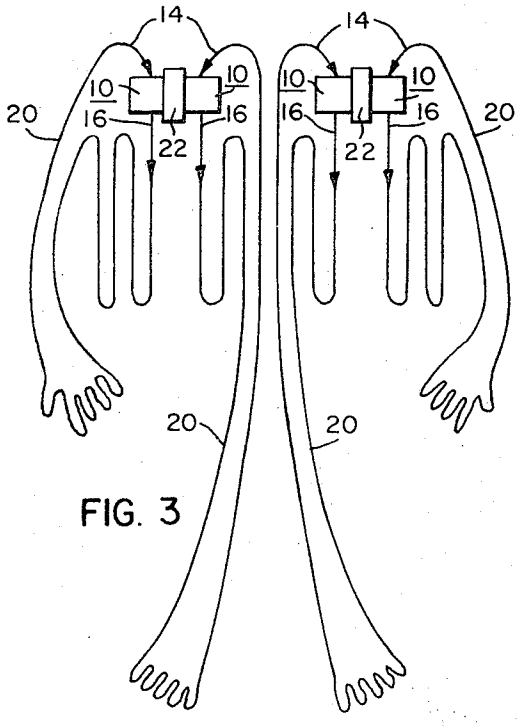


FIG. 3

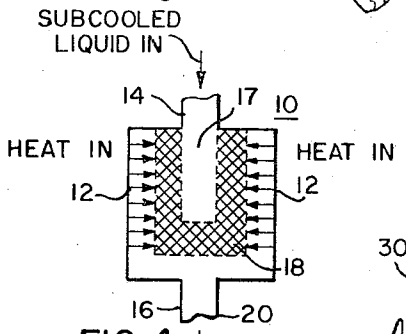


FIG. 4

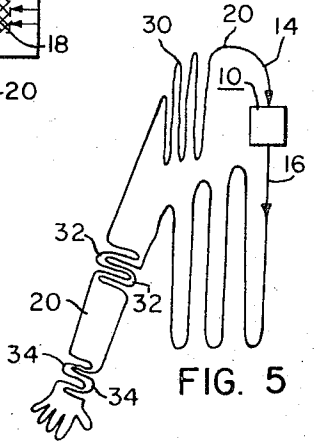


FIG. 5

THERMAL CONTROL GARMENT

BACKGROUND OF THE INVENTION

This invention pertains in general to thermal control garments and more particularly to such garments that employ static self-contained capillary pumped heat generating mechanisms.

One of the hazards swimmers and astronauts encounter is the thermal gradients produced by the low temperature environments to which they are subjected. For example, even tropical waters do not match the human body temperature. Furthermore, the temperature of water drops with increasing depth. Most deep sea diving is performed in ambient temperatures of 25° to 50° below the normal body temperature. The result is that the body temperature gradually decreases as a function of exposure time. Physiologically, the important body temperature, associated with survival, is the core temperature (the inner body temperature measured at about heart level). Body protective mechanisms are designed to protect the body core temperature. If the core temperature begins to diminish, the effectiveness of body function is affected and human performance deteriorates. The core temperature drops at a gradually increasing rate as a function of decreasing environmental temperature and increasing exposure time.

In deep diving operations, a helium-oxygen gas mixture is generally used as a constituent of the breathing apparatus. Helium is a light gas which minimizes or overcomes the problems encountered with ordinary air supplies since air becomes very dense at pressures greater than those experienced at a hundred foot depths. It also minimizes the narcotic effects of nitrogen. However, helium is a poor insulator, thus facilitating a faster body heat loss rate.

The prior art has employed suits manufactured from various insulating materials to retain body heat and permit the wearer to endure in relatively cold climates. While such suits have achieved some degree of success for short exposures, the amount of insulation required for long exposures is relatively high, resulting in a heavy, bulky, and awkward suit. In extremely cold climates, of approximately −50° Fahrenheit and below, the amount of insulation required is so great as to make such suits unfeasible for active personnel.

Suits incorporating various internal heating devices operated by portable battery supplies have also been employed. However, the weight of the batteries required, the limiting factor of battery life and the low voltages generated at extremely low ambient temperatures have created serious handicaps.

An alternate concept which has been utilized in thermal attire employed in the past has been to transport heat generated from a radioactive isotopic heat source by a dynamically pumped fluid circulation system. This system is more fully described in the Schivers U.S. Pat. No. 3,402,709 issued Sept. 24, 1968. The concept thus disclosed is limited by the pump required to circulate the fluid and the power source required to operate the pump.

To overcome the disadvantage of limited battery life in any long lasting survival suit, the need for an auxiliary power source must be eliminated. The main difficulty encountered in obtaining this objective is the need for transporting fluids over long distances without a pump. One possible solution is to employ heat pipes for this purpose. However, the large liquid pressure drops encountered over the area of the suit reduces the feasibility of using heat pipes in such an application. Furthermore, heat pipes are relatively inflexible and therefore would hamper movement within such a suit.

SUMMARY OF THE INVENTION

In order to overcome the aforementioned difficulties experienced by the prior art, this invention provides a thermal control garment which employs a capillary pumped heat source. The heat source is a self-contained unit which is thermally coupled to an evaporator unit having a heat transporting medium contained therein. The heat transporting medium is transported throughout the suit by a capillary network which is interwoven into an insulated garment which may be of the fish net variety. Each end of the capillary tubing is communicably coupled to the input and output sections of the evaporator unit, respectively. Thus, the capillary pumped loop contains no moving parts, requires no auxiliary power source, and the life of the system is dependent solely on the life of the heat source, which can be of the chemical or radioisotopic variety.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, reference may be had to the preferred embodiment, exemplary of the invention, shown in the accompanying drawings in which:

FIG. 1 is a perspective view of one embodiment of this invention;

FIG. 2 is a perspective view of another embodiment of this invention;

FIG. 3 is a schematic view of one embodiment of this invention;

FIG. 4 is a schematic view of the evaporator unit shown in the embodiment illustrated in FIG. 2; and

FIG. 5 is a schematic view of an alternate embodiment which may be employed with this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

This invention contemplates the use of a capillary pumped loop transport system to eliminate the pump and auxiliary power units required by the prior art to distribute heat throughout a thermal garment. The principle and feasibility of capillary pumped loops of significant lengths has already been domonstrated in a publication by F. J. Stenger entitled "Experimental Feasibility Study of Water-Filled Capillary Pumped Heat Transport Loops," NASA TMS-1310, 1964.

In accordance with this invention a capillary loop network is provided to uniformly distribute heat throughout a thermal garment and is generally described by reference character **20** illustrated in FIGS. **1**, **2**, **3**, **4** and **3**. The capillary pumped loop consists of capillary tubes of a given length and diameter as determined by the heat transfer requirements and the working fluid employed as will be readily appreciated by those skilled in the art. In this exemplary embodiment the capillary tubes are constructed out of a flexible material, such as plastic, which is compatible with

the working fluid transported therein and are interwoven into an insulated garment such as one constructed in a fish net design as illustrated in FIG. 1. The garment there illustrated is exemplary of this invention employs thin (2 mm.) plastic water pipes incorporated into Brynie type (fishnet) undergarments so as to have heat exchanger capillary tubes covering the skin about 2 cm. apart. For a more detailed explanation of alternate designs reference may be had to a publication by E. L. Beckman, entitled "Current Concepts and Practices Applicable to the Control of Body Heat Loss in Air Crew Subjected to Water Emersion," Volume 37, No. 4, April 1966. The capillary tubes are connected to boots and mittens similar to the resistance heated boots and mittens described in the aforementioned publication. Whereas, the water loop described by Beckman is pumped mechanically, the present invention employs a heat transfer loop and the fluid therein is pumped by capillary forces as described hereinafter.

A second embodiment of a thermal control garment utilizing this invention is illustrated in FIG. 2. The garment, thus illustrated, comprises an inner base cloth linear to having a capillary pumped distribution network **20** woven thereon. The network **20** is covered with an outer foam neoprene insulator **42**. A belt **44** is provided which carries a self continued heat source and evaporator unit, the operation of which will be described hereinafter.

FIG. 3 schematically illustrates one embodiment of this invention and is used to describe the overall heat transfer loop system. This invention employs a self-contained heat source, **22**, such as a radioisotopic heat source or one which employs an exothermic chemical reaction similar to the chemical reaction illustrated in the Beckman reference. Such heat sources are well known in the art; one such source being illustrated in the Shivers et al U.S. Pat. No. 3,402,709 entitled Suit Heater issued Sept. 24, 1968. The heat source is thermally coupled to an evaporator unit generally described by reference character **10** in FIG. 3, which contains a working fluid therein. The working fluid is vaporized in the evaporator **10** (to be described in more detail hereinafter) and is transported through the capillary tubing network **20** where it gradually condenses as it distributes the heat associated therewith throughout the garment in which the capillary network is interwoven. The condensed working fluid, which is subcooled by the external environment to which the garment is subjected, is returned to the evaporator **10** by the capillary forces in the tubing network **20**. This capillary phenomena is well known in the art and is more fully described in the Stenger reference. The process thus described is continually repeated within the closed loop network **20** to supply uniform heat distribution over the entire garment. The exemplary embodiment illustrated in FIG. 3 employs four such evaporator-heat transfer loops, which provide redundancy and a more uniform temperature distribution. Two of the loops thus illustrated supply heat to the arm and back regions and the remaining two loops warm the leg and chest regions of the thermal garment. The embodiment thus illustrated shows the tubes running in a vertical direction, though it is to be understood that this is not a limitation of the invention but merely an illustration of one example incorporating this invention. For fluid transport along the arms and legs, the capillary tubes may be coiled to permit more freedom of movement. This modification is shown in FIG. 5 for one such loop transport network **20**, illustrating the transport loop in the arm region of the garment. Note that the coiled tubes are employed around the joints of the body designated by reference characters **30**, **32** and **34** Again, plastic tubes are desirably employed for this purpose to permit more flexibility of movement, though the invention is not meant to be limited by the special materials illustrated herein.

Referring now to FIG. 4, a more detailed explanation of the evaporator unit generally described in FIG. 3 by reference character **10** will be given. It is to be understood that the exact evaporator design will vary depending upon the heat source used (the thermal coupling thereby required) and the working fluid employed. The exemplary unit described herein is designed to be used with a heat source which can be thermally coupled to the evaporator walls **12**. The evaporator illustrated comprises a center plenum **17** which contains a working fluid or heat transport medium such as water. A variety of other working fluids may be used depending upon the power level and operating temperature desired. The plenum **17** is surrounded on three sides by a wicking or porous media **18** such as asbestos. The porous section **18** provides the capillary pumping action that drives the working fluid through the evaporator **10**. The heat radiating from the heat source vaporizes the liquid in the porous media and the capillary forces at this vapor liquid interface provides the main driving force which transports the saturated vapor out of the evaporator exit **16** and through the capillary network **20** where it is gradually condensed and returned by the capillary action of the network tubes **20** to the evaporator inlet **14**. The process is then continuously repeated to provide uniform heat distribution over the thermal garment.

Thus, a system has been described which eliminates significant liquid pressure drops and allows loops of appreciable tube length to be utilized. The capillary pumped loop, thus shown, contains no moving parts and the life of the system is dependent solely on the life of the heat source.

We claim as our invention:

1. A thermal control garment comprising:

a working fluid;

heat generating means for heating said working fluid;

at least one evaporator unit having an input and output section associated therewith, said evaporator unit being thermally coupled to said heat generating means for evaporating said working fluid; and

a capillary network communicably coupled at each end to the input and output sections respectively of said evaporator unit, said capillary network being interwoven into said garment for transporting said working fluid throughout said garment so as to distribute the heat associated therewith.

2. The thermal control garment of claim **1** wherein said heat generating means comprises a radiosotopic heat source.

3. The thermal control garment of claim **1** wherein said heat generating means comprises an exothermic chemical reaction heat source.

4. The thermal control garment of claim 1 including a plurality of said evaporator units, each of said plurality of evaporator units having a corresponding capillary network associated therewith.

5. The thermal control garment of claim 4 wherein said plurality comprises four of said evaporator units, two of said evaporator units being coupled to capillary networks running through the arm and back regions of said thermal garment and the remaining two of said evaporator units being coupled to capillary networks running through the chest and leg regions of said thermal garment.

6. The thermal control garment of claim 1 wherein at least a portion of said capillary network includes coiled capillary tubes.

7. The thermal control garment of claim 6 wherein said coiled capillary tubes are positioned over each of the joints of the body covered by said thermal control garment.

* * * * *