

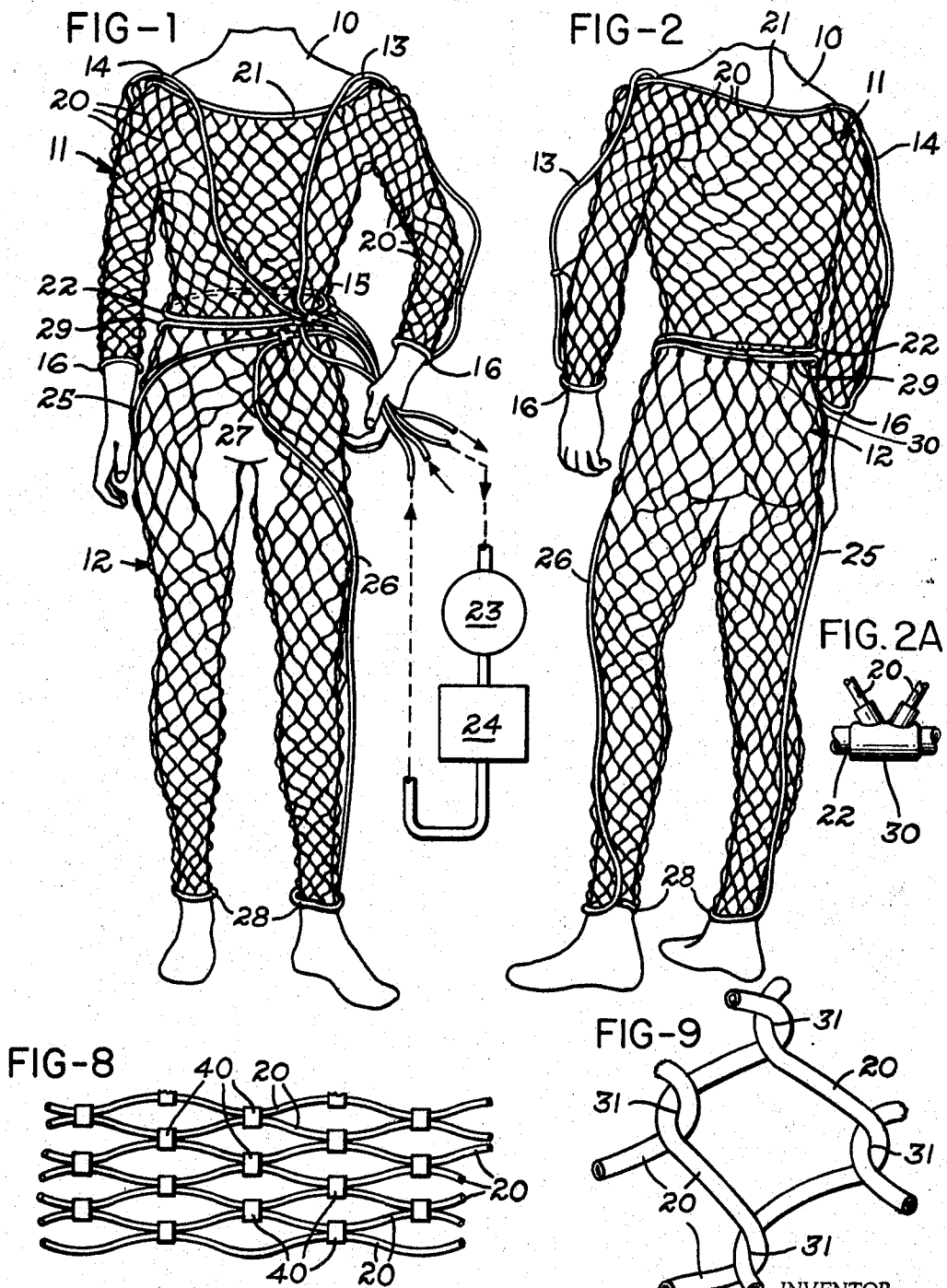
March 4, 1969

J. F. CROCKER
LIQUID COOLED GARMENT

3,430,688

Filed Oct. 27, 1966

Sheet 1 of 2



INVENTOR.
JEREMY F. CROCKER

BY
Marshall, Biibel, French & Bugg
ATTORNEYS

March 4, 1969

J. F. CROCKER

3,430,688

LIQUID COOLED GARMENT

Filed Oct. 27, 1966

Sheet 2 of 2

FIG-4

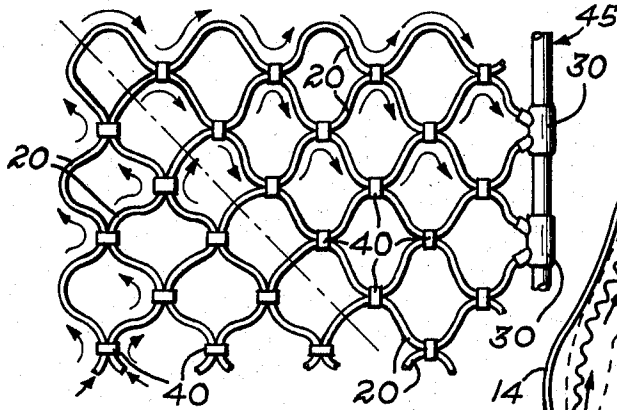


FIG-3

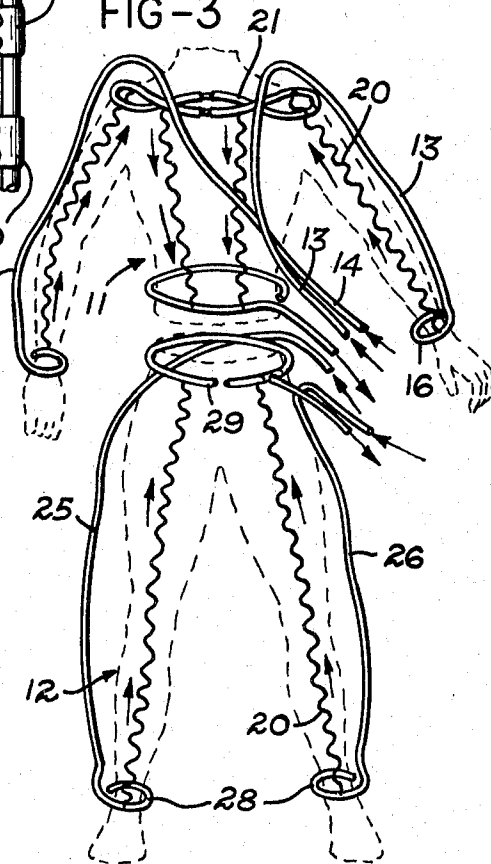


FIG-5

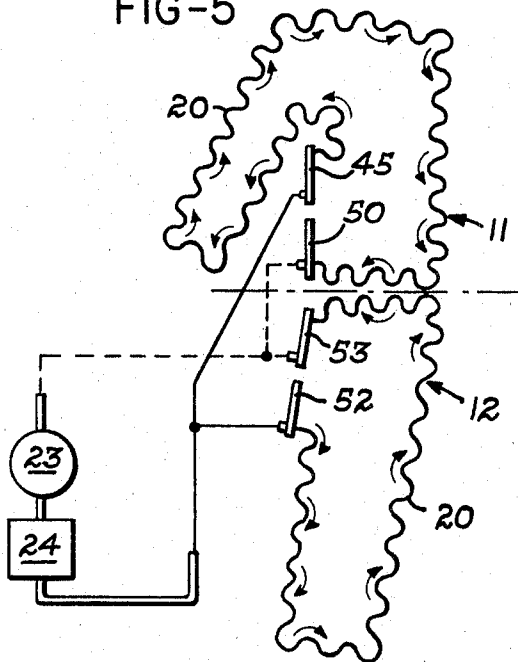


FIG-6

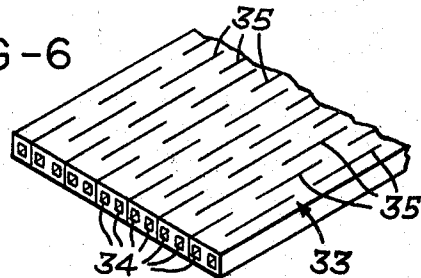
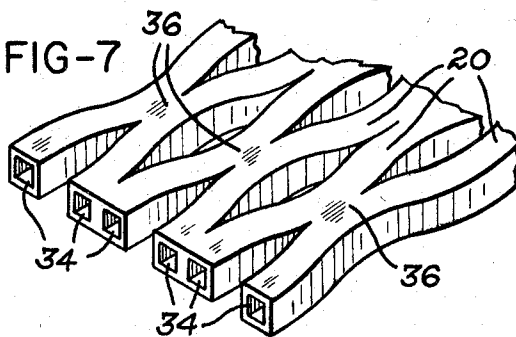


FIG-7



1

3,430,688

LIQUID COOLED GARMENT

Jeremy F. Crocker, Yellow Springs, Ohio, assignor to Webb Associates, Inc., Yellow Springs, Ohio, a corporation of Ohio

Filed Oct. 27, 1966, Ser. No. 590,025

U.S. Cl. 165—46

Int. Cl. F28f 7/00

3 Claims

ABSTRACT OF THE DISCLOSURE

A heat transfer garment comprises a network of flexible tubes joined together at staggered spaced apart locations to prevent relative longitudinal movement of the tubes thus resiliently restraining the tubes from separation and maintaining the garment under tension to press securely against the skin of the wearer over the entire extent of the garment thereby promoting efficient heat transfer from the body of the wearer through the walls of the tube to a fluid running through the interior of the tubes.

This invention relates to a liquid cooled, heat exchanging garment to aid in maintaining the temperature of a human body within a specified temperature range.

It is necessary to provide a means to cool the body of a person who is placed in a heavy, air-tight, protective outer garment such as that used in high altitude and space exploration. To facilitate the cooling of the body this invention provides that a heat transfer fluid be passed over the surface of the body by a series of small flexible tubes which are resiliently urged toward the skin of the wearer over the entire extent of the garment.

Previously, one method of constructing a heat exchanging garment, which was both time consuming and expensive, was to sew by hand a series of flexible polyvinyl tubing on a supporting garment of cotton mesh. This invention proposed to reduce the cost and time of construction of a liquid cooled, heat exchanging garment and improve the heat exchanging ability of the suit by eliminating the cotton mesh supporting garment and the necessity for hand sewing and consequently reduce the labor required to manufacture the garment.

The liquid cooled heat exchanging garment of this invention uses a series of flexible polyvinyl or polyethylene tubes which are joined together in such a way to form a network of heat exchanging tubes from which the garment is constructed. The flexible heat exchanging tubes are held together to form an elastic, close fitting garment.

Accordingly, it is an object of this invention to provide a liquid cooled, heat exchanging garment adapted to be used under a sealed outer protective garment which is low in cost of manufacture.

It is a further object of this invention to provide a liquid cooled, heat exchanging garment which requires no other supporting material to maintain the shape and dimensional stability of the garment.

It is still another object of this invention to provide a liquid cooled, heat exchanging garment which is constructed entirely of a series of flexible tubes which are resiliently urged in contact with the skin of the wearer to maintain optimum heat transfer characteristics.

Other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

In the drawings:

FIG. 1 is a front view of a complete liquid cooled garment as it is worn by a person;

FIG. 2 is a rear perspective view of a complete liquid cooled heat exchanging garment shown in place on the body of a person;

2

FIG. 2a is an enlarged fragmentary view showing a portion of the garment in detail;

FIG. 3 is a schematic front view of the liquid cooled garment shown in FIGS. 1 and 2 illustrating the flow of the heat exchanging fluid, the upper and lower parts of the garment being separated for the purpose of illustration;

FIG. 4 is a detail view showing a portion of the heat exchanging network at a point where the direction of travel of fluid flow has been changed;

FIG. 5 is a front view of a heat exchanging garment wherein the mainfolds encircling the waist, wrist, ankles and neck lines have been eliminated;

FIG. 6 shows an extruded strip containing a plurality of fluid passageways which may be used for the heat exchanging network of the garment;

FIG. 7 shows the extruded tubing of FIG. 6 after it has been slit and stretched into a wearing position;

FIG. 8 shows a series of heat exchanging flexible tubes which have been tangentially joined according to this invention; and

FIG. 9 shows a series of tubes which have been formed into a mesh by interlocking a series of tubes.

Referring now to the drawings which show preferred embodiments of the invention, FIGS. 1 through 3 show the body of the wearer 10 covered with the heat exchanging garment of this invention, consisting of an upper or torso portion 11 which also covers the arms and a lower portion 12, which covers the legs and abdomen.

Heat exchanging fluid is injected into the upper or torso portion 11 through conduits 13 and 14 which may be joined by a suitable fitting at 15. The heat exchanging fluid passes through conduit 13, for example, to a manifold 16 encircling the wrist of the wearer. The heat exchanging fluid passes from this manifold upwardly across the arm of the wearer through flexible tubes 20 to a manifold 21 encircling the neck of the wearer. In one form of the garment constructed according to this invention, the flexible tubes 20 were constructed of a $\frac{3}{16}$ outside diameter and a $\frac{1}{16}$ inside diameter flexible vinyl tubing.

From manifold 21, the heat exchanging fluid flows downwardly through the flexible heat exchanging tubes 20 surrounding the torso of the wearer into a manifold 22 placed around the waist. The fluid is then passed through pump 23 and heat exchanger 24 and recirculated through the heat exchanging network of the garment.

In a like manner the heat exchanging fluid is also injected into the lower portion of the garment 12 through conduits 25 and 26 which also may be joined by a suitable fitting 27 to the heat exchanger 24. Encircling the angle is a manifold 28 through which the heat exchanging fluid is passed to the flexible tubes 20. The fluid is then directed upwardly across the legs and abdomen of the wearer to a manifold 29 which encircles the waist and is then passed through the pump 23 and heat exchanger 24.

Each of the conduits 12, 14, 25 and 26 is directed along the body on lines of minimum elongation. For example, conduit 26 would pass along side the leg of the wearer on the outside of the knee so that when the knee is flexed the conduit is not folded or stretched causing bulging of the outer garment or restriction of the flow of the heat exchanging fluid.

Each of the heat transfer tubes 20 is joined to the manifold by a connection such as shown in the enlarged fragmentary view of FIG. 2a. A K-shaped joint 30 is sealed into manifold 22 and a heat transfer tube 20 is secured in each of the extending legs of the joint.

The series of individual heat transfer tubes 20 are formed into a network which provides dimensional stability and elasticity to the garment. For the most effective heat transfer relation between the body and the fluid, it is necessary that the tubes 20 carrying the heat trans-

ferring fluid be resiliently urged against the body. It is also necessary to insure that the garment conform to the contour of the body throughout all the motions of the limbs as the person engages in physical activity.

Several methods of forming the heat transfer tubes 20 into a suitable network have been tried and found useful in this application. It is desired that the garment be constructed so as to be elastic and urge the heat transfer tubes into good thermal contact with the skin of the wearer. In its broadest aspect, the heat transfer tubes are held together by various means displaced longitudinally of the tube members to form a staggered relation of said locations.

The holding means restrain the tubes from moving longitudinally with respect to each other, and resiliently restrain lateral separation of the tubes. Due to the separation of the tubes in the areas intermediate the points of joining between tubes, a range of lateral movement is possible, thus allowing the garment as a whole to distend and the network formed by the tubes to expand into a generally diamond shaped pattern. With the tubes separated, a restoring force will cause the tubes to remain under tension and press the tube members against the skin of the wearer over the entire extent of the garment thereby promoting efficient heat transfer between the skin and the fluid in the interior of the tubes.

FIG. 9 shows the individual tubes 20 formed into an interlocking mesh. The tubes may be held together at the point of overlap 31 by cementing or welding to insure that the garment maintains its shape both while being worn or while in storage.

Alternately, the garment may be formed from an extruded strip 33 which contains a plurality of passageways 34. The strip may be cut between the passageways 34 in a staggered fashion at 35 as shown in FIG. 6. Stretching the material, as shown in FIG. 7, will produce a diamond shaped mesh which will provide the necessary elasticity to the garment. With the heat exchanging network constructed as shown in FIG. 7, the individual heat transfer tubes 20 will be integrally held at points 36.

The heat transfer tubes 20 may also be tangentially held by merely cementing adjacent tubes in a staggered or alternating fashion with the aid of a jig fabricated from a plastic material to which the cement would not adhere. Greater mechanical stability of this type of joint can be produced if, in addition to the cementing of the tubes, a wrap of plastic tube or a film supplemented with cement were applied in a staggered arrangement to hold the tubes together.

A preferred network of tubes constructed according to this invention is shown in FIG. 8. A sleeve fabricated from a short length of large diameter shrinkable vinyl tubing 40 is slid in place over two adjacent heat transfer tubes 20 in an alternating pattern as shown in FIG. 8. After the sleeves 40 are in place, hot air or radiant heat is applied thereby shrinking the tubes in place.

A garment constructed from flexible plastic tubing joined in the manner shown in FIG. 8 has been found to exhibit good resiliency and conforms to the surface of the skin even where the surface contour is irregular such as at the elbow or knee. When the tubing 20 is laterally stretched into a diamond shaped pattern, it is found to exhibit a spring rate which is adequate to insure proper heat transfer characteristics between the skin of the wearer and fluid contained within the tube.

The manifolds which encircle the wrist, waist, neckline and ankles may be constructed of a $\frac{3}{16}$ inch outside diameter vinyl tubing. When worn under protective clothing or when the body is positioned so that the manifolds are placed between the body and a hard surface, pressure may be caused to build up and discomfort to the wearer from the pressure or merely from the size and positioning of the manifolds may occur.

It is possible to eliminate these manifolds by the construction shown in FIGS. 4 and 5. Fluid from the heat

exchanger 24 is injected into the torso portion 11 of the garment through an inlet manifold 45 placed longitudinally on the side of the wearer near the waist at a point where no pressure is likely to be applied and where movement and elongation of the manifold will be at a minimum. Flow is then directed toward the limbs through half of the tubes 20 which form the garment while the return flow occupies the other half. At waist, the flow direction is changed in the manner shown in FIG. 4. A right angle change in direction of flow is made by changing the orientation of sleeves 40 which hold the tubes 20 in position. In a like manner, the flow direction at the wrist can be completely reversed. An outlet manifold 50 is placed longitudinally near the waist of the wearer and carries a return flow from tubes 20 through the pump 23 and heat exchanger 24. A similar construction is provided for the lower portion of the garment. Thus, an inlet manifold 52 and an outlet manifold 53 are oriented longitudinally along the side of the lower portion 12 of the garment where movement and elongation will be at a minimum.

Thus, by changing the direction of fluid flow in the manner described above, the manifolds encircling the wrist, waist, ankles and neckline can be eliminated thus reducing points of discomfort and the bulkiness associated with large diameter tubing.

Accordingly, a heat transfer garment for modulating the rate of heat flow from the body to maintain the comfort of a person who is placed in an adverse environment has been provided. A garment constructed according to this invention is self-supporting, easy to construct and insures the proper physical contact between the heat exchanging fluid and the body to insure proper heat transfer.

While the forms of apparatus herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise forms of apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. A heat transfer garment for modulating the rate of heat flow from the body of a wearer to maintain comfort of the wearer, said garment comprising a network of flexible tubing including a plurality of tube members normally tending to assume a close side-by-side relation to each other, means holding the walls of adjoining said tube members at spaced locations preventing separation of said tube members at said locations in response to force tending to expand the garment, said holding means being displaced longitudinally of said tubes to form a staggered arrangement of locations where said tubes are restrained from separation and thereby providing for distention of the garment as a whole by separation of the tubes at intermediate areas such that the garment retains its general shape and the network of tubing is maintained under tension to press against the skin of the wearer over the entire extent of the garment, said network being formed from an integral section of material having a plurality of generally parallel passages therethrough, and in which staggered slits are formed through said material between adjacent ones of said passages leaving staggered integral connections forming the means holding the walls of adjacent tube members and providing the restraint against separation at said integral connections, means forming an inlet connection on said network through which a flow of fluid is supplied to the interior of all said tube members, and means forming an outlet connection on said network through which fluid can leave said network.

2. A heat transfer garment for modulating the rate of heat flow from the body of a wearer to maintain comfort of the wearer, said garment comprising a network of flexible tubing including a plurality of tube members normally tending to assume a close side-by-side relation to each other, said network being formed to provide a torso section and limb sections extending therefrom with

5

the tube members of said limb sections being continuous with the tube members of said torso section to provide a garment which will cover the torso and a major portion of the limbs of the wearer, means holding the walls of adjoining said tube members at spaced locations preventing separation of said tube members at said locations in response to force tending to expand the garment when it is worn by a person and the person is engaged in physical activity requiring movement of all or part of his body resulting in a change in body form, said holding means being displaced longitudinally of said tube members to form a staggered relation of said locations where said tubes are restrained from separation and thereby providing for distention of the garment as a whole by separation of the tubes at areas intermediate said holding means such that the garment retains its general shape and the network expands in a generally diamond-shaped pattern and is simultaneously maintained under tension to press the tube members against the skin of the wearer over the entire extent of the garment thereby promoting heat transfer through the walls of said tube members between the skin of the wearer and fluid supplied to the interior of said tube members, said network being formed from an integral section of material having a plurality of generally parallel passages there-through, and in which staggered slits are formed through said material between adjacent ones of said passages

6

leaving staggered integral connections forming the means holding the walls of adjacent tube members and providing the restraint against separation at said integral connections, means forming an inlet connection on said network through which a flow of fluid is supplied to the interior of said tube members, and means forming an outlet connection on said network through which the fluid can leave said network.

3. A garment as defined in claim 2 wherein said inlet connections include supply tubes connected to the extreme end of each of the limb sections of the network providing for supply of fluid into the network at each of the extreme ends of said limb sections, and wherein said outlet connection means is formed and connected to said torso section of the network to cause fluid supplied through said inlet connections to pass through said tube members over the limbs of the wearer and thence over the torso of the wearer to be discharged through said outlet connection.

No references cited.

ROBERT A. O'LEARY, *Primary Examiner*.

MANUEL A. ANTONAKAS, *Assistant Examiner*.

U.S. Cl. X.R.

126—204; 62—259

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,430,688 Dated March 4, 1969

Inventor(s) Jeremy F. Crocker

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 49, "angle" should be -- ankle --.

Column 6, line 21, "No references cited" should read:

3,000,616	Spangler	9/61
3,154,926	Hirschhorn	11/64
3,289,748	Jennings	12/66
3,295,594	Hopper	1/67
746,650	Engel (German)	8/44.

SIGNED AND
SEALED
MAR 3 - 1970

(SEAL)

Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents