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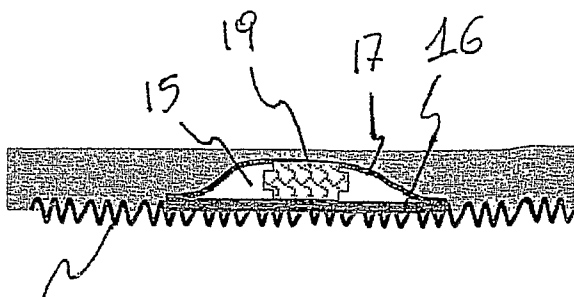
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(54) Title: AIR-CONDITIONING SYSTEM FOR TECHNICAL WEA



(57) Abstract: The present invention relates to a thermoelectric motor (3) in which a material is interposed between the external plate (12) of a thermoelectric module and an external heat exchanger (4), to reduce heat resistance therebetween; the present invention further relates to a thermoelectric motor (3) in which the heat-carrying fluid flows directly over the internal plate (13) of a thermoelectric module, a temperature controlled garment with an inner metal layer and a convex heat exchanger.

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Air-conditioning system for technical wear

The present invention relates to an air-conditioning system for technical wear, namely for
5 motorcycling suits.

Air-conditioning systems for clothings are known, for example, from US patent application 2003/0019476 or international patent application WO 2004/014169.

These documents describe garments having
10 substantially similar structures: they contain a heat-carrying fluid, generally water, which flows in a canalization system formed within the thickness of the garment and feature a thermoelectric device allowing to heat or cool the heat-carrying fluid regardless of the
15 environmental conditions.

In other words, the thermoelectric device creates a controlled microclimate within the garment, so that the body of the wearer is not exposed to too high or too low outer temperatures.

20 Thermoelectric devices are now commonly made by combined use of thermoelectric modules and suitable heat exchangers. Thermoelectric modules are made using semiconductor materials which exploit the Peltier effect to heat or cool two opposed plates.

25 This system is particularly advantageous because it is both sturdy and reversible; this means that, by supplying electric current having a certain polarity, one plate is heated and the other is cooled; by inverting the polarity of the electric current supplied
30 to the thermoelectric module, the opposite effect can be obtained.

Two heat exchangers are usually connected to the thermoelectric module: one for exchanging heat with the external environment (air) and another for exchanging heat with the heat-carrying fluid (water).

5 Applications have so far always had a relatively low thermal efficiency, never enough for application on sportswear garments: a low thermal efficiency requires the supply of considerable power for operating the thermoelectric device.

10 Particularly, in motorcycle racing, power cannot be easily drawn from the motorcycle motor, as performances might be unacceptably affected thereby: even a few hundredths of a second can make the difference in a competition.

15 Therefore, a device having a standalone power source (such as a battery), which could provide the garment with enough power to cover the whole duration of a race would allow a motorcyclist to race without being exposed to environmental hot or cold conditions;
20 therefore, the driver would not have to use his/her own psychophysical resources to resist environmental temperature and could concentrate on driving only.

In view of the prior art as described above, the object of the present invention is to provide a garment
25 with a thermoelectric device having a higher efficiency than in prior art, to be able to provide an air-conditioned motorcycling suit.

According to the present invention, this object is achieved by a thermoelectric device as defined in claim
30 1 or 5, an air-conditioned garment as defined in claim 14 or 22, or a heat exchanger as defined in claim 31.

The features and advantages of the present invention will appear from the following detailed description of one practical embodiment, which is illustrated without limitation in the annexed drawings, in which:

- Figure 1 is a schematic view of a motorcycle racer wearing a motorcycling suit having a so-called "hump",

FIG. 2 is an exploded perspective view of a thermoelectric device according to a preferred embodiment of this invention,

- Figure 3 is a schematic sectional view of a garment according to a preferred embodiment of this invention,

- Figure 4 is a schematic view of a preferred embodiment of this invention,

- Figure 5 is an exploded perspective view of a micro-finned exchanger having two thermoelectric modules according to a preferred embodiment of this invention.

In Figure 1, numeral 1 designates a protective motorcycling suit; it is generally equipped with an additional element 2, known as "hump", which is designed both to prevent turbulence in the area behind the helmet and to protect the neck from excessive torsion backwards.

Figure 2 schematically shows the thermoelectric motor 3: it is made up by a first heat exchanger 4 and by a second heat exchanger 7, both of them being in thermal connection with one or more thermoelectric modules 11.

The thermoelectric modules 11 are normal Peltier

thermoelectric modules, which are made by semiconductor material interposed between an external plate 12 and an internal plate 13.

An external heat exchanger 4 allows heat transfer
5 between the thermoelectric module/s 11 and the external environment.

An internal heat exchanger 7 allows heat transfer between the thermoelectric module/s 11 and the heat-carrying fluid.

10 The external environment, the external heat exchanger 4 and the external plate 12 thus form a chain of elements in series which allow heat transfer from the external plate to the external environment or vice versa.

15 When the heat-carrying fluid is to be cooled and heat is to be released to the external environment, the external plate 12 acts as a hot source; when the heat-carrying fluid has to be heated, it will act as a cold source.

20 Maximum efficiency requires minimization of thermal resistances among the elements of the chain, and particularly those at the interface between the external heat exchanger 4 and the external plate 12.

Both the external plate 12 of the thermoelectric
25 module 11 and the bottom surface 5 of the external heat exchanger 4 are formed with a defined surface roughness, which limits actual contact between the two surfaces to a fraction of the overall extension of the surfaces themselves.

30 To avoid the need of particularly complex mechanical working, a filling material (not shown) is

interposed between the bottom surface 5 of the external exchanger 4 and the external plate 12 of the thermoelectric module 11, which material can adapt its shape both to the bottom surface 5 of the external exchanger 4 and to the top surface of the external plate 13, thereby avoiding any effect caused by surface roughness.

Such filling material may have a high ductility and a high thermal conductivity, for instance it can be a metal oxide-based thermally conductive paste, or graphite-based high conductivity thermal interfaces, or a phase transition conductive material, i.e. having a melting point of 50°C to 100°C.

Advantageously, the thickness of this intermediate layer is of 50 to 200 micrometers.

The graphite layer is applied by interposing it between the two surfaces and exerting enough pressure thereon to deform it (e.g. a pressure of 1 to 15 bar), whereas the layer of the phase-transition thermally conductive paste is applied as follows: first, the paste is interposed between the two surfaces, then the temperature of the thermoelectric module 11 is increased above the melting point of the paste, to cause liquefaction thereof, and finally such temperature is decreased to cause re-solidification; thus, the temporary liquid layer allows the intermediate layer to take the form of the two surfaces, perfectly adapting to the roughness of the two surfaces 5 and 13.

The external heat exchanger 4 is designed to have as large heat exchange surface as possible.

One limitation to the shape of the exchanger is

that it has to be accommodated in the hump 2 of the suit 1 of the motorcycle racer.

These humps mat have various shapes: all of them have a convex outer surface and a radius of curvature 5 which is generally in a range of 80 to 160 mm.

A first option is to form the external heat exchanger 4 with one or more fins 5 allowing heat transfer with the surrounding environment.

Therefore, the external exchanger may be formed 10 from aluminum or an alloy thereof, preferably as a monobloc, to combine the advantages of light weight, good heat conductivity and thermal isotropy, or for a still lighter weight, from graphite or a graphite-based material.

15 When the external exchanger 4 is formed from graphite, it is fabricated by superposing a plurality of sheets so that their planes are parallel to the planes of the fins 5; the graphite exchanger 4 is therefore thermally anisotropic, that is, has a very good heat 20 conductivity (approximately equivalent to copper), along the preferred plane defined by the sheets, but substantially acts as an insulator perpendicular to such plane.

Advantageously, the bottom surface 5 of the 25 external exchanger 4, when considered in the direction perpendicular to the preferred heat conduction plane of graphite is substantially as large as the external plate 13 of the thermal module 11, when considered in the same direction.

30 Whenever multiple thermoelectric modules 11 are provided, they can be generally considered as a

thermoelectric unit, composed of such plurality of thermoelectric modules 11.

The thermoelectric modules 11 may be disposed in parallel arrangements within s thermoelectric unit, in
5 rows, columns or in any other arrangement.

This may provide a graphite heat exchanger of greater width than a single thermoelectric module 11, wherefore the outer surface of the hump may be totally used.

10 The thermoelectric unit will have its own extension both along the axis perpendicular to the preferred heat conduction plane of the graphite and in the direction perpendicular thereto; the above geometric considerations related to single thermoelectric modules
15 will apply thereto.

Such heat exchanger 4 with fins 5 may have such construction as to be entirely contained in the outer profile of the hump or, more advantageously, to at least partially project therefrom.

20 In the latter case, the fins of the heat exchanger are at least partly in the air flow path around the racer.

To improve heat exchange efficiency without affecting the aerodynamics of the motorcycle/racer
25 assembly, the suit may be formed with front air passages, e.g. on the shoulders, which are connected to conduits carrying the air introduced therein to the external exchanger 4.

By suitably sizing the air passages and the
30 conduits in the suit, an air flow may be directed through the fins 5 of the external exchanger, which flow

may be sufficient to ensure proper operation of the thermal device 3 with no need for marked external extensions on the suit hump.

Alternately, as shown in Figure 5, the external
5 exchanger 4 may be equipped with micro-finned elements, i.e. thermally conductive elements, preferably made of metal, of small thickness, generally below 30 mm and preferably below 15 mm, whose top profile does not have real fins, but teeth and grooves, e.g. triangular, which
10 increase the heat exchange surface to air.

These grooves or teeth may advantageously have a pitch of 1 mm to 5 mm, and the distance between the groove bottoms and the teeth tops may be in the same range.

15 This second type of external exchanger is more compact than the external finned exchanger and does not suffer from its aerodynamic drawbacks; therefore, it can be directly incorporated in the hump without requiring air flow conveying systems.

20 Advantageously, the micro-finned exchanger has a curved average outer profile, with a radius of curvature generally from 80 mm to 160 mm, to obtain a curvature substantially corresponding to that of the hump to be covered and/or replaced thereby.

25 If the exchanger will have to be incorporated in the hump, it will be disposed by exposing to the external environment its heat exchanging surface only, so that the aerodynamic performances of the hump are not affected.

30 A third alternative consists in forming the external exchanger with a thermally conductive porous

material.

Substantially porous materials, e.g. formed of more or less regular wire hanks, are not suitable for the purpose and cannot be considered as porous metal materials for the purposes of this disclosure.

These hanks have a small contact surface between wires and cannot ensure an adequate heat exchange.

Porous materials as mentioned herein are materials having a metal matrix with cavities therein, such as those disclosed in patent application WO 06/31306.

Heat exchangers formed from thermally conductive porous materials have the advantage of a lighter weight, assuming an equal amount of exchanged thermal power, and are better suited for the proposed application.

The heat-carrying fluid, the internal plate 13 and the thermoelectric module 11 and, in case, the circulation pump, form the second chain of elements in series for transferring heat from the internal plate to the heat-carrying fluid or vice versa.

The heat-carrying fluid may include, for instance, a mixture of water and alcohol, Freon, or any other heat-carrying fluid commonly used in the field of refrigeration.

Like in the previous case, the internal plate 13 may either be the hot source, if the heat-carrying fluid has to be heated, or the cold source, if it has to be cooled.

To minimize thermal resistances at the interface between the heat-carrying fluid and the internal plate 13, the internal exchanger 7 is formed so that the heat-carrying fluid flowing therethrough passes directly over

the internal plate 13 to directly eliminate any thermal resistance therebetween.

For this purpose, the internal heat exchanger 7 has a main hollow body, with a heat-carrying fluid inlet conduit 8 and a heat-carrying fluid outlet conduit 9 and one or more ports 10.

Therefore, the inner cavity of the internal heat exchanger 7 is at least partly directly delimited by the one or more internal plates 13 of the one or more thermoelectric modules 11 at the one or more ports 10.

The internal plate 13 of the thermoelectric module 11 (or the internal plates 13 of the thermoelectric modules 11) is attached, e.g. glued, at its outer periphery, to provide a water-tight seal and prevent the heat-carrying liquid from leaking therefrom. Alternatively, it can be fastened by using a seal and fastening screws.

The inner cavity advantageously comprises means (not shown) for increasing turbulence in the heat-carrying fluid flow, such as protuberances arranged in a regular or irregular pattern, and advantageously formed on the surface of the inner cavity which is opposite the part formed by the internal plate 13 of the thermoelectric module 11.

For size-reducing purposes, the circulation pump may be advantageously incorporated in the internal heat exchanger.

The heat-carrying fluid flowing out of the conduit 9 of the internal exchanger 7 is introduced in a garment, e.g. covering the racer's trunk, such as a suit, a vest or a jacket, for heat exchange with the

body of the racer.

Once again, the efficiency of the heat exchanger has to be optimized by reducing thermal resistances; Figure 3 schematically shows an embodiment of this invention which provides this additional advantage.

The garment of this invention comprises an inner metal layer 14, which may be in contact with the racer's body, preferably formed of a metal mesh.

Such inner metal layer 14 has a network of conduits 15 attached thereto, through which the heat-carrying fluid flows.

The conduits 15 are preferably welded to the inner metal layer 14.

For the conduits 15 to be welded to the inner metal layer 14, the latter is covered by a layer 16 of a polymer material, preferably polyurethane, to allow a structure 17, preferably made from the same polymer as the layer 16, to be later welded thereto.

A support 19 is provided in the conduits 15, which prevents the structure 17 from collapsing onto the layer 16; such collapse would cause the conduit 15 to be throttled and occluded, which would prevent effective operation of the air-conditioning system.

Currently available motorcycling suits may be essentially divided into two types: a first type with a central hinge, and a second type with two hinges, arranged symmetrically at the trunk sides, which hold a separable central element.

To achieve the advantages this invention from this second suit type, two inner wings are provided, which extend from the suit sides under the hinges and towards

the center of the trunk, and cover the area in contact with the racer's trunk during use.

In this case, the conduits 15 are formed within the wings which may be in turn advantageously equipped with devices (such as a central hinge) to hold the central edges close together.

As schematically shown in Figure 4, the garments manufactured according to this invention may advantageously comprise a control and monitoring system 20, having one or more humidity 21 and/or temperature sensors 22.

The control and monitoring system 20 receives signals from one or more sensors 21, 22 and, based on such signals, it determines the optimal operating conditions for the thermoelectric motor 3.

Therefore, the air-conditioning system can use the feedback provided by the humidity and/or temperature values detected from the racer's body; operation may be also designed to be a fixed-temperature operation and/or based on external temperature.

According to a further preferred embodiment, the air-conditioned garment may advantageously comprise batteries, preferably lithium batteries, connected to thermoelectric motor 3 and to control and monitoring system 20, for supplying power to them; it can also have means for connecting to a remote power source, such as a cable for connecting to the mains and allow both recharging and normal operation thereof.

Thus battery life may be used only when required, e.g. during the race or tests, at the same time keeping the advantages of the air-conditioning throughout the

race preparation time, in which the motorcycle is still at boxes, without reducing the battery life.

Those skilled in the art will obviously appreciate that a number of changes and variants may be made to the
5 arrangements as described hereinbefore to meet incidental and specific needs, without departing from the scope of the invention, as defined in the following claims.

CLAIMS

1. Thermoelectric motor (3), comprising:

5 - a thermoelectric module (11) comprising an external plate (12) and an internal plate (13) with Peltier elements interposed therebetween, which are suitable for creating a temperature difference between said external plate (12) and said internal plate (13) when energized;

10 - an internal heat exchanger (7) defining a working fluid guiding path so that said fluid can exchange heat with said internal plate (13);

characterized in that

15 said fluid path of said internal heat exchanger (7) allows such heat-carrying fluid to flow directly over said internal plate (13), at least over a contact area, so that said internal plate (13) directly exchanges heat with said heat-carrying fluid.

20 2. A thermoelectric motor (3) as claimed in claim 1, wherein said internal heat exchanger (7) has protuberances for increasing the turbulence of said heat-carrying fluid flow at said contact area.

25 3. A thermoelectric motor (3) as claimed in any one of claims 1 and 2, wherein said internal heat exchanger (7) further has inlet (8) and outlet (9) ports for the heat-carrying fluid and at least one opening (10) at said contact area, said opening (10) being closed by said internal plate (13).

30 4. A thermoelectric motor (3) as claimed in claim 3, wherein said internal plate (13) is glued to said internal heat exchanger (7).

5. A thermoelectric motor (3), comprising:

- an external heat exchanger (4) for exchanging heat with the external environment;

- a thermoelectric module (11) comprising an external plate (12) and an internal plate (13) with Peltier elements interposed therebetween, which are suitable to create a temperature difference between said external plate (12) and said internal plate (13) when energized;

10 said external plate (12) of said thermoelectric module (11) being in thermal contact with said external heat exchanger (4);

characterized in that

15 a material is interposed between said external plate (12) and said external heat exchanger (4), having a thermal resistance per unit area of less than $0.05 \text{ cm}^2 \text{ } ^\circ\text{C} / \text{W}$.

6. A thermoelectric motor (3) as claimed in claim 5, wherein said material is selected from the group consisting of: graphite, graphite-containing materials, phase transition thermal pastes.

7. A thermoelectric motor (3) as claimed in claim 6, wherein said phase transition thermal paste has a melting point above 50°C and below 100°C .

25 8. A thermoelectric motor (3) as claimed in any one of claims 5 to 7, wherein said external heat exchanger (4) is made from a material selected from the group consisting of: aluminum, aluminum alloys, graphite, materials which substantially comprise graphite.

30 9. A thermoelectric motor (3) as claimed in any one of claims 5 to 8, wherein said external heat exchanger (4)

has one or more heat exchanging fins (5) for exchanging heat with ambient air.

10. A thermoelectric motor (3) as claimed in claim 9, wherein said external heat exchanger (4) is formed of
5 graphite sheets in such arrangement that the main planes of said fins (5) are parallel to said graphite sheets.

11. A thermoelectric motor (3) as claimed in claim 10, wherein said external heat exchanger (4) has a size, as measured perpendicular to said preferred heat conduction
10 plane, which is substantially not larger than the overall size, as measured along the same axis, of said thermoelectric module (11).

12. A thermoelectric motor (3) as claimed in claim 10, comprising a plurality of said thermoelectric modules
15 (11), together forming a thermoelectric unit, wherein said external heat exchanger (4) has a size, as measured perpendicular to said preferred heat conduction plane, which is substantially not larger than the overall size, as measured along the same axis, of said thermoelectric
20 module (11).

13. A thermoelectric motor (3) as claimed in any one of claims 5 to 8, wherein said external heat exchanger (4) is microporous or microfinned.

14. An air-conditioned garment comprising a
25 thermoelectric motor (3) as claimed in any one of claims 1 to 4, and/or in any one of claims 5 to 13.

15. An air-conditioned garment as claimed in claim 14, wherein said garment is a motorcycling suit (1) having a hump (2) on the upper part of the back of the suit, said
30 thermoelectric motor (3) being provided at said hump (2).

16. An air-conditioned garment as claimed in claim 15, wherein said external heat exchanger (4) is as claimed in any one of claims 9 to 11, and said garment has one or more air passages, preferably formed at the shoulders, and comprises one or more conduits for putting said one or more air passages in fluid communication with the external heat exchanger (4) of said thermoelectric motor (3), so that, when air flows in through said air passages, it can be guided to provide heat exchange with said external exchanger (4).

17. An air-conditioned garment as claimed in claim 15, wherein said external heat exchanger (4) is as claimed in claim 12 and is located in the proximity of the outer surface of said hump (3) so that the air flow generated around said garment can flow thereon.

18. An air-conditioned garment as claimed in any one of claims 14 to 17, further comprising one or more humidity sensors (21) and preferably also one or more temperature sensors (22), said humidity sensors (21) being adapted to sense the humidity in the internal spaces of the garment, generated by the wearer's perspiration.

19. An air-conditioned garment as claimed in claim 18, comprising a device (20) for receiving signals from said sensors (21, 22) and controlling the operation of said thermoelectric motor (3) based on said received signals.

20. An air-conditioned garment as claimed in any one of claims 14 to 19, comprising one or more batteries suitable for powering said thermoelectric module.

21. An air-conditioned garment as claimed in any one of claims 14 to 20, comprising means for connection to an external power source, for energizing said

thermoelectric module from said external power source.

22. An air-conditioned garment comprising an inner metal layer (14),

characterized in that

5 said inner metal layer (14) lies on at least a portion of the surface of said garment that, with the garment being worn by a wearer, faces towards the body of said wearer.

23. An air-conditioned garment as claimed in claim 22,
10 wherein said metal layer (14) is a metal mesh.

24. An air-conditioned garment as claimed in any one of claims 22 to 23, wherein said metal layer (14) is covered by a polymer.

25. An air-conditioned garment as claimed in claim 24,
15 wherein said polymer is of the polyurethane type.

26. An air-conditioned garment as claimed in claim 24 or 25, comprising a network of conduits (15) which is welded to said polymer that covers said metal layer (14).

20 27. An air-conditioned garment as claimed in claim 26, said network of conduits (15) being formed from the same polymer as the one that covers said metal layer (14).

28. An air-conditioned garment as claimed in claim 26 or 27, comprising a rigid support (19), substantially
25 adapted to prevent occlusion of the conduits of said network of conduits (15) during normal use of said air-conditioned garment.

29. An air-conditioned garment as claimed in claim 28, wherein said support (19) is formed from the same
30 material as said network of conduits (15).

30. An air-conditioned garment as claimed in any one of

19

claims 14 to 21 and any one of claims 22 to 29.

31. A heat exchanger (4) of micro-finned or microporous material, having a main heat exchanging surface,

characterized in that

5 said main surface is convex and has an average radius of curvature of 80 to 160 mm.

32. A heat exchanger (4) as claimed in claim 31, said exchanger (4) being configured to allow association thereof to the hump of a motorcycling suit, so that the
10 contour of said hump associated to said heat exchanger is not more than 5 mm from the contour of said hump before application of said exchanger.

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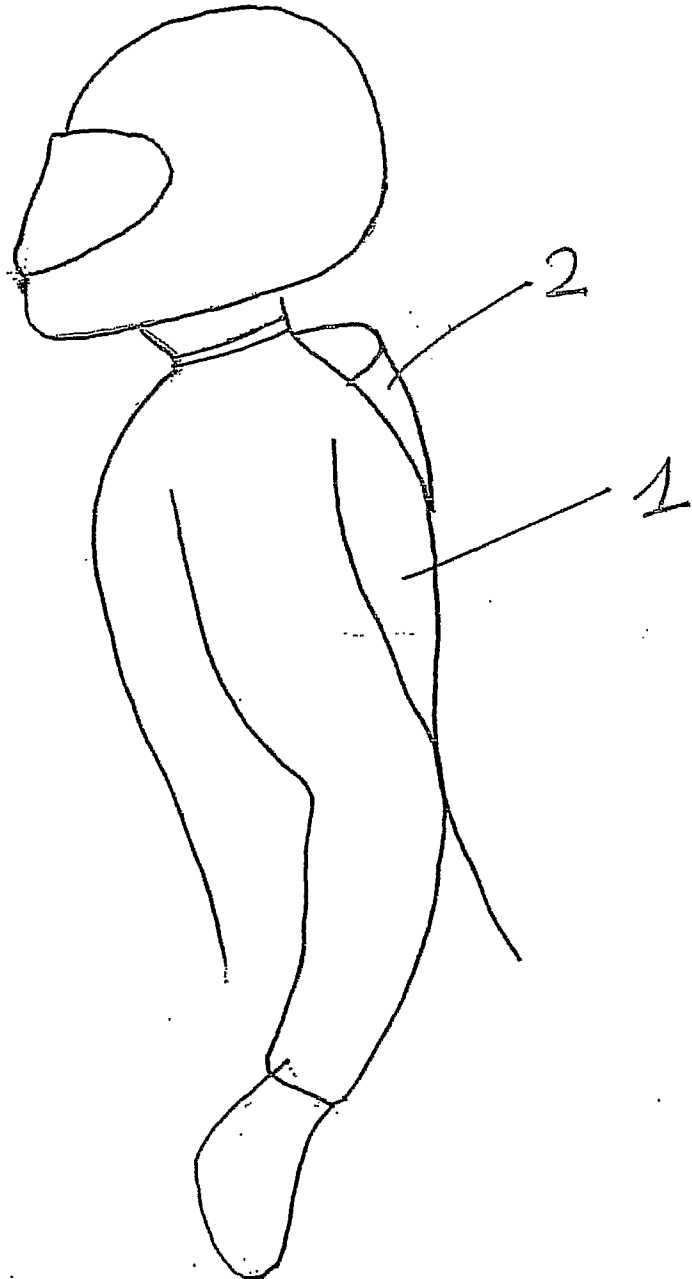
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Fig 1



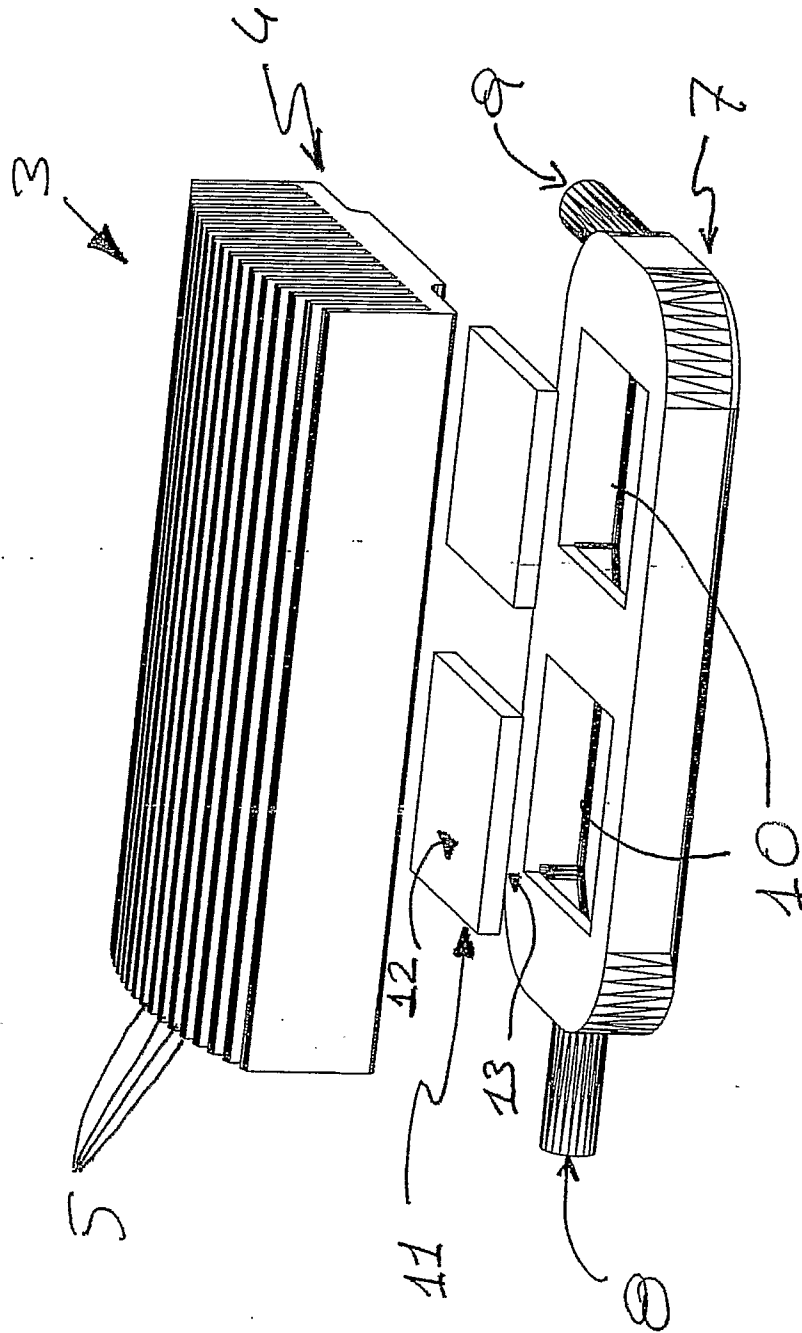


Fig. 2

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Fig. 4

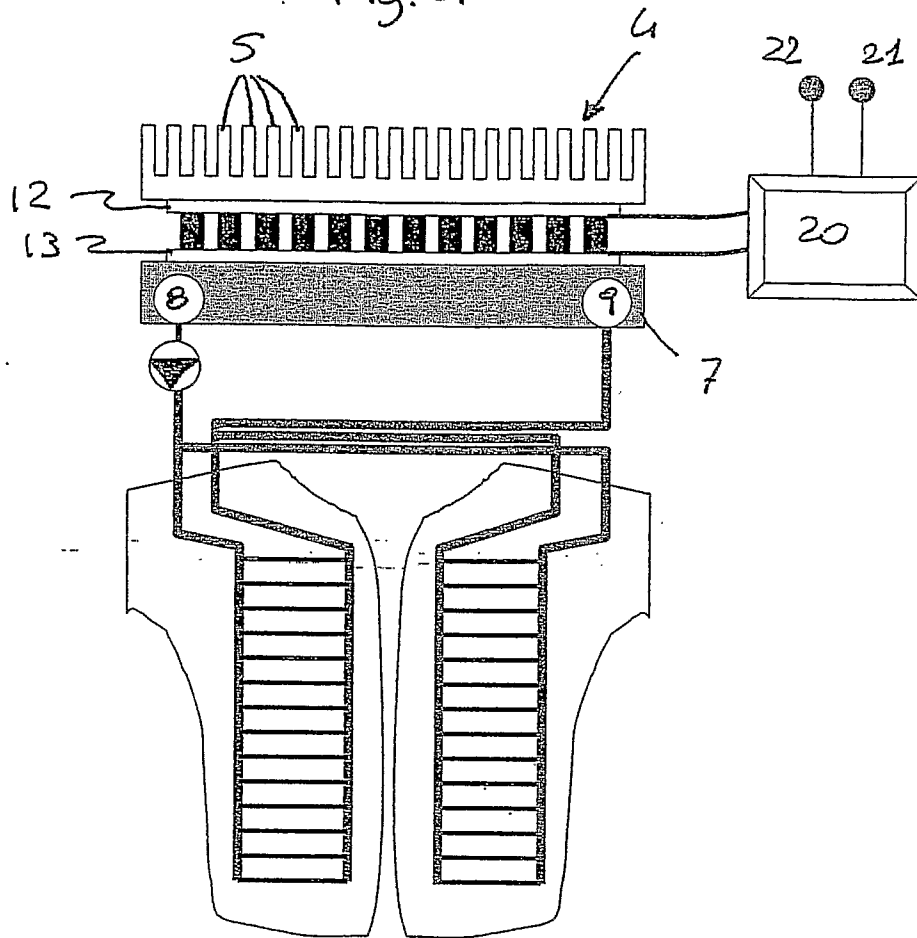
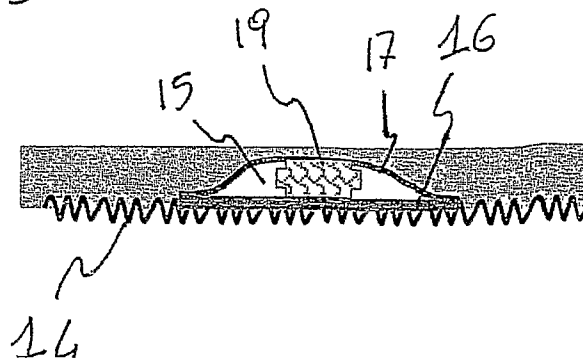


Fig. 3



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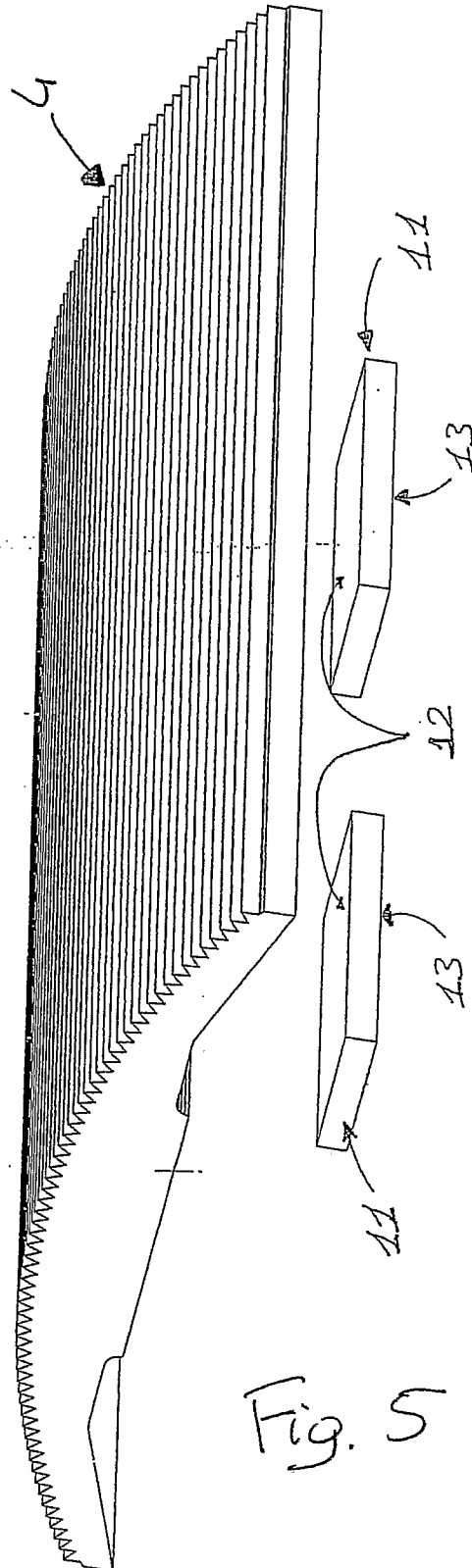


Fig. 5