

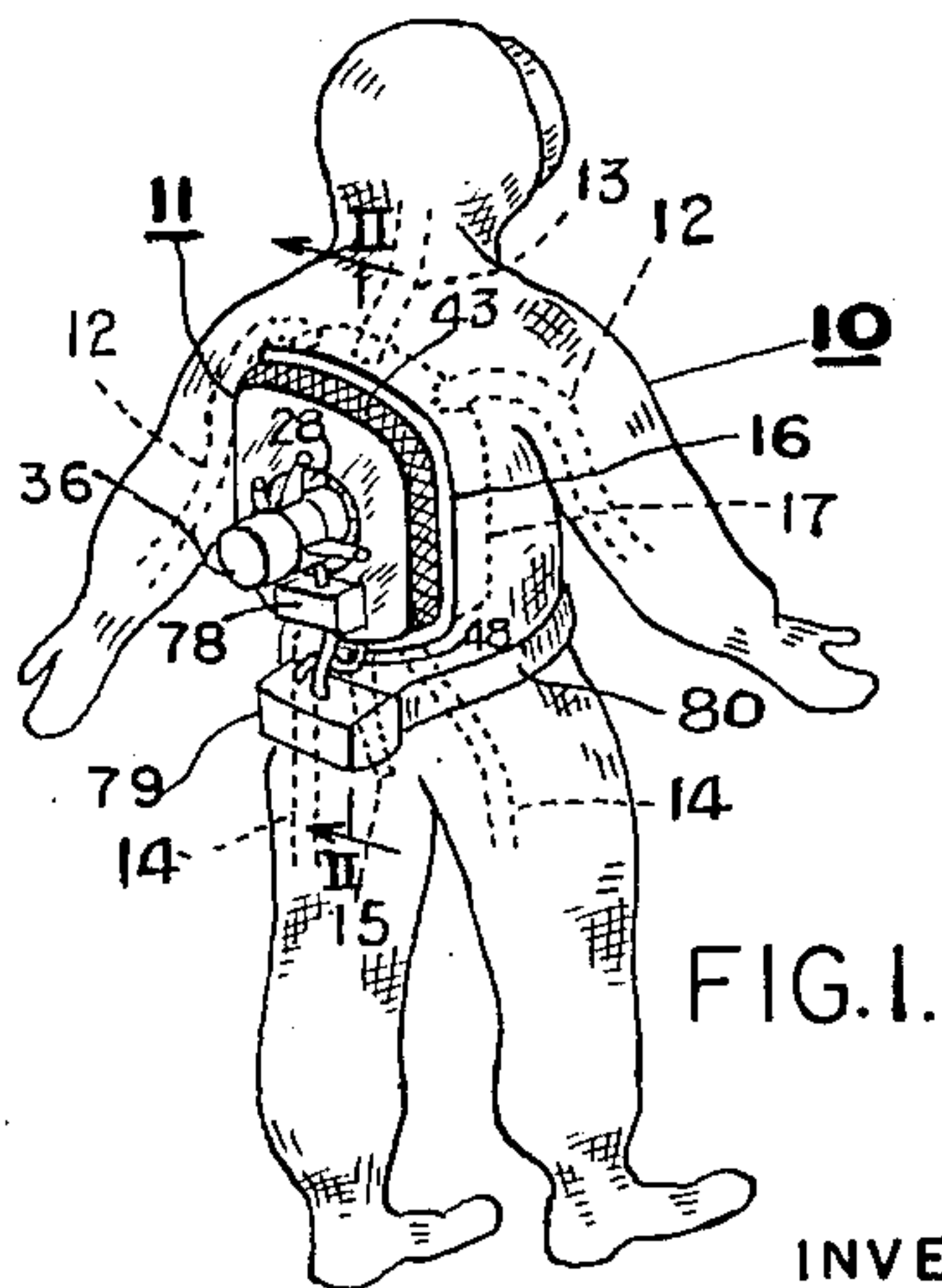
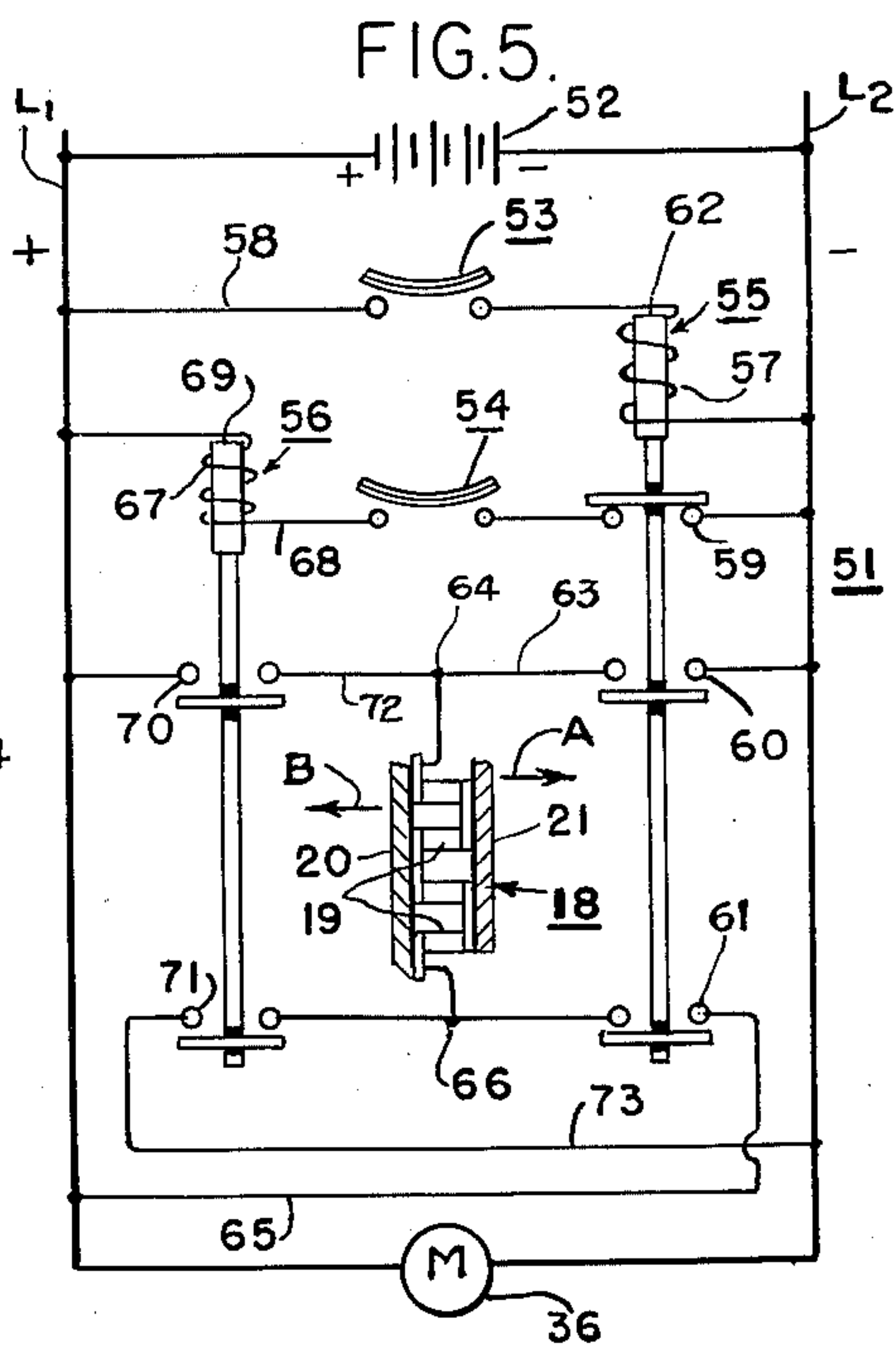
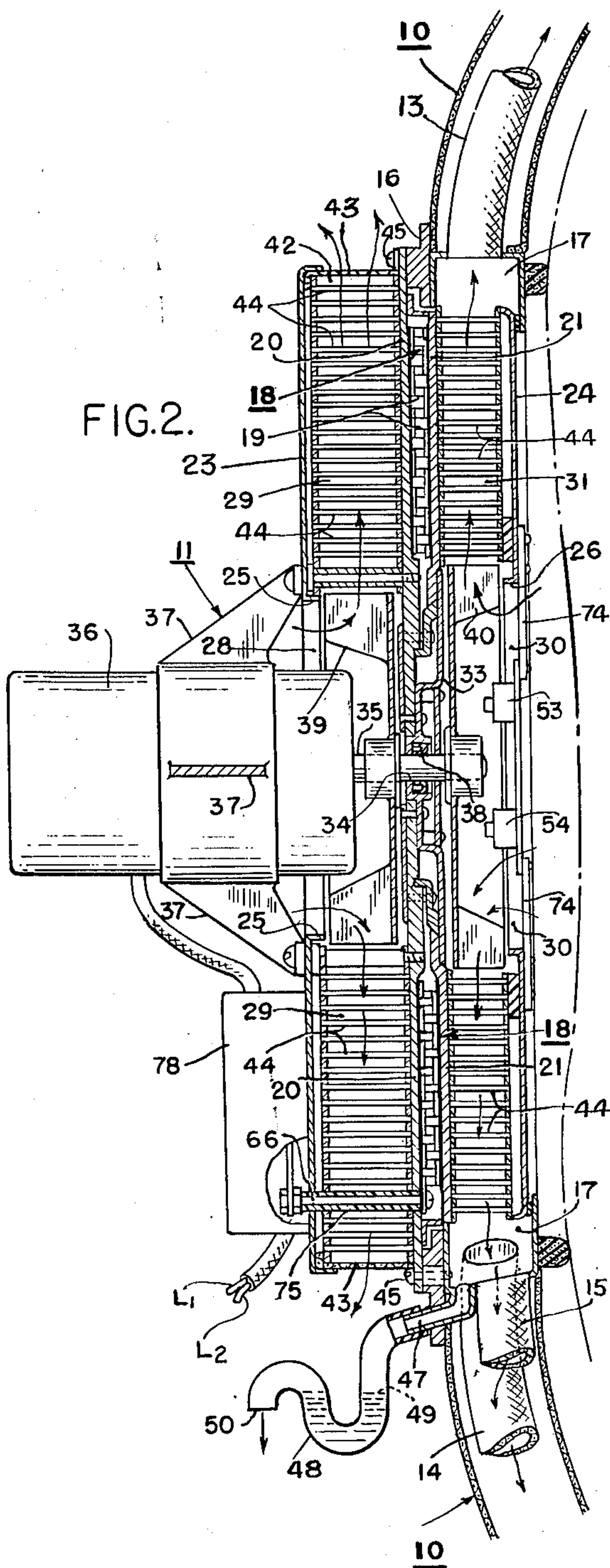
April 16, 1963

E. W. FRANTTI
THERMOELECTRIC AIR CONDITIONING APPARATUS
FOR A PROTECTIVE GARMENT

3,085,405

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FIG. 3.

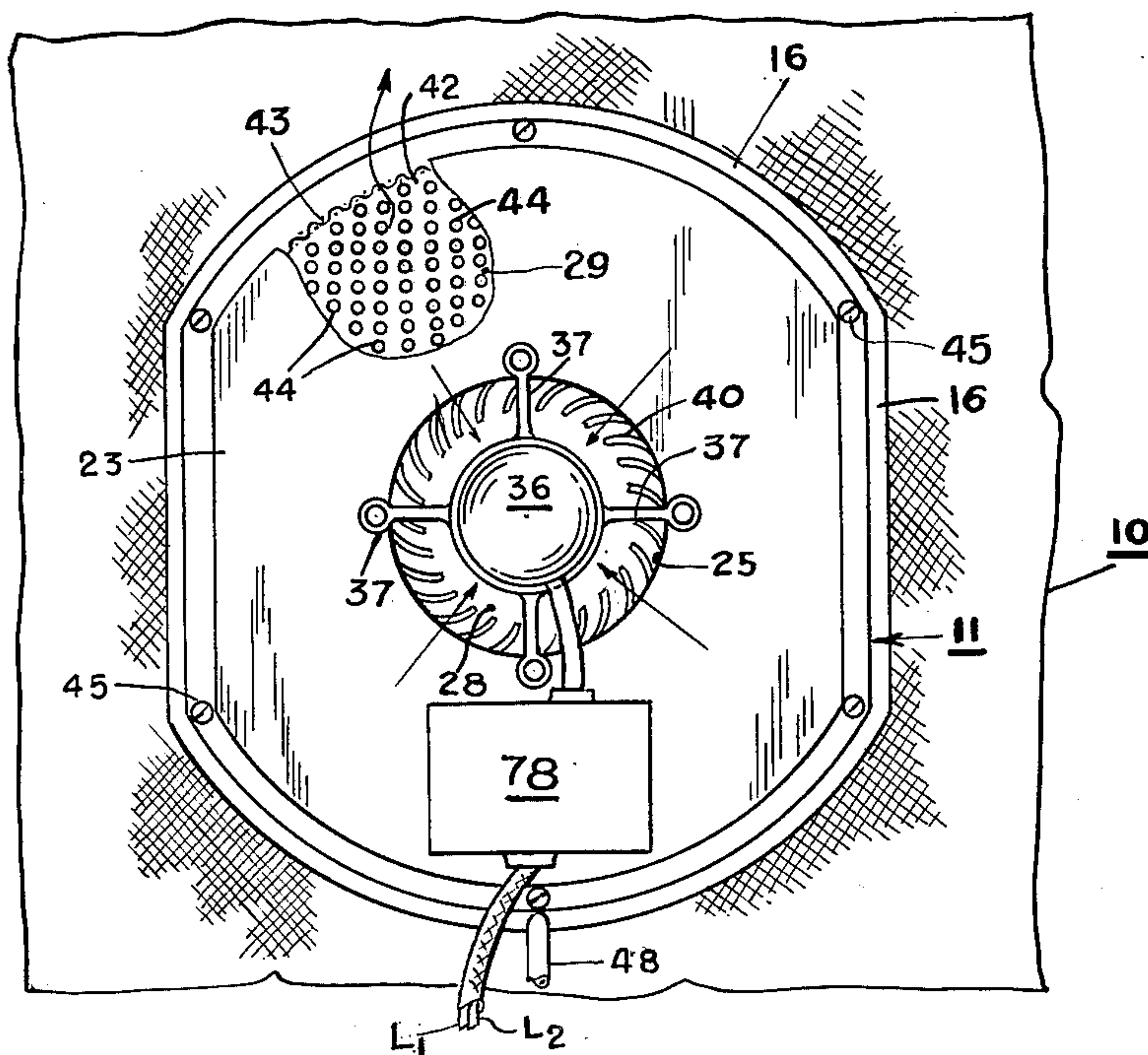
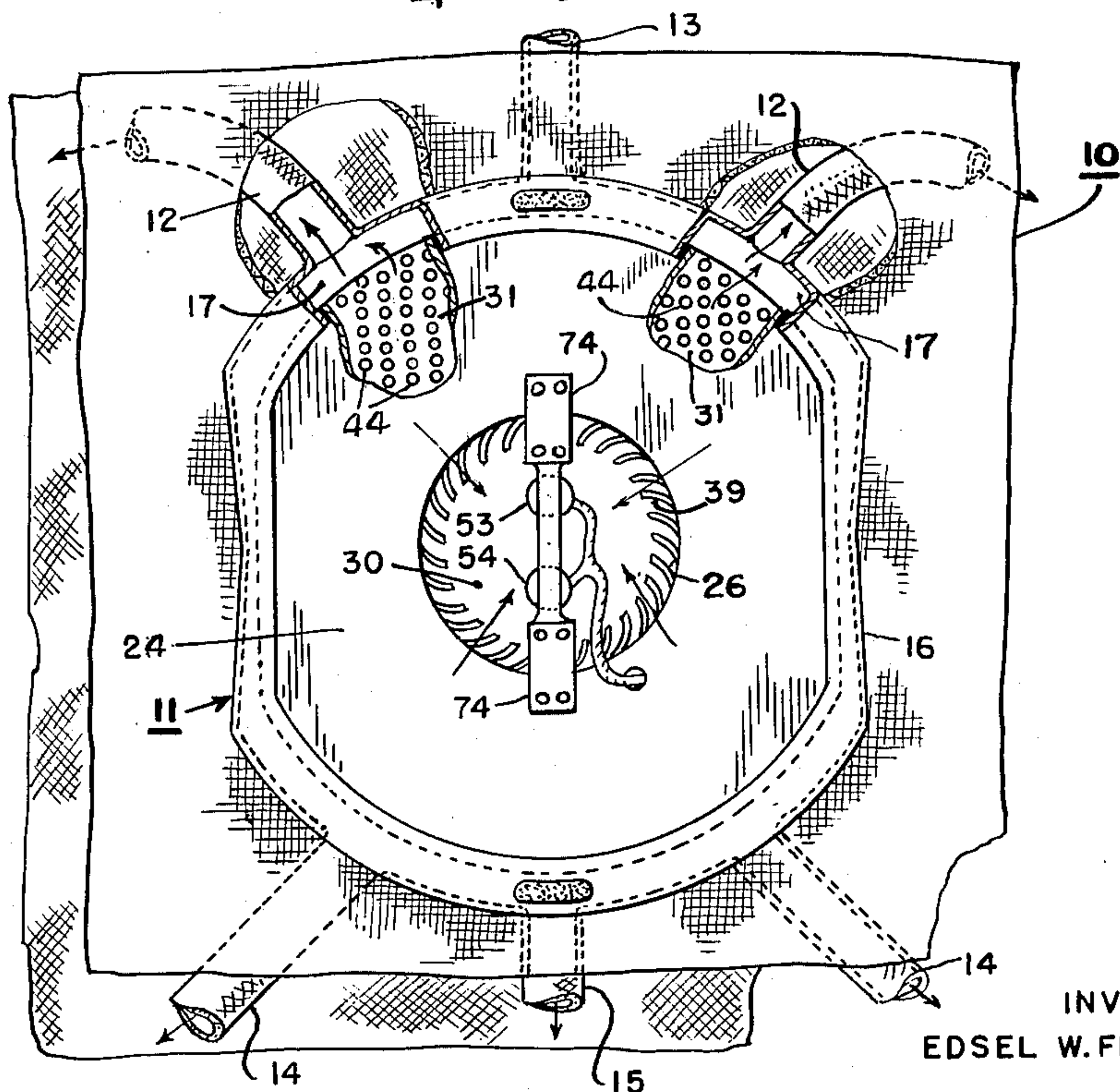


FIG. 4.



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THERMOELECTRIC AIR CONDITIONING APPARATUS FOR A PROTECTIVE GARMENT

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5 Claims. (Cl. 62—3)

This invention relates to air conditioning apparatus and more particularly to a portable device employing thermoelectric pumping means for heating or cooling an elastic fluid such as air.

Thermoelectric heat pumping devices employing the Peltier principle of heat absorption and heat dissipation at junctions of current-carrying, dissimilar thermoelectric bodies are particularly suitable for portable or small device applications because of the absence of moving parts and relative lightness in weight. However, one of the principal disadvantages at the present time lies in the large number of thermoelectric bodies and junctions required to produce a useful heat pumping effect with presently known materials.

One of the objects of this invention is to provide a lightweight and compact portable device of high efficiency having a thermoelectric heat pumping panel structure for providing heated or cooled air to a protective garment, as required, to maintain the interior of the garment within a comfortable range of temperature for the wearer, regardless of the temperature of the ambient.

Another object of the invention is to provide a control responsive to temperature of the air at the inlet of the conditioned air passage to automatically control the direction of flow of the energizing D.C. current through the heat pumping panel, as required, to maintain the temperature of the conditioned air within a predetermined range, regardless of ambient temperature.

Preferably, in accordance with the invention, there is provided a portable device adapted to be attached to the back of a protective garment for conditioning and circulating the conditioned air through the interior of the garment to a sufficient degree to maintain the wearer of the garment within a heat comfort range, regardless of wide variations from cold to hot temperatures of the ambient atmosphere.

The portable device includes a thermoelectric heat pumping panel of generally planar form disposed within housing structure including a front wall and a rear wall disposed in spaced relation with the panel and on opposite sides thereof and jointly therewith defining first and second air flow passages of annular shape. The walls are provided with central apertures providing air inlets for said first and second passageways, respectively. First and second blower wheels are centrally disposed in the first and second passageways and are jointly driven by a suitably mounted motor having a drive shaft extending perpendicularly through the thermoelectric panel and drivingly supporting the blower wheels.

The outer periphery of the rear wall jointly with the outer periphery of the thermoelectric panel defines a peripheral outlet for the first air flow passageway and, similarly, the outer periphery of the front wall and the thermoelectric panel jointly define a peripheral outlet for the second air passageway. The peripheral outlet of the first passageway is in direct communication with the atmosphere, while the peripheral outlet of the second passageway is adapted to be disposed in communication with a suitable annular manifold attached to the protective garment. Hence, when the thermoelectric panel is energized in a direction to absorb heat from the second passageway and pump the thus absorbed heat through the

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panel to the first passageway, as the motor is energized, the two blowers are driven to circulate air through the two passageways past the adjacent faces of the thermoelectric panel.

The blower in the second passageway draws air through its associated central inlet from the garment and impels this air through the second passageway in radially outward directions to the peripheral outlet thereof. During flow through the second passageway, heat is absorbed by the thermoelectric panel from the air flow, thereby cooling the same and returning the thus cooled air to the garment for cooling purposes. Concomitantly therewith, the blower wheel in the first passage is effective to draw atmospheric air through its associated central inlet and pump it in radially outward directions through the first passageway to absorb the heat pumped by the thermoelectric panel from the first passageway. After the air flows through the first passageway, it is returned to the atmosphere through the peripheral outlet.

The above described conditioning device is automatically controlled to heat the air coming into the first passageway when the temperature of the air is below a predetermined low value, for example, below 73 degrees F., and to cool the incoming air when the temperature of the air is above a predetermined high value, for example, above 83 degrees F. The control system includes thermostatic means disposed adjacent the air inlet to the second passageway and responsive to the temperature of the incoming air to complete a circuit from a suitable D.C. power supply through the thermoelectric panel in a direction to effect heating of the air in the second passageway when the temperature is below the above mentioned predetermined low temperature and to reverse the connections between the thermoelectric panel and the D.C. power supply when the temperature is above the above mentioned predetermined high value, thereby to initiate operation of the thermoelectric panel in a manner to absorb heat from the air flow through the second passageway.

One of the main features of the above described control system resides in provision of a set of contacts arranged to interrupt the heating circuit when the cooling circuit is energized, thereby providing a positive "lock-out" arrangement preventing simultaneous operation of the two circuits.

The above and other objects are effected by the invention as will be apparent from the following description taken in connection with the accompanying drawings, forming a part of this application, in which:

FIG. 1 is a perspective view illustrating a protective garment provided with a portable air conditioning device in accordance with the invention;

FIG. 2 is a highly enlarged sectional view taken on line II—II of FIG. 1 and showing the detailed structural arrangement of the device;

FIGS. 3 and 4 are rear and front views, respectively, of the device with portions cut away to show the internal structure; and

FIG. 5 is a schematic wiring diagram illustrating the electrical system for controlling the air conditioning device.

Referring to the drawings in detail, in FIG. 1 there is shown a protective garment 10 adapted to encase and protect the wearer from external hot or cold ambient temperatures. The protective garment 10 forms no part of the invention but has been illustrated to show one of the primary applications of an air conditioning device 11 formed in accordance with the invention. However, it will be understood that the protective garment 10 is provided with a plurality of flexible ducts or tubes 12, 13, 14 and 15 for conducting air conditioned by the air conditioning device 11 to various parts of the body of the

wearer, such as the arms, the head, the legs and the rear portion of the torso, respectively, in a closed or recirculating circuit.

As best shown in FIG. 2, the protective garment 10 is provided with a suitable annular manifold structure 16 forming an annular plenum chamber 17 disposed in communication with the inlets of the flexible ducts 12 to 15, inclusive.

The air conditioning device 11, as best shown in FIG. 2, includes a thermoelectric heat pumping panel 18 having a plurality of thermoelectric bodies 19 connected to each other in electrical series and confined between a pair of heat conducting plate members 20 and 21 in any suitable manner. The thermoelectric bodies 19 may be of any suitable known type, for example, they may be of the type shown in C. F. Alsing patent application Serial No. 22,442, filed April 15, 1960, now Patent No. 3,040,538 dated June 26, 1962 and assigned to the same assignee as this invention; hence, they need not be further described. However, it must be understood that the thermoelectric panel 18, when energized by a supply of direct current, absorbs heat from one of the plates 20, 21 and rejects the absorbed heat to the other of the plates 20, 21 with a continuous pumping action, in accordance with the Peltier principle.

The general peripheral contour of the air conditioning device 11 is substantially circular at its upper and lower edges with substantially straight left and right edges, as best shown in FIGS 3 and 4 to permit freedom of arm movement by the wearer of the protective garment. Accordingly, the thermoelectric panel is of substantially the same contour as described above, with the thermoelectric bodies 19 disposed in an annular array.

Rear and front wall structures 23 and 24, respectively, of substantially planar annular shape are disposed in rearwardly and forwardly spaced relation with the heat conducting plates 20 and 21, respectively. The rear wall structure 23 is provided with an enlarged central aperture 25 and, in the same manner, the front wall structure 24 is provided with an enlarged central aperture 26. The central aperture 25 defines a centrally disposed air inlet 28 for a first annular air passageway 29 defined by the rear wall structure 23 and the heat conducting plate 20, while the central aperture 26 defines a centrally disposed air inlet 30 for a second annular air passageway 31 defined by the front wall structure 24 and the heat conducting plate 21.

The thermoelectric panel 18 is further provided with a disc-like bearing support structure 33 having a central aperture 34 through which the drive shaft 35 of a suitable electric motor 36 extends. The motor 36 is preferably attached to the rear wall structure 23 by a plurality of radially extending strut members 37 and is so arranged that the drive shaft 35 extends through the aperture 34 with its axis perpendicular to the plane of the thermoelectric panel 18. Also, a suitable annular sealing member 38 is provided in the bearing support member 33 to prevent air from flowing through the aperture 34. The drive shaft 35 rotatably supports a pair of impellers or blower wheels 39 and 40 for joint rotation and the two impellers are so arranged that, in operation, they draw air in through the associated air inlets 28 and 30, respectively, and pump the air thus drawn in radially outwardly directions through their associated air passages 29 and 31, respectively. Atmospheric air is drawn through the air inlet 28 and is returned to the atmosphere through a peripheral outlet 42 disposed in communication with the air passage 29 and preferably protected by a suitable annular screen member 43. Air from the garment 10 is drawn through the air inlet 30, directed radially outwardly through the passage 31, into the plenum chamber 17 of the protective garment 10, and thence returned through the ducts 12-15, inclusive, to the garment.

The heat exchange surface area of the heat conducting plate members 20 and 21 may be considerably extended

in a manner well known in the art by a plurality of pins 44 extending transversely across the air flow passages 29 and 31 and disposed in good metal-to-metal contact with their associated plate members 20 and 21 and wall structures 23 and 24. Hence, during operation, the heat absorbed by one of the plate members and its associated pins 44 from the air flowing through its associated passageway is readily transmitted to the thermoelectric bodies 19 and the heat pumped to the other plate member and its associated pins 44 is readily transmitted to the air flowing therepast.

The air conditioning device 11 may be detachably connected to the manifold structure 16 of the protective garment 10 in an air-tight manner by a plurality of quick-acting screw members 45 of any suitable type, spaced peripherally about the heat conducting plate 20, as best shown in FIGS. 2 and 3.

When the air conditioning device 11 is employed to cool the air flow delivered to the garment, the heat conducting plate 21 may be at a temperature below the dew point, so that some moisture in the air flowing therepast is condensed on the surface of the plate. The condensate thus formed drops downwardly by gravitational effect to the bottom of the manifold 16 and may be delivered therefrom to the atmosphere through a drain tube 47. Since the conditioned air flow cycle is a closed loop, it is desirable to prevent entry of atmospheric air into the passageway 31. A tubular trap 48 of inverted U-shape is connected at one end to the end of the tube 47 and is filled with a suitable liquid, such as water, to the height indicated at 49, thereby effectively sealing the outlet of the tube 47 against direct communication with the atmosphere. However, as condensate flows into the right-hand leg (FIG. 2) to a height above the existing level 49, the height of the liquid in the left-hand leg will also rise until the excess condensate is spilled into the atmosphere through the outlet 50 of the U-shaped tube.

The air conditioning device 11 is energized and controlled to provide heated air or cooled air to the protective garment 10, as required, by a control system generally designated 51 and illustrated schematically in FIG. 5. Referring to FIG. 5, a source of D.C. power, for example, a battery 52 is connected to a pair of thermostatic switches 53 and 54 by a pair of electrical conductors L1 and L2. Each of the thermostats is provided with a bimetallic member responsive to the air temperature at the inlet 30 for closing and opening an associated pair of contacts, thereby to control the energization of the thermoelectric panel 18 to heat or cool the air from the garment, as required. The thermostat 53 controls the energization of a relay 55, while the thermostat 54 controls the energization of a relay 56, which, in a manner shortly to be described, are arranged to connect the thermoelectric panel 18 to the D.C. power supply 52 for heating and cooling, respectively, by reversing the polarity of the D.C. supply across the thermoelectric panel.

The relay 55 includes an inductive winding 57 connected across lines L1 and L2 by a conductor 58 having the thermostatic switch 53 interposed therein. The relay 55 is provided with a first pair of normally closed contacts 59 and second and third pairs of normally open contacts 60 and 61, and a magnetic armature 62 cooperatively associated with the winding 57 and arranged to actuate the contacts 60 and 61 to their closed positions and to actuate the contacts 59 to their open positions when the winding 57 is energized. The contacts 60 are disposed in a conductor 63 completing a circuit between line L2 and one terminal 64 of the thermoelectric panel 18, while the contacts 61 are disposed in a conductor 65 completing a circuit from line L1 to the other terminal 66 of the thermoelectric panel.

The relay 56 includes an inductive winding 67 connected across lines L1 and L2 by a conductor 68 having the contacts of the thermostatic switch 54 and the relay contacts 59 interposed therein in a series arrangement. The relay 56 further includes an armature 69 operatively

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associated with the winding 67 and arranged to actuate first and second pairs of normally open contacts 70 and 71. The relay contacts 70 are connected to line L1 by a conductor 72, thus completing a circuit to the terminal 64 of the thermoelectric panel 18, while the relay contacts 71 are connected to line L2 by a conductor 73, thus completing a circuit to terminal 66 of the thermoelectric panel 18.

In the usual manner, the thermostatic switches 53 and 54 inherently open at one temperature and close at another temperature. This phenomenon is known as temperature differential and may be on the order of two or three degrees. However, the differential between the opening and closing temperatures of the thermostats is employed in a desirable manner. For example, the thermostatic switch 53 is arranged to complete the circuit across its contacts upon a drop in temperature of the air at the inlet 30 to a value of 73 degrees F. and to interrupt the circuit at a slightly higher temperature determined by its differential, for example, about 76 degrees F. On the other hand, the thermostatic switch 54 is arranged to complete the circuit across its contacts upon a rise in temperature to 83 degrees F., and to interrupt the circuit upon a drop in temperature equal to its differential, for example, about 80 degrees F.

From the above, it will be seen that when the air temperature adjacent thermostatic switch 53 drops to 73 degrees F., the relay 55 is energized and a circuit is made from the negative side of the D.C. power supply 52, through line L2, relay contacts 60, conductor 63, the terminal 64 of the thermoelectric panel 18, through the thermoelectric bodies 19 to terminal 66, and thence through relay contacts 61 and conductor 65 to line L1. When current flows through the thermoelectric bodies 19 in this direction, heat is absorbed by the heat conducting plate 20 and pumped to the heat conducting plate 21 by the thermoelectric bodies 19 (as indicated by the directional arrow A). Accordingly, the air flow through the passageway 31 is heated in transit therethrough and returned to the protective garment 10 by way of the ducts 12 to 15, inclusive. As the air temperature rises to about 76 degrees F., the thermostatic switch 53 interrupts the circuit through the relay 55, thereby deenergizing the thermoelectric panel.

When the temperature of the air from the garment rises to 83 degrees F., the relay 56 is energized and the terminal 64 of the thermoelectric panel 18 is connected to the positive side of the D.C. power supply 52, while the terminal 66 of the thermoelectric panel 18 is connected to the negative side of the D.C. power supply by a circuit extending from the positive side of the power supply 52, the line L1, the relay contacts 70, conductor 72, terminal 64, thermoelectric panel 18, terminal 66, relay contacts 71, conductor 73 and line L2 to the negative side of the power supply. When the thermoelectric panel 18 is connected to the power supply in this manner, heat is absorbed by the heat conducting plate 21 and pumped through the panel 18 by the thermoelectric bodies 19 to the heat conducting plate 20, as indicated by the directional arrow B. Accordingly, the air flowing through passageway 31 is cooled in transit therethrough before returning to the garment by way of the ducting 12 to 15, inclusive.

The motor 36 is directly connected across conductors L1 and L2, and since both of the impellers 39 and 40 are jointly energized by the motor, conditioned air is continuously recirculated through the garment in a closed loop, while atmospheric air is continuously pumped through the passageway 29 and thence returned to the atmosphere through the peripheral outlet 42 after absorption of heat energy (during the cooling cycle) or release of heat energy (during the heating cycle).

When the thermostatic switch 53 is cooled sufficiently to complete the circuit through its contacts and energize the relay 55, the relay contacts 60 and 61 are actuated to

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the closed positions, while the relay contacts 59 are actuated to their open positions. Accordingly, the relay contacts 59 may be termed interlocking contacts, since they are employed to positively "lock out" or prevent energization of the relay 56 during the cooling cycle, even though the thermostatic switch 54, due to possible malfunction, may accidentally complete the circuit across its contacts.

The thermostatic switches 53 and 54 are supported in the inlet 30 by a strap member 74 extending diametrically across the air inlet and attached to the front wall member 24. With this arrangement, the thermostatic switches are disposed in the optimum position for sensing temperature of the air returned from the garment 10, thereby providing a quick and accurate control for the control system 51.

The terminals 64 and 66 of the thermoelectric panel 18 extend through the lower portion of the air passage 29 and are suitably electrically and thermally insulated by insulating sleeve members 75.

The relays 55 and 56 are disposed within a suitable casing 78 attached to the rear wall 23 in any suitable manner and the battery 52 may be enclosed within a casing 79. The conductors L1 and L2 are extended from the lower portion of the relay casing 78 into the casing 79. The casing 79 may be strapped to the body of the wearer by a suitable strap 80.

It will now be seen that the invention provides a compact air conditioning device of a portable type which may be connected to a protective garment and which is effective to cool or heat a protective garment by recirculating the thus heated or cooled air through the garment in a closed cycle.

It will further be seen that the invention provides a temperature responsive control system for automatically connecting the thermoelectric panel in a heating mode for heating the air during recirculation through the garment, when required, and for connecting the thermoelectric panel in a cooling mode for cooling the circulating air through the garment, when required, in a highly effective yet simple manner.

It will now also be seen that the invention provides a portable device of the above type in which atmospheric air is prevented from flowing into the closed loop circuit through the aperture that accommodates the motor drive shaft as well as through the drain outlet for condensate formed and collected during the cooling cycle.

While the invention has been shown in but one form, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various changes and modifications without departing from the spirit thereof.

What is claimed is:

1. A portable device for providing conditioned air to a protective garment comprising a thermoelectric heat pumping panel of annular shape having an array of thermoelectric bodies disposed in an annular pattern and interposed between a pair of annular heat conducting plate members, said plate members being in good heat exchange relation with said array, a pair of wall members disposed in fixed spaced relation with said heat conducting plates and jointly therewith defining first and second annular air flow passages, a first blower centrally disposed in said first passage, a second blower centrally disposed in said second passage, a motor carried by one of said wall members, said motor having a drive shaft supporting said blowers for joint rotation, said drive shaft extending transversely through said heat pumping panel, means for supporting said drive shaft in rotatable relation with said panel, means for preventing flow of air from said first to said second passage, each of said wall members having a central aperture, said apertures defining air intake openings for said first and second passages, and said blowers being arranged to draw air through said apertures and to pump the air in radially outward directions through said passages.

2. A portable device for providing conditioned air to a protective garment comprising: a substantially planar

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thermoelectric heat pumping panel of annular shape, said panel including an array of thermoelectric bodies disposed in an annular pattern and a pair of heat conducting plate members disposed in parallel spaced relation with each other and having said array disposed therebetween, said plate members being in good heat exchange relation with said array; a pair of wall members disposed in fixed spaced relation with said heat conducting plates and jointly therewith defining first and second annular air flow passages; a first blower centrally disposed in said first passage; a second blower centrally disposed in said second passage; a motor carried by one of said wall members, said motor having a drive shaft supporting said blowers for joint rotation, said drive shaft extending perpendicularly through said heat conducting plates and said thermoelectric array; means for supporting said drive shaft in rotatable relation with said panel; sealing means disposed between said drive shaft and said plates for preventing flow of air from said first to said second passage, each of said wall members having a central aperture, one said aperture defining an air intake opening for said first passage and the other said aperture defining an air intake opening for second passage, said blowers being arranged to draw air through said apertures and to pump the air in radially outward directions through said passages, and means including an inverted U-shaped trap member for ejecting condensate from one of said passages.

3. A portable device for providing heated or cooled air to a protective garment comprising a thermoelectric heat pumping panel of annular shape, said heat pumping panel including a pair of heat conducting plates having an array of thermoelectric bodies disposed therebetween and arranged to pump heat from one to the other of said plates, means including first and second wall members disposed in fixed spaced relation with said plates and jointly therewith defining first and second air flow passages, said first wall member having a central aperture defining an air inlet for said first passage and an outer periphery forming an annular outlet for said first passage, said second wall member having a central aperture defining an air inlet and an outer periphery forming an annular outlet for said second passage, a motor disposed in registry with the central aperture of said first wall member, said motor having a drive shaft extending through said central aperture in said first wall member and said heat pumping panel, means for supporting said

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shaft in rotatable relation with said panel, first and second blowers disposed centrally in said first and second passages, respectively, and carried by said drive shaft, said first and second blowers being arranged to draw air through their associated apertures and pump the air in radially outward directions through said first and second passages, respectively.

4. The structure recited in claim 3 and further including a D.-C. power supply for energizing said thermoelectric heat pumping panel, temperature responsive means disposed adjacent the central aperture in said second wall member and responsive to temperature of air flow therethrough, and first and second sets of electrical contacts controlled by said temperature responsive means, one of said sets of contacts being arranged to effect connection of said D.-C. power supply to said heat pumping panel in a manner to pump heat from said first passage to said second passage upon a drop in temperature below a predetermined value, the other of said sets of contacts being arranged to reverse the connection of said D.-C. power supply to said heat pumping panel upon a rise in temperature above said predetermined value to pump heat from said second passage to said first passage.

5. The structure recited in claim 3 and further including a D.-C. power supply for energizing said thermoelectric heat pumping panel, a pair of thermostats disposed adjacent the aperture in said second wall member and responsive to temperature of air flow therethrough, one of said thermostats being arranged to effect connection of said D.-C. power supply to said heat pumping means in a manner to pump heat from said first passage to said second passage at a temperature below a first predetermined value, the other of said thermostats being arranged to reverse the connection of said D.-C. power supply to said heat pumping means at a temperature above a second and higher predetermined value to pump heat from said second passage to said first passage.

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