Jan. 3, 1967 J. H. HOPPER 3,295,594

THERMAL GARMENT

Filed Sept. 3, 1964 3 Sheets-Sheet 1

FIG. 1

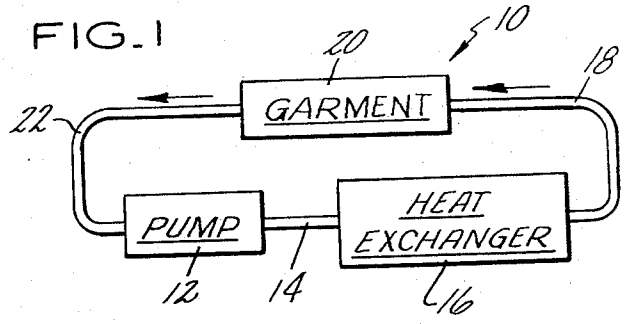


FIG. 4

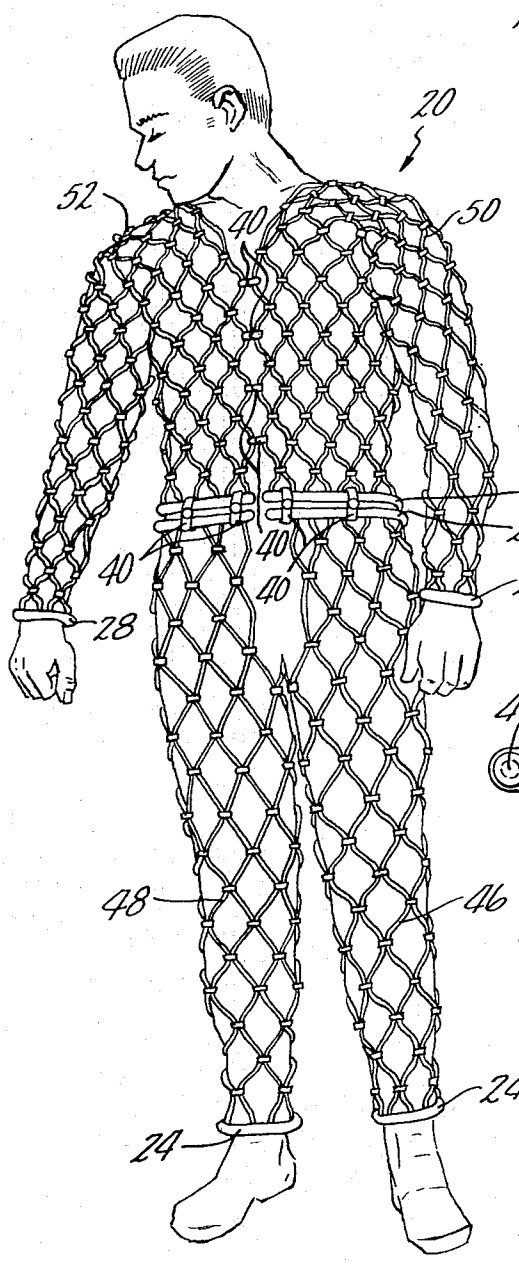


FIG. 3

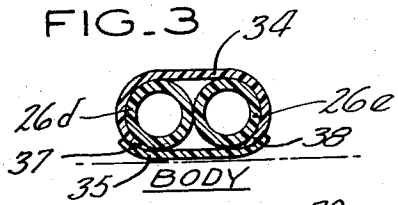
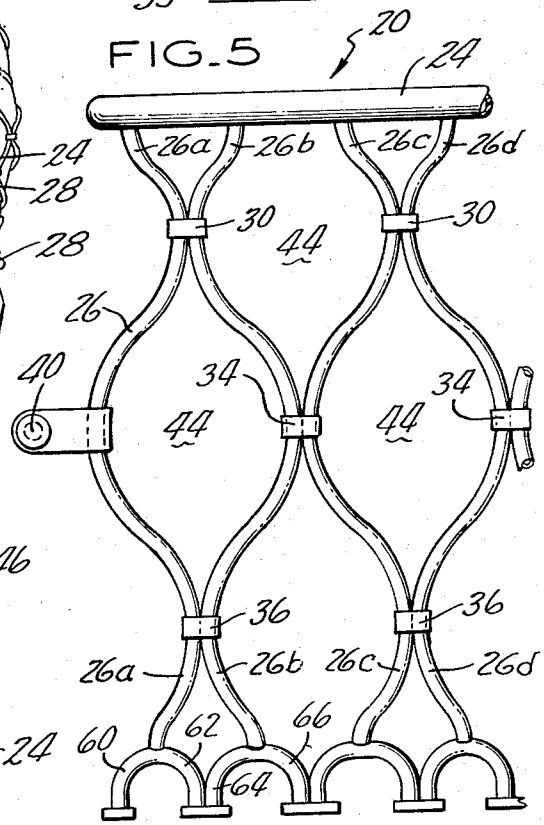


FIG. 5



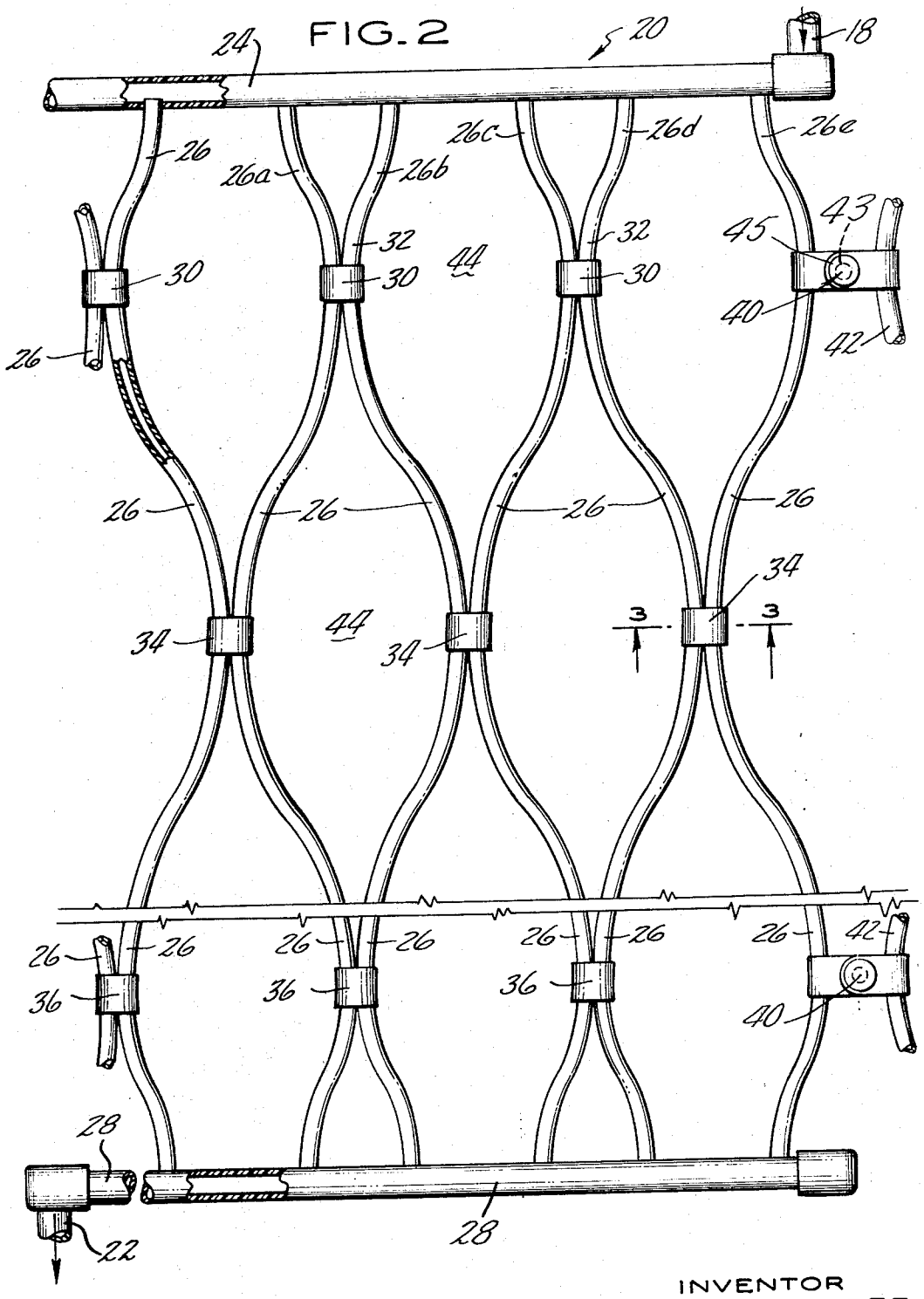
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FIG. 2



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FIG.6

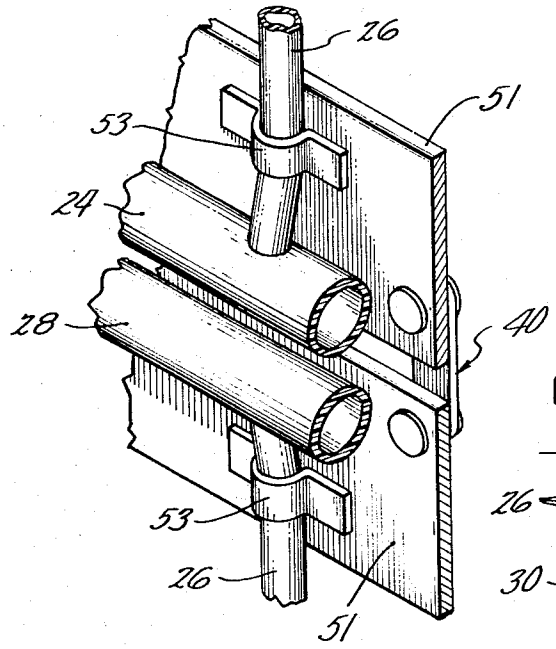


FIG.7

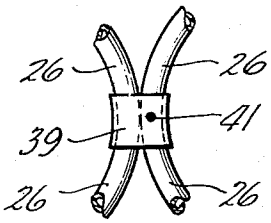


FIG.9

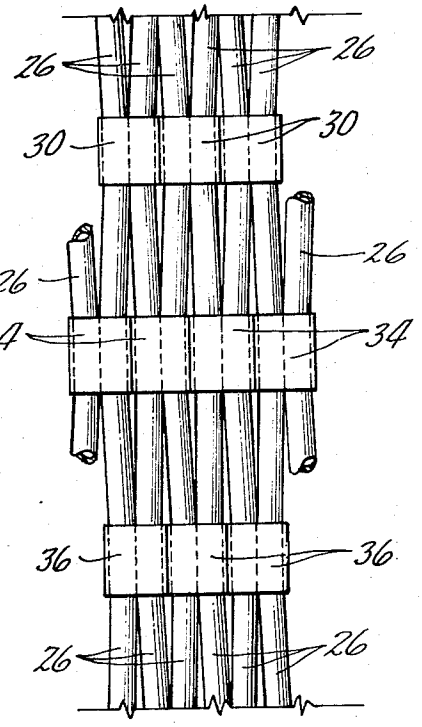
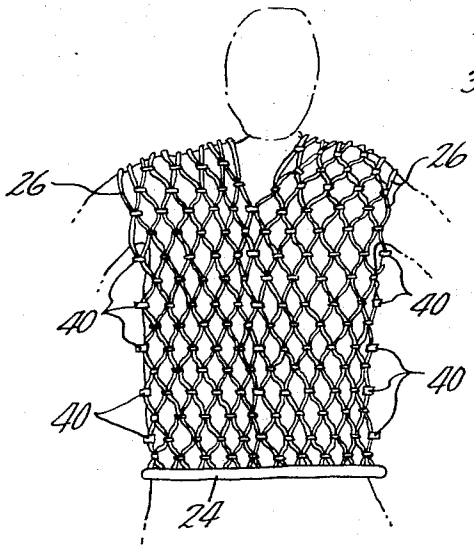


FIG.8



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3,295,594

THERMAL GARMENT

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Filed Sept. 3, 1964, Ser. No. 394,280
10 Claims. (Cl. 165—46)

This invention relates to thermal garments and more particularly to thermal garments which are made entirely of tubing.

It is an object of this invention to teach a thermal garment and the method of manufacture thereof, or a portion of a thermal garment, which is made entirely of fluid carrying tubing joined in such a way that the tubes form a network or mesh fabric which is expandable and flexible such that the garment will conform to the contours of the human body and such that all tubes lie against the body of the occupant at all times. A thermal garment which precisely assumes and maintains the human form of the occupant is said to be anthropomorphic.

It is a further object of this invention to teach a thermal garment which is made entirely of flexible tubing including an intake and an outlet header or manifold and a plurality of individual tubes running therebetween and joined together in serpentine or sinusoidal fashion so that the network made of the tubing is both flexible, expandable or stretchable and retractable or contractable and so that such tubing is of sufficient strength that it will not be flattened when sat upon or otherwise brought under pressure by the space suit occupant.

It is a further object of this invention to teach a thermal suit made entirely of tubes and in which each tube forms a separate fluid channel from all other tubes.

It is still a further object of this invention to teach a thermal garment or a partial thermal garment which is made entirely of joined tube pairs, which tube pairs are so joined that one such joined tube remains free running at all times.

Other objects and advantages will be apparent from the specification and claims and from the accompanying drawings which illustrate an embodiment of the invention.

FIG. 1 is a schematic representation of the system for providing fluid to a thermal garment.

FIG. 2 is a showing of a thermal garment portion made entirely of tubes and including inlet and outlet tube headers or manifolds.

FIG. 3 is a section taken along line 3—3 of FIG. 2 to show adjacent tubes joined in side-by-side relation.

FIG. 4 is a showing of a human body to illustrate how a thermal garment made in the fashion taught herein could be used.

FIG. 5 is a modification of my thermal garment construction showing how single tubes may be forked into double tubes and so forth.

FIG. 6 is a perspective showing taken from the position of the occupant's body to show the support and connection between the thermal tubes and the thermal manifolds.

FIG. 7 is a modification to the connection between adjacent thermal tubes and is an alternate to the type of connection shown in FIG. 3.

FIG. 8 is a thermal partial garment for use on the torso of the occupant.

FIG. 9 is a partial showing of a plurality of thermal tubes interconnected and in their unexpanded or retracted positions.

Referring to FIG. 1 we see a schematic representation of the support system for a thermal garment. A thermal garment, which may be used either to heat or cool the garment occupant, must be provided fluid, such as water, anti-freeze or the like, at the proper temperature, pressure and flow rate to be able to properly perform its function. The portable fluid providing system **10** of FIG. 1 comprises pump **12** which pumps the fluid through conduit **14** into conventional heat exchanger **16**, where the fluid is brought to the proper temperature. Upon leaving heat exchanger **16**, the fluid passes through conduit **18** and into garment or garment portion **20**, from whence it is passed through conduit **22** back to pump **12** for recirculation.

It is an important teaching of this invention that the thermal garment or thermal garment portion be made entirely of thermal tubing and be joined in such a fashion that the web, net, mesh fabric or network formed by the tubing is resilient, flexible and expandable so that it will lie flat against the body of the occupant and conform readily to the contours of the occupant's body whether the occupant is still or moving. The thermal garment is accordingly said to be anthropomorphic.

The preferred garment construction is illustrated in FIG. 2, which includes inlet manifold tubing **24**, which receives thermal fluid from conduit **18** and also includes a plurality of thermal tubes **26** which extend between intake or inlet manifold or header tubing **24** and outlet or scavenge manifold or header tubing **28**. Conduit **22** projects from outlet manifold tubing **28** to permit the return of the thermal fluid from garment **20** to pump **12** as illustrated in FIG. 1. Tubes **24**, **26** and **28** are of conventional hollow construction and are joined by molding, gluing or any conventional type of connection such that the interior of each tube **26** is in communication with the interior of both tube **24** and tube **28**. Accordingly, thermal fluid from tube **24** will flow into and through each tube **26** and then, from each tube **26**, into tube **28** where it is returned through conduit **22** to pump **12**. So that the garment or fabric **20** will lie flat against and remain in contact with the surface of the occupant's body at all times, tubes **26** are joined at spaced points or stations in sinusoidal or serpentine fashion as illustrated in FIG. 2. Adjacent tubes **26***a* and **26***b*; and **26***c* and **26***d* are joined by clips **30** to form tube pairs **32**. Clips **30** preferably lie in a single plane parallel to manifold tube **24**. Then, adjacent tubes of adjacent tube pairs **32**, such as **26***b* and **26***c*; and **26***d* and **26***e*, are joined by clips **34** at a second planar station parallel to the first planar station of clips **30**. Adjacent tubes such as **26***a* and **26***b*; and **26***c* and **26***d* are then joined by clips **36** at a third planar station parallel to the planar stations of clips **34** and **30**, thereby beginning the recycling of the tube joining process.

FIG. 3 illustrates a cross-sectional showing of clip **34**, and it should be borne in mind that clips **30** and **36** are identical therewith. Clip **34**, which is presumably a plastic clip, joins tubes **26***d* and **26***e* and is preferably attached to one such tube, such as **26***e* but the other such tube, such as **26***d* is free running within clip **34** so as to add to the flexibility and expandability of the network **20** so that it will more readily follow the contours of the occupant's body and lie flat thereagainst. Clips **30**, **34** and **36** join the tubes **26** in side-by-side relation thereby avoiding tube overlapping and the attendant displacement of the tubes **26** from the occupant's body. Since the tubes **26***d* and **26***e* are joined in free-running relation within clip **34**, these tubes will be restrained from moving laterally with respect to each other but are free to move longitudinally with respect to each other thereby permitting the space garment so fabricated to follow the contours of the wearer's body as the wearer moves about, thereby making the garment anthropomorphic.

It will be noted that plastic tape **35** extends over and between the knife-like edges **37** and **38** of clip **34** and bears against the body of the space suit occupant. Tape **35** is about .004" thick and is a good thermal conductor.

FIG. 7 illustrates another manner in which tubes **26**

may be joined. FIG. 7 shows vinyl sleeve **39** encircling adjacent tubes **26** and is preferably attached to one said tube as at point **41**, while the other tube is free running.

Snap **40** serves to join the edges of the thermal garment together or the edges of adjacent thermal garment portions together. For example, as best shown in FIG. 2, snap **40** may join tube **26***e* of thermal garment **20** to tube **42** of the adjacent thermal garment portion.

Snap **40** comprises male snap member **43** and female snap member **45**, each of which are attached to a circular grommet (not shown) which surrounds tube **26**.

It is deemed advisable to support tubes **26** adjacent their point of connection to manifolds **24** and **28** and, therefore, it is recommended that webbing or a belt **51** (FIG. 6) be placed outside of tubes **26** and include grip members **53**, which surround and support tubes **26** adjacent their connection to the manifolds **24** and/or **28**.

It will be evident to those skilled in the art that tube **42** could as well be the end tube of garment **20** when garment **20** is to be used on a human appendage such as a leg and tubes **42** and **26***e* will be joined by clips or snaps **40** when garment **20** is wrapped around the occupant's leg and joined by clips or snaps **40** in legging fashion.

By viewing FIG. 2 it will be noted that each tube **26** is joined alternately to the adjacent tubes on opposite sides thereof. For example, tube **26***c* is first joined to tube **26***d* then to tube **26***b*, then to tube **26***d* and so on so that each tube, such as **26***c* forms a sinusoidal or serpentine pattern and so that voids **44** are formed between adjacent tubes **26**.

FIG. 9 illustrates a plurality of tubes **26** joined by clips **30**, **34** and **36** and lying substantially parallel to one another in their unexpanded or retracted position. This is the position which the tubes will be in before they are expanded at their opposite ends to connect to manifolds **24** and **28** and before they are expanded at their central positions and held in that expanded position by snaps **40** as they cover the body or a portion of the body of the space suit occupant.

Referring to FIG. 4 we see thermal garment **20** on a human body. Thermal garment **20**, in the FIG. 4 configuration, is made in four sections, namely, the left leg section **46**, the right leg section **48**, the left torso and left arm section **50** and the right torso and right arm section **52**. Considering left leg portion **46** as typical, inlet manifold **24** may be positioned around the ankle thereof while outlet manifold **28** is preferably around the suit occupant's waist. The respective positions of the inlet and outlet manifold could obviously be changed; however, for convenience, it will probably be advisable to bring garment inlet tube **18** of FIG. 1 to the occupant at waist level and to position outlet conduit **22** of FIG. 1 at waist level also. It will accordingly be necessary to run either conduit **18** or **22** the length of the space suit occupant's leg to bring either the incoming or scavenging thermal fluid to or from the ankle area.

Considering left torso and left arm section **50**, the inlet manifold **24** may be at the occupant's waist, while outlet manifold **28** is at the wrist, or vice versa, but in all instances inlet and outlet tubes **18** and **22**, respectively, should be brought in at space suit occupant's waist.

FIG. 8 illustrates a garment portion made in accordance with my invention. Thermal tubes **26** extend from inlet manifold **24**, which extends across the front waist of the occupant, up the front of the torso of the occupant, across his shoulders, then down the back torso of the occupant to outlet manifold **28** (not shown) which extends across the back waist of the occupant. Snaps **40** preferably join the garment edges along the sides.

Referring to FIG. 5 we see a modification of garment **20** in which tubes **26***a–d* are joined as in FIG. 2, first at clips **30** then at clips **34**, then at clips **36**, but thereafter each tube **26** forks into two tubes, for example, tube **26***a* forks into tubes **60** and **62** while tube **26***b* forks into tube **64** and **66**.

It will be evident to those skilled in the art that tubes **24**, **26** and **28** may be made of several different types of material each of which are non-absorbent and non-porous but it is preferable that the material be a good heat conductor. Tubes **24–28** could be made of rubber or plastic and a garment has been so fabricated using a polyvinylchloride as the tube material. For tubes **26**, polyvinyl chloride of ⅛" O.D. and 1/16" I.D. has been found to be quite satisfactory. It will be evident that tubes **24–28** can be of circular cross section or other oval type cross section so as to provide greater heat transfer surfaces against the body of the space suit occupant.

During space suit use, water at 10–20 p.s.i.g. would be provided to garment **20** at temperatures between 32° F. and 80° F. and at flow rates of four pounds per minute down to two pounds per minute.

While, in the preferred embodiment, clips **30–36** are preferably as shown in FIG. 3, it should be borne in mind that rings of polyethylene or glued joints could be substituted therefor.

It is to be understood that the invention is not limited to the specific embodiment herein illustrated and described but may be used in other ways without departure from its spirit as defined by the following claims.

I claim:

1. An anthropomorphic thermal garment made entirely of tubes and adapted to cover a portion or the entire body of the occupant and comprising a first header-type tube, a second header-type tube, a plurality of third tubes each extending between said first and second tubes and with the interiors of said third tubes communicating with the interior of said first and second tubes, means to gather and retain adjacent third tubes together in side-by-side and free-running relation to thereby form tube pairs so that said third tubes so gathered and joined are restrained from lateral movement with respect to each other but are free to move longitudinally with respect to each other, and means to gather and retain adjacent tubes of said tube pairs together in side-by-side and free-running relation so that said tubes of said tube pairs so gathered and joined are restrained from lateral movement with respect to each other but are free to move longitudinally with respect to each other at selected second stations between said first stations to thereby form a flat, flexible, expandable network.

2. Apparatus according to claim **1** and including means to pass fluid through the interior of said tubes.

3. Apparatus according to claim **1** wherein said fluid passing means includes pumping means to pump fluid into said first tube, then through said second tubes, then through said third tube and back to said pumping means.

4. Apparatus according to claim **3** and including heat exchanger means within said fluid pumping means.

5. Apparatus according to claim **1** wherein one of said third tubes forks into at least two tubes.

6. An anthropomorphic thermal garment made entirely of tubes and adapted to cover a portion or the entire body of the occupant and comprising a plurality of hollow, flexible tubes, and means to join adjacent tubes at selected stations, said joining means being of thin-walled construction and shaped to at least partially envelope the adjacent tubes joined thereby so that the adjacent tubes so joined are in side-by-side relation within the joining means and with at least one of the adjacent tubes so joined being free running through the joining means so that said adjacent tubes so joined are restrained from lateral movement with respect to each other and are free to move longitudinally with respect to each other to thereby form a flat, flexible, expandable tube network, and means to supply fluid to said hollow tubes.

7. Apparatus according to claim **6** wherein the interior of each of said tubes is independent of the interior of

all other tubes throughout the length thereof so that each tube forms a separate fluid channel.

8. Apparatus according to claim 7 and including an inlet header joined to one end of said tubes and an outlet header joined to the other end of said tubes so that said tubes extend between said headers in single-pass fashion.

9. A thermal garment comprising a plurality of flexible tubes which are parallel and separated at a first substantially planar station and which have adjacent tubes joined in side-by-side and free-running relation so that said adjacent tubes so joined are restrained from lateral movement with respect to each other but are free to move longitudinally with respect to each other at a second substantially planar station substantially parallel to said first substantially planar station thereby forming tube pairs, and further having adjacent tubes of adjacent tube pairs joined in side-by-side and free-running relation so that said adjacent tubes of said adjacent tube pairs are restrained from lateral movement with respect to each other but are free to move longitudinally with respect to each other at a third substantially planar station substantially parallel to said first and second substantially planar stations, thereby forming a flat, flexible, expandable mesh fabric, and means to supply fluid to said hollow tubes.

10. An anthropomorphic thermal garment made entirely of tubes and adapted to cover a portion or the entire

body of the occupant and comprising a plurality of flexible, hollow tubes, means joining adjacent tubes in side-by-side, free-running relation so that said adjacent tubes so joined are restrained from lateral movement with respect to each other but are free to move longitudinally with respect to each other at selected stations to form a flexible, expandable layer of fabric adapted to lie flat against the occupant's body, and means to supply fluid to said hollow tubes.

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M. A. ANTONAKAS, *Assistant Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,295,594 January 3, 1967

James H. Hopper

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, after line 11, insert the following paragraph.

> The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U. S. C. 2457).

Signed and sealed this 3rd day of October 1967.

(SEAL)
Attest:

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Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents