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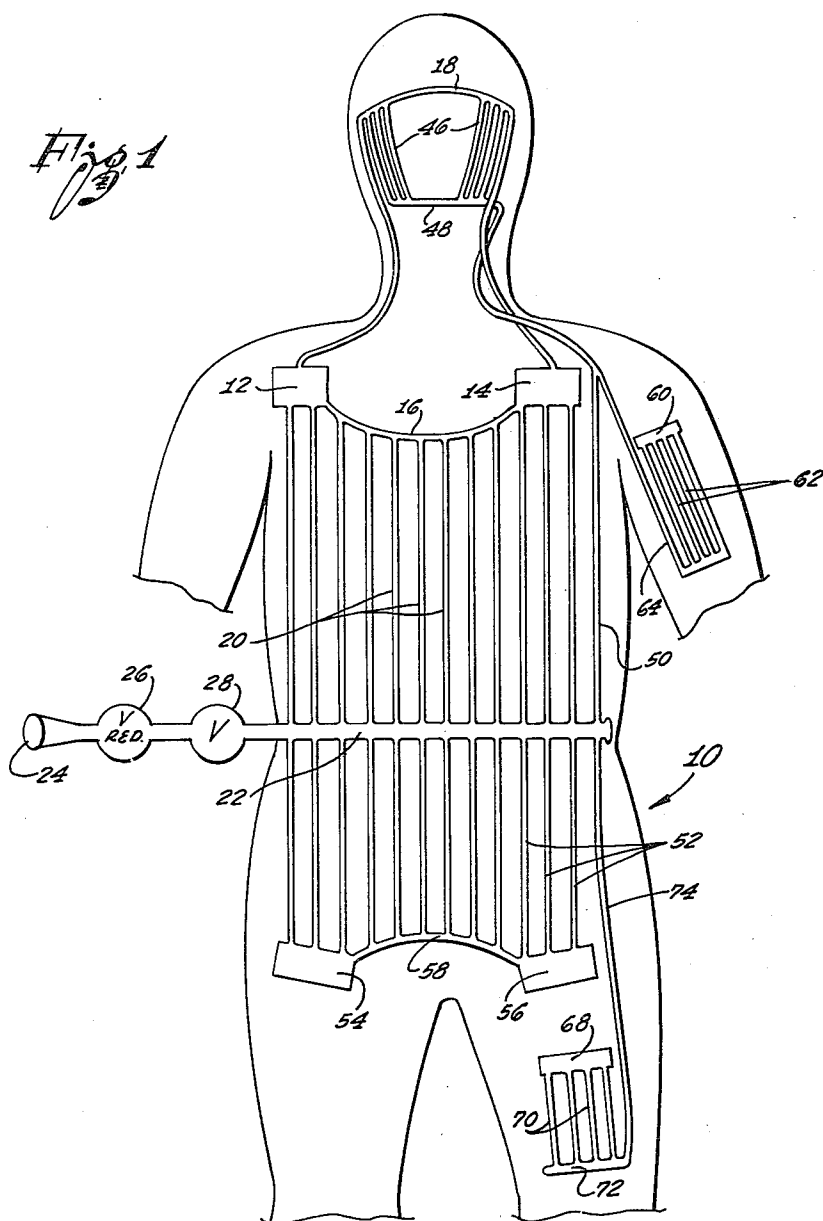
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3,079,765

COOLING GARMENT

Filed Sept. 26, 1961

2 Sheets-Sheet 1



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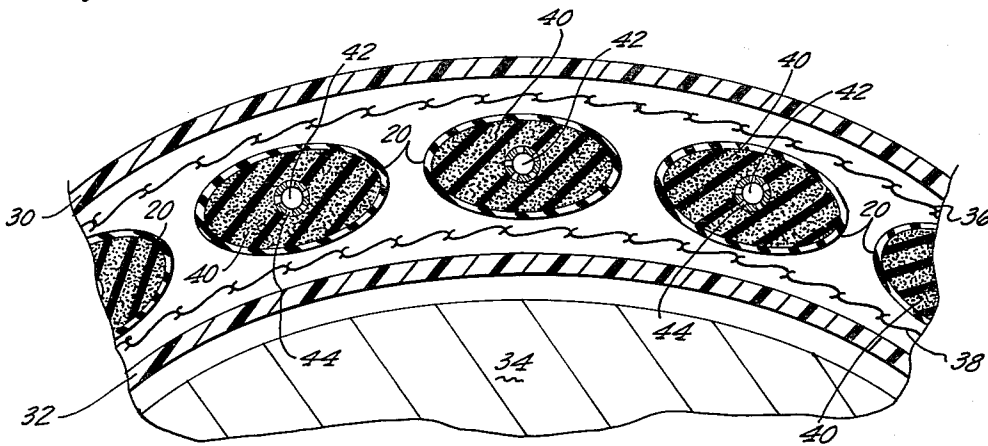
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Fig. 2



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COOLING GARMENT

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This invention relates to arrangements for controlling the temperature within a space suit, and more particularly to cooling apparatus for inclusion in space suits or other garments for use in space or at high altitudes.

Many garments or similar arrangements worn adjacent the body have been suggested for similar purposes, either for heating or cooling a human body when exposed to extreme conditions, and most of them involve the circulation of fluid through a system of containers and tubes. In most cases, the container system involves a network of flexible tubes and the fluid is supplied at a desired temperature from an external source. An obvious disadvantage of such prior art garments resides in the fact that the tube network must be continuously connected to the source of the constant temperature fluid. Such an arrangement necessarily impedes the freedom of movement of the wearer. This drawback has been overcome in some designs, for example in the case of heating garments, by a built-in vapor generating plant which forms part of the garment. Such arrangement is cumbersome and even dangerous, due to the presence of a fuel tank close to the body of the wearer. It appears that cooling suits heretofore were supplied in all cases from an external source of cooled air or other fluid, because the required coolers including compressor units are too heavy to be built into a garment.

Another type of garment has been designed for counteracting the effects of changes in speed and direction of movement to which pilots are occasionally subjected. Although this type of garment includes generally a network of containers such as flexible tubes, its purpose is to counteract sudden changes in blood pressure by means of external pressure applied to the body, and no change or control of temperature is involved.

It is one of the objects of this invention to utilize the specific condition of prevailing low pressure surroundings for cooling garments or other arrangements for this purpose positioned adjacent a human body. Another important object of this invention is to avoid the use of an external source of cooling fluid. Further objects of this invention include eliminating the compressor-type source of low temperature fluid and combining all of the components required for producing the cooling effect, so that a self-contained unit is obtained, which is independent from external sources. Consequently, the wearer of the garment is not impeded in his movements.

Extremes of heat and cold constitute a significant problem which must be faced by the present generation of space travelers. Thus, when a space man is exposed to the untempered rays of the sun, the radiation impinging on his space suit will tend to raise its temperature to excessive levels. On the other hand, when the space man is shielded from the sun by celestial bodies or by his space craft, the lack of incident radiation and the outgoing radiation from his space suit will tend to cool his body to relatively low levels. The present invention is primarily directed to cooling a space suit, when it is exposed to the heat of the sun, for example.

In accordance with the present invention, an arrangement for cooling or selectively controlling the temperature of the human body, when exposed to a low pressure atmosphere, includes an impermeable hollow structure, preferably a network of flexible tubes, which structure contains liquid-absorbing matter such as a sponge-like

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plastic material. This absorbing material is maintained impregnated with a liquid and provisions are made for establishing communication between the internal space in the tubes and the low pressure atmosphere. Upon connection with the low pressure atmosphere, the liquid with which the sponge-like filling material is impregnated reaches its boiling point at a low temperature corresponding to its vapor pressure at a low pressure level. It evaporates and exerts a cooling action on the tubes, and thereby on the garment and the wearer thereof, by extracting heat from its surroundings.

In practice, and in accordance with one feature of the invention, the garment includes one or more reservoirs containing water as the preferred cooling fluid and communicating with the internal space in the flexible tubes. In accordance with another feature of this invention, an outlet conduit connecting this internal space with the low pressure atmosphere includes a pressure regulator or reducing valve of any type well known in the art. By adjusting the pressure regulator, the pressure prevailing within the flexible tubes may be set to such a value that the boiling point of the water reaches the selected temperature.

Assuming that a temperature at which a person feels comfortable lies within the range of about 25° to 30° C. and based on the known facts that about 579 calories are required for every cubic centimeter of water to be evaporated and, furthermore, that about 352 watts are generated by a person under moderately severe working conditions, a simple calculation based on average values shows that about 1400 to 1500 grams of water are sufficient for reducing the temperature of a human body to a comfortable level during about four hours. In this calculation, heating resulting from radiation from the sun has been neglected since such heating is dependent upon exposure to the sun's rays, and would not occur when the wearer is shielded from the sun by his space ship, or another object. When not exposed to radiation, the wearer of a space suit as contemplated herein will generally shut off the valve or change the regulator adjustment to reduce cooling action. The total volume of the reservoirs can readily be determined according to the specific requirements in each case of application.

In accordance with additional features of the invention a space suit may be provided with a plurality of tubes filled with sponge-like material suitably connected to a manifold, the manifold forming the common outlet conduit and including the adjustable pressure regulator. Additional shutoff valves and separating tubes, extending axially through the tubes filled with the sponge-like material and forming the escape passageway for the water vapor, constitute further features of this invention.

The garment as set forth in the foregoing general description is maintained at a constant temperature by using the cooling effect resulting from vaporization of water at low pressure. As compared to prior art arrangements, it constitutes a self-sustained unit which does not need any connection to an external source of a cooling fluid so that the wearer is not impeded in his movements. By simply adjusting the regulator, the temperature may be adjusted to the desired level.

Other objects, features and advantages will become apparent from a consideration of the following detailed description and of the accompanying drawings in which

FIGURE 1 is a schematic view illustrating in a simplified manner a cooling garment in accordance with the invention; and

FIGURE 2 is a cross sectional fractional view taken along any portion of the cooling garment of FIGURE 1.

FIGURE 1 schematically illustrates the distribution of the network of flexible tubes over the different por-

tions of the human body, and as supported by a garment of the type under consideration known per se in the art. Specifically, the garment may be a known form of pressure-tight space suit, wherein the pressure is maintained at normal atmospheric pressure, despite external vacuum conditions. With regard to detailed construction, the tube network built into the garment, generally designated by reference numeral 10, includes portions covering the chest, abdomen and separate sections for the head, the arms and the legs may be provided, if desired. Similarly, a section for the back, not shown in the drawings, may also be included.

Referring now to the section covering the chest, water reservoirs 12 and 14 are suitably positioned at the upper portion of the chest and connected to each other by a pair of tube sections 16 and 18, the latter providing water supply to the head section of the garment. Reservoirs 12, 14 and the connecting conduit 16 communicate with the upper ends of a number of flexible, substantially vertically positioned parallel extending tubes 20.

The lower ends of tubes 20 are connected to a common manifold 22 forming the outlet conduit of the cooling system. As shown on the left-hand side of FIGURE 1, the outlet opening is designated by reference numeral 24. The terminal section of the outlet conduit includes a regulator 26 of any known type such as a spring-loaded reducing valve, and suitably a shutoff valve 28. For use under vacuum or low pressure conditions certain known precautions, such as the use of lubricants which do not evaporate, should be followed.

A detailed cross sectional view of the parallel tubes such as tubes 20 is shown in FIGURE 2. The type of garment under consideration generally includes outer and inner layers 30 and 32, respectively, made of any suitable material, such as plastic or the like, with at least the outer layer 30 being made of impermeable material so that the unit as a whole is a pressure-tight space suit fulfilling all the requirements for this type of garment. In FIGURE 2, the inner layer 32 is illustrated in contact with a human body 34. Adjacent the outer layers or shells 30 and 32, a pair of layers 36 and 38 of fabric generally forms part of garments of this type. The cooling system in accordance with the invention is supported by the garment and arranged between inner layers 36 and 38. It includes the parallel extending tubes 20, suitably fabricated from a flexible elastomer. The tubes are filled with a liquid-absorbing material 40 of sponge-like consistency, such as open cell rigid plastic. This filling material is arranged in such a manner that axial extending channels 42 remain in the center of each of the tubes 20. When using plastic sponge-like material which has been preshaped to assume the desired configuration, the channels may be provided in the material before inserting it into the tubes 20. However, when using pulverized sponge material, additional perforated tubes for separating the channels 42 from the filling material particles may be inserted into the tubes 20 before the filling step. Such additional, channel-forming inner tubes are shown in FIGURE 2 and designated by reference numerals 44.

Considering now the manner of operation of the cooling garment and particularly referring to the chest section, it will be clear that the sponge-like filling material 40 contained in the tubes 20 remains impregnated with water supplied from reservoirs 12 and 14, either directly or through connecting tube 16. Assuming that the outlet aperture 24 opens into a low pressure atmosphere, and with the shutoff valve 28 in its open position, the pressure prevailing within the channels 44 can be adjusted by setting the pressure regulator 26 to a pressure value which is that of water vapor pressure at the selected temperature. With increasing temperature prevailing at the skin of the wearer of the cooling suit, due to metabolic heat produced by the body, the water retained by the filling material reaches the boiling point associated with the

pressure to which the pressure regulator has been adjusted. The escaping-water vapor travels along the open channels 42 within the perforated tubes 44, through manifold 22 and passes through valves 28 and 26 toward the outlet aperture 24. Since low pressure prevails in the atmosphere surrounding aperture 24, the vapor pressure within the tubes 20 is also at a low level, and the boiling point of the water within the tubes 20 is reached at a low temperature. Accordingly, and by setting regulator 26 to a vapor pressure corresponding to a boiling point of about 25° to 30° C., the suit as a whole is maintained at this temperature. Since conversion of water to steam or water vapor extracts 579 calories for every cubic centimeter of water evaporated, the desired cooling action is achieved, as discussed above.

It will be apparent from the arrangement shown in FIGURE 1 that the system of parallel tubes 46 in the head section of the garment is supplied with water through connecting tube 18, with the water vapor escaping through manifolds 48, conduit 50 and manifold 22 toward outlet aperture 24.

The lower body section comprising the network of tubes 52 receives water from reservoirs 54 and 56, or through the tube 58 connecting reservoirs 54 and 56.

In a similar manner, FIGURE 1 illustrates the arrangement in one of the arm sections supplied from reservoir 60, with the tubes designated by reference numeral 62. The outlet conduit 64 from the arm section is suitably connected to tube 50 and thereby leads into the common manifold 22.

In an identical manner, the leg section includes reservoir 68, tubes 70, manifold 72 and outlet conduit 74. It will be understood that tubes 46, 62 and 70 pertaining to the head section, the arm sections and the leg sections, respectively, are constructed as described with respect to tubes 20 of the chest section, and as shown in FIGURE 2.

Even though shutoff valve 28 may be omitted, it was found advisable to provide a possibility of isolating the reducing valve 26 from the entire tube network supported by the garment 10, because under extreme conditions reducing valve 26 could be rendered inoperative by the formation of ice.

It will be apparent that even though only one arm and leg section of comparatively small dimensions are shown in FIGURE 1, the number and size of areas covered by cooling tube sections can be selected in accordance with prevailing circumstances and the purpose of the cooling garment. As a matter of course, either both leg and arm sections will include the cooling system according to this invention or, if found unnecessary, arm sections, leg sections and the head section may be omitted.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention. Thus, by way of example but not of limitation, other known materials may be used, in place of those suggested above; the system may be used with other types of garment or underwear; shutoff valves may be provided at the outlet from the reservoirs for emergency purposes; and the present invention is also applicable to double-walled space craft or the like. Accordingly, from the foregoing remarks, it is to be understood that the present invention is to be limited only by the spirit and scope of the appended claims.

What is claimed is:

1. In an arrangement for selectively controlling the temperature of a human body when exposed to a low pressure atmosphere, an impermeable hollow structure, means for absorbing a liquid arranged within the hollow structure, means for selectively establishing communication between the absorption means and the low pressure atmosphere to cause the liquid to evaporate, and

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garment-like means for maintaining the hollow impermeable structure adjacent the human body.

2. In an arrangement for maintaining at a substantially constant level the temperature of a human body when exposed to a low pressure atmosphere, an impermeable hollow structure, means for absorbing a liquid arranged within the hollow structure, reservoir means for holding a liquid communicating with the internal space within the hollow structure to maintain the absorbing means impregnated with the liquid, conduit means for establishing communication between the absorption means and the low pressure atmosphere to cause the liquid to evaporate, and means for maintaining the hollow impermeable structure adjacent the human body.

3. In combination, a network of intercommunicating impermeable hollow containers, sponge-like liquid-absorbing means within the containers, reservoir means for holding a liquid communicating with the internal space within the containers to maintain the absorbing means impregnated with the liquid, means for establishing communication between the absorption means and a low pressure atmosphere to cause the liquid to evaporate, and means including a pressure-tight garment for maintaining the container network adjacent a human body.

4. In an arrangement for maintaining a human body at a selectively predetermined temperature level when exposed to a low pressure atmosphere, an impermeable hollow structure, means for absorbing a liquid arranged within the hollow structure, conduit means for establishing communication between the absorption means and the low pressure atmosphere to cause the liquid to evaporate, means for regulating the pressure within the structure to adjust the vapor pressure of the liquid to a value associated with the selected temperature level, and means for maintaining the hollow impermeable structure adjacent the human body.

5. In an arrangement for maintaining a human body at a selectively predetermined temperature level when exposed to a low pressure atmosphere, a network of intercommunicating impermeable tube sections, sponge-like water-absorbing means within the tubes, at least one water reservoir communicating with the internal space in the tube sections for maintaining the absorption means impregnated with water, an outlet conduit for establishing communication between the internal space within the tubes and the low pressure atmosphere to cause the water to evaporate, a pressure regulator in the outlet conduit for adjusting the pressure prevailing within the tubes to a value corresponding to the water vapor pressure at the selected temperature, and means for flexibly combining with each other the tube sections to form a portion of a garment adapted to be worn by humans.

6. In a cooling arrangement for space conditions, a vacuum tight double wall enclosing a space for accommodating at least one human being, liquid absorbing material within said double wall, a liquid reservoir communicating with said absorbing material, and valve means for selectively releasing vapor from said absorbing material to the outside of said double wall.

7. In an arrangement for maintaining a human body at a selectively predetermined temperature level when exposed to a low pressure atmosphere, a network of intercommunicating impermeable tube sections, a garment-like structure supporting the tube sections for removably maintaining them adjacent a human body, sponge-like water-absorbing material positioned within the tubes and adjacent the walls thereof to leave a substantially central channel extending axially through the tubes, at least one water reservoir communicating with the internal space in the tubes sections for maintaining the absorbing material impregnated with water, an outlet conduit for establishing communication between the internal space within the tubes and the low pressure atmosphere to cause the

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water to evaporate, and a pressure regulator in the outlet conduit for adjusting the pressure prevailing within the tubes to a value corresponding to the water vapor pressure at a selected temperature.

8. In combination, a pressure-tight garment, at least one water reservoir built into the garment, a network of intercommunicating containers including a plurality of flexible tubes joined to a common flexible manifold also built into the garment, each tube being partly filled with an open cell rigid plastic material to leave a central passage axially extending through each of the tubes, a conduit connecting the reservoir with the tubes to maintain the filling material impregnated, an outlet conduit for connecting the common manifold with the outer low pressure atmosphere, and a pressure regulating valve in the outlet conduit for adjustably setting the pressure prevailing within the tubes, whereby the water absorbed by the filling material reaches its boiling point at the temperature corresponding to the pressure selected by the valve position.

9. An arrangement for maintaining a human body at a selectively predetermined temperature level when exposed to a low temperature atmosphere, comprising a garment, at least one water reservoir built into the garment, a network of intercommunicating containers including a plurality of flexible tubes joined to a common flexible manifold also built into the garment, each tube being partly filled with an open cell rigid plastic material to leave a central passage axially extending through each of the tubes, at least one water reservoir also built into the garment, a conduit connecting the reservoir with the tubes to maintain the filling material impregnated, an outlet conduit for connecting the common manifold with the outer low pressure atmosphere, a pressure regulating valve in the outlet conduit for adjustably setting the pressure prevailing within the tubes, whereby the water absorbed by the filling material reaches its boiling point at the temperature corresponding to the pressure selected by the valve position and a shutoff valve provided in the outlet duct between the tubes and the regulator valve.

10. An arrangement for maintaining a human body at a selectively predetermined temperature level when exposed to a low temperature atmosphere, comprising a garment, a network of intercommunicating containers including a plurality of outer flexible tubes joined to a common flexible manifold built into the garment, each tube being partly filled with an open cell rigid plastic material to leave a central passage axially extending through each of the tubes, each central passage being defined by a perforated inner tube substantially coaxially extending within the flexible outer tube, at least one water reservoir also built into the garment, a conduit connecting the reservoir with the outer tubes to maintain the filling material impregnated with water, an outlet conduit for connecting the common manifold with the outer low pressure atmosphere, and a pressure regulating valve in the outlet conduit for adjustably setting the pressure prevailing within the tubes, whereby the water absorbed by the filling material reaches its boiling point at the temperature corresponding to the pressure selected by the valve position.

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