Feb. 4, 1969 E. M. TUCKER 3,425,487

SPACE SUIT HEAT EXCHANGER

Filed Oct. 27, 1967 Sheet 1 of 2

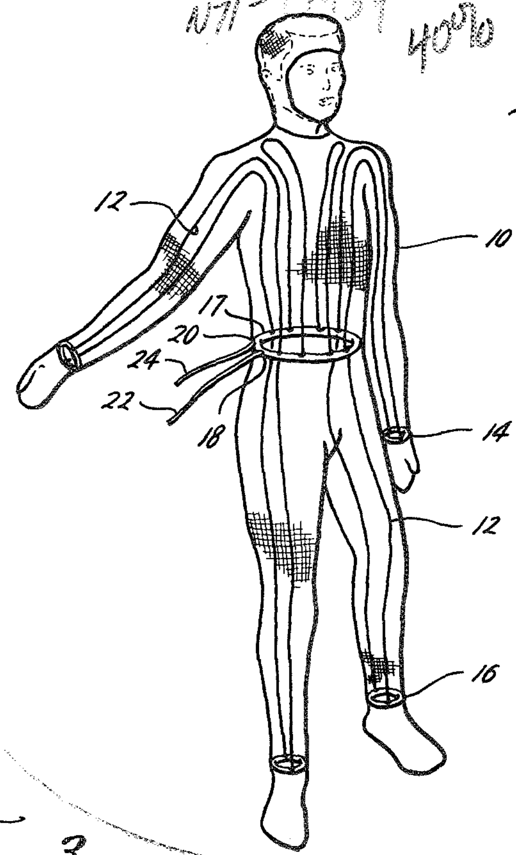
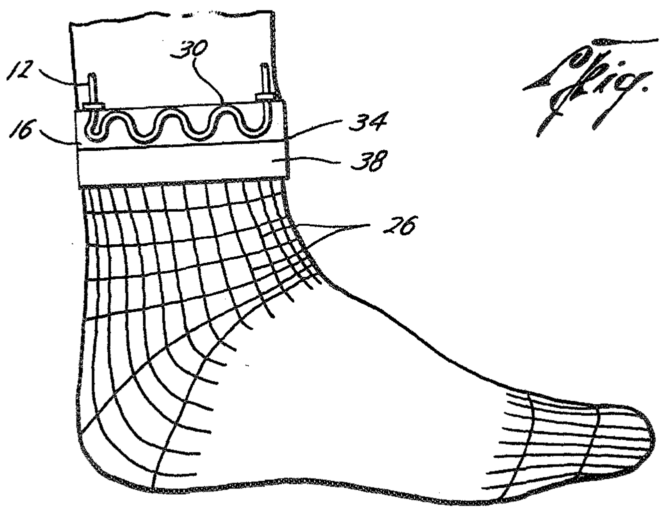


Fig. 1

Fig. 3



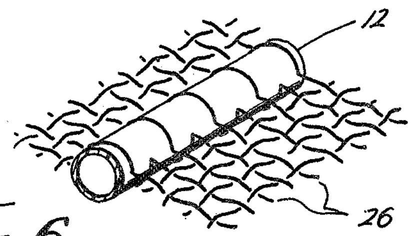


Fig. 6

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Fig. 2

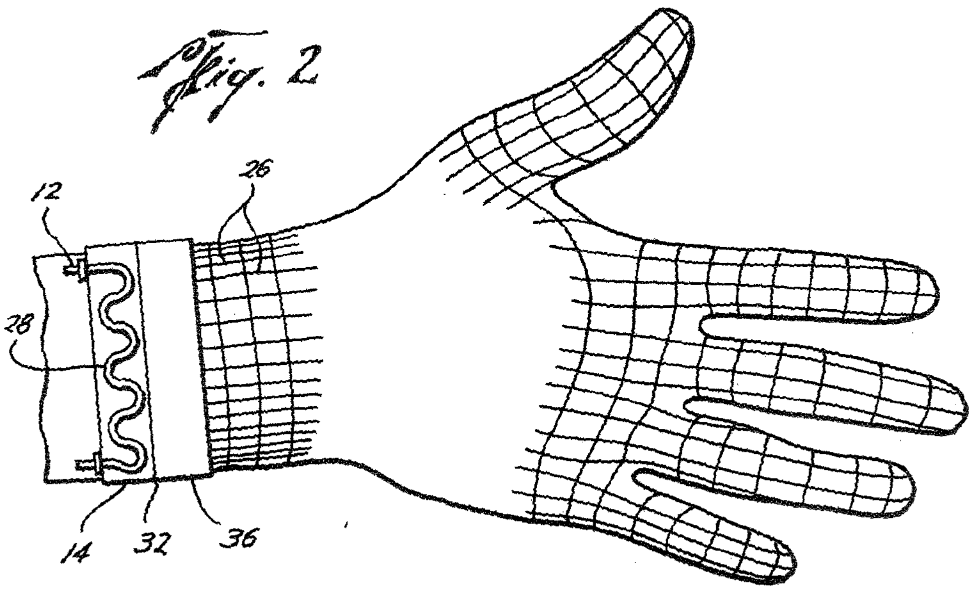
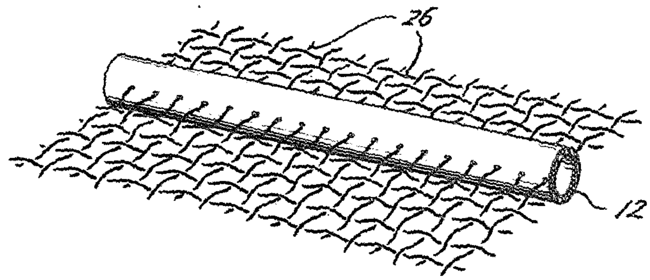


Fig. 4



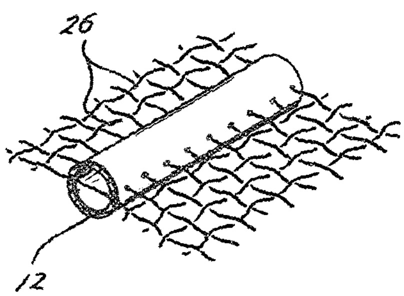


Fig. 5

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SPACE SUIT HEAT EXCHANGER

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Int. Cl. F28f *7/00;* A61f *7/00;* F25d *3/08*

ABSTRACT OF THE DISCLOSURE

A body heat exchanger for usage with space suits, the purpose of which is to transfer thermal energy to or away from the body surface of the wearer. The heat exchanger is a very fine grid of small, flexible, high thermal conductance yarn in intimate contact with the body, which serves to transfer heat from the body surface into a liquid coolant loop, included as a portion of the assembly, through which circulates a fluid of a desired temperature.

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

Background of the invention

The present invention relates to a heat exchanger particularly suitable for integration into a garment designed to maintain a desirable thermal balance of the wearer.

One major problem of manned space flight is the proper thermal control of the crewman during intravehicular and extravehicular missions. Heat generated metabolically and also from the external environment must be removed from the crewman's environment in order to protect him from excess thermal loads.

Existing cooling assemblies utilize a cooled gaseous flow within the space suit to provide for evaporative cooling of body-generated heat. Protection from external heat is achieved through the use of combinations of conductive and radiation insulations. The problems attendant with these designs are numerous. The cooling effect is not adequate to prevent thermal discomfort, particularly of the hands and feet, because of the lack of direct cooling flow for these areas. The hands tend to become wet with perspiration, which promotes discomfort and inefficiency. Convective cooling in these areas is difficult to obtain, due to the mobility requirements of the hands.

An alternate arrangement is to provide the garment with small diameter tubing, extensive throughout the suit, through which circulates a cooling fluid. The tubing is highly concentrated in a parallel arrangement over the body, therefore requiring a large amount of tubing (over 200 feet) and large power requirements to pump the fluid through the tubing. Again, there is no feasible means to provide direct thermal control of the hands, fingers, and feet, and simultaneously provide for flexibility and low bulk when using this alternate arrangement. Furthermore, the heat dissipation will be concentrated in the immediate vicinity of the tubing, thus limiting the temperature extremes at which the coolant can circulate and still provide comfort to the crewman.

Summary

The instant invention provides a very fine grid of small, high thermal conductance yarn in intimate contact with the skin of the wearer. The grid assembly serves to transfer heat into or away from a heat sink assembly incorporating a circulating fluid of a controlled temperature. In the trunk, arm, and leg sections of the thermal garment, the heat sink is in the form of a flexible coolant duct thermally connected to the grid section covering those portions of the body. In the glove and boot components of the suit, the heat sink is in the form of a heat exchanger cuff, a wristlet, or anklet, thermally connected to the grid section covering the particular extermity. In all cases, the grid is coextensive so as to cover the body, including selected portions of the head if so desired. The coolant duct is located strategically about the trunk, arms, and legs, so as to minimize the amount of tubing necessary, the thermal conductance of the grid primarily being relied on to effect the heat transfer from the surface of the skin.

The advantages of this assembly are obvious. Thermal control of the torso and the extremities, particularly the hands and fingers, is effectuated with reduced external insulation and its attendant bulk and with substantial improvements in wear comfort. The glove can be made more flexible and can provide the wearer with increased tactility and mobility as required for pressure suit operations. Perspiring is minimized as compared with systems utilizing gaseous flow. Less tubing is required than systems relying solely on tubing without the thermal grid assembly. All this adds up to a lightweight, comfortable, flexible, highly efficient space suit heat exchanger for control of body skin surface temperature.

It should be noted that the instant invention has utilization in applications other than space activities. Thermal protection is affordable by means of this heat exchanger, as an undergarment, to anyone working in extreme hot or cold environments. This assembly could easily be adapted for use in underwater missions. The glove component, as a separate item, could be used by laboratory and industrial personnel required to handle very hot or cold items for extended periods of time. The advantages of the heat exchanger in such non-space utilizations correspond with use in space.

Although the invention is particularly pointed out in the appended claims, the invention itself will be better understood by referring to the following description of a preferred embodiment taken in connection with the accompanying drawings in which like numerals identify like parts and in which:

Brief description of the drawings

FIG. 1 is a perspective schematic view of body heat exchanger as disclosed herein.

FIG. 2 is an enlarged view of the glove component of FIG. 1.

FIG. 3 is an enlarged view of the boot component of FIG. 1.

FIG. 4 is a perspective detail of the junction of the grid and the coolant duct.

FIG. 5 is a perspective end view of FIG. 4, showing an assembly detail.

FIG. 6 is a perspective detail of an alternate thermal junction of the grid assembly and the coolant duct.

Description of the preferred embodiment

FIG. 1, FIG. 2, and FIG. 3 schematically illustrate the heat exchanger assembly **10** of a space suit system. This system is designed to be in contact with the skin of the wearer, either directly or in very close proximity, perhaps through a thin layer of fabric designed to improve comfort of the assembly. As such, the heat exchanger assembly is used as an undergarment within the space suit.

Liquid carrying coolant duct **12** is located strategically so as to provide a localized heat sink for the torso, arm, and leg portions of the heat exchanger assembly **10** as shown in FIG. 1. The coolant duct **12** also conducts the liquid through wristlet and anklet heat sinks **14** and **16**, respectively, which will be described below. The duct

12 carries liquid, such as water, at a low temperature, supplied by the life support system, entering the waist manifold 17 at inlet 18, flowing throughout the system, and leaving through outlet 20. Supply and exhaust lines 22 and 24, respectively, are attached to the waist manifold 17 at inlet 18 and outlet 20 by any well-known quick-disconnect means, not shown. The duct is of a flexible material, such as polyethylene or polyvinylchloride. The design is such as to place reliance on the grid structure to transfer the majority of the heat, rather than on the more localized duct. This allows the fluid to circulate at a lower temperature than in systems relying on coolant tubing solely, since there is less concentration of heat transfer and more even heat dissipation with the grid assembly. The overall effect is increased efficiency and comfort.

The grid structure 26 consists of small, high thermal conductance yarn fabricated from strands of silver, copper, or such, in a loose-knit weave.

The torso, arm, and leg components of the heat exchanger assembly comprise heat sink coolant duct 12 thermally connected to grid 26, which grid is coextensive so as to cover the entire body of the crewman. As previously described, duct 12 is arranged strategically about the body such as shown in FIG. 1, so as to effect an efficient, uniform heat transfer from the skin through conductance grid 26, and into the coolant circulating through duct 12.

The grid portion in contact with duct 12 is best shown in FIGS. 4 and 5. The part of the grid weave, which is transverse to the duct, passes through the duct at its diameter. In this manner, heat transfer is effected from the grid directly into the coolant flowing through the duct. Duct 12 may be molded directly on the grid 26; it may be split longitudinally and cemented together with the grid at the interface, or assembled in some other suitable fashion, such as in FIG. 6, wherein the grid is woven about coolant duct 12.

The glove and boot components of the heat exchanger assembly are best depicted in FIGS. 2 and 3, respectively. Because of the high degree of flexibility and lack of bulk required of these components, the basic structure varies somewhat from that of the torso, arm, and leg components. Duct 12 terminates and is in communication with liquid coolant loop 28 in wristlet 14, and with a corresponding liquid coolant loop 30 in anklet 16. Wristlet 14 and anklet 16 at the extremities of assembly 10 serve as heat sinks for the glove component and the boot component, respectively, which components are readily detachable from the extremity of the assembly by means of any well-known quick-disconnect means, not shown. A thermally conductive material, such as copper, is chosen for the wristlet and the anklet. On the glove and boot members, at the portion which is adapted to be connected to the extremity of the assembly at the wristlet and anklet, are corresponding thermally-conductive copper rings 36 and 38, respectively, which thermally contact the wristlet and anklet through the quick-disconnect means at 32 and 34. The advantage in this particular structure can be readily understood. It would be extremely difficult to have coolant flow through the glove and boot components themselves, because of the attendant bulk and the difficulty in valving the coolant through the quick-disconnect means of the glove and boot when such components are removed from the space suit. The instant arrangement allows the coolant to flow through the wristlet and ankle of the main body portion of the suit, the heat transfer being effected by conduction through the rings 36 and 38 and the quick disconnect means. The thermal grid assembly of the glove and boot components, included as a separate inner glove or sock, or as an integrated assembly with the boot and glove, is thermally joined to rings 36 and 38 such as by silver soldering the longitudinal portions at the points of contact circumferentially about the rings. Thus, with the glove or boot connected to the assembly, thermal energy will flow by conductance from the skin through the grid which encompasses the extremity, to conductive ring 36 or 38, through the quick-disconnect means, through wristlet 14 or anklet 16, and into the liquid circulating through coolant loop 28 or 30 within wristlet 14 or anklet 16, respectively. This particular structure enables the glove and boot components to be extremely flexible, free of excess bulk, and quickly removable. Coolant tubing is localized in the wristlet and anklet and not in the glove or boot itself. Direct passive thermal control of the hands, fingers, and feet is accomplished in a comfortable, feasible way.

Other embodiments of the space suit heat exchanger might include an absorbent fabric interwoven into the thermally conductive grid for the purpose of absorbing perspiration. For industrial purposes where only the glove component may be used, the quick-disconnect means can be eliminated, the tubing carrying fluid directly to a coolant loop in thermally conductive ring to which the grid portion is attached.

As to utilization of the heat exchanger assembly with the space suit, it is noted that the grid may be separate and positioned either inside or outside the usual gas bladder. It may also be impregnated with the bladder elastomer, thus becoming an integral part thereof.

The life support system (not shown) is conventional, and supplies the coolant fluid to circulate through the assembly.

Thus, it will be seen that a garment heat exchanger assembly is disclosed which will greatly enhance the comfort of the crewman, increase overall mobility for extended periods of wear, and increase the efficiency of heat exchange in appropriate applications.

Although a particular embodiment of the subject invention has been illustrated and described in order to explain the invention, it will be understood that various changes and modifications may be made by those skilled in the art, yet remain within the principle and scope of the invention as expressed in the appended claims.

What is claimed and desired to be secured by Letters Patent is:

1. A heat exchanger adapted to maintain body temperature within a predetermined range comprising:
   continuous duct means for circulating a fluid to the various body portions of the person;
   continuous, conductive grid means comprising interwoven threads of solid material thermally connected to said duct means and depending therefrom in close proximity to the skin of a person and extensive about the body portions so as to substantially conform to the shape of the person, said grid means adapted to conductively exchange thermal energy between the skin of the person and the duct means; and
   means allowing ingress and egress of the fluid to and from said duct means.

2. The heat exchange assembly of claim 1 wherein said duct means is of a flexible material, and said thermal connection of said grid means and said duct means comprises a portion of the grid means woven about the duct means for effecting heat transfer from the skin of the person to the circulating fluid.

3. The heat exchange assembly of claim 1 wherein said duct means is of a flexible material, and said thermal connection of said grid means and said duct means comprises a portion of the grid means intersecting the duct means for effecting heat transfer directly between the grid and said fluid circulating in said duct means.

4. The heat exchange assembly of claim 3 wherein said duct means is molded directly onto said grid means.

5. An extremity heat exchange assembly for maintaining an extremity of a person within a predetermined range comprising:

continuous duct means for circulating a fluid to the various body portions of the person;

a continuous conductive grid means comprising interwoven threads of solid material thermally connected to said duct means and depending therefrom in close proximity to the skin of the extremity of the person and coextensive thereabout so as to substantially conform to the shape of the extremity, said grid means adapted to conductively exchange thermal energy between the skin on the extremity of the person and the duct means; and

means allowing ingress and egress of the fluid to and from said duct means.

6. An extremity heat exchange assembly for maintaining an extremity of a person within a predetermined range comprising:

an annular ring of a thermally conductive material through which flows a fluid;

a continuous conductive grid means comprising interwoven threads of a solid material thermally connected circumferentially about said ring and depending therefrom in close proximity to the skin of the extremity of the person and coextensive thereabout so as to substantially conform to the shape of the extremity, said grid means adapted to conductively

exchange thermal energy between the skin on the extremity of the person and the ring; and

means allowing ingress and egress of the fluid to and from said ring.

7. The extremity heat exchange assembly of claim 6 wherein said ring is comprised of two quickly detachable sections, the first of said sections, through which flows said fluid, being integral with a suit heat exchange assembly, and the second of said sections being a cuff means to which said grid is attached by said thermal connection.

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