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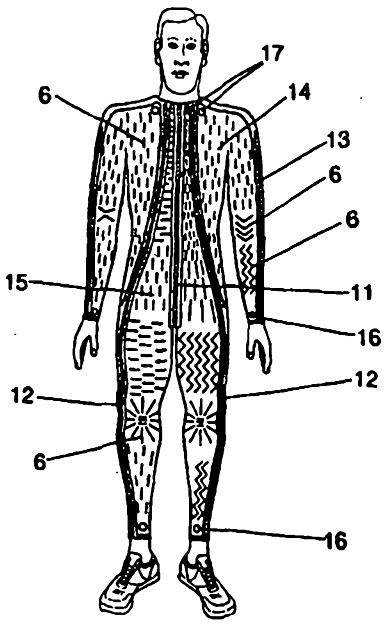
(57) Abstract

The inventive suit is comprised of, together with a lining and a slipover, an active part which is arranged between the same. This active part is at least partially constructed of a layer (3) which faces the body and of a layer (4) which faces away from the same. Both layers are made of a liquid-tight, slightly stretchable textile material and are connected to one another at connection points (6) by gluing, heat sealing or by sewing. The results in the production of cavities (5). The cavities are filled with a liquid through valves (16, 17). Connecting parts which only transfer tensile stress can be arranged between areas which are comprised of the layers (3, 4), for example, upper parts (14) and frontal parts (15). This builds up a compensating pressure, said pressure being proportional to the acceleration acting in the momentary and local direction, on the body parts under the suit and thus relieves the pilot's body from the effects of such accelerations. The suit is closed by zip fasteners (11, 12, 13), is fitted to the momentary body requirements of the wearer by means of hook-and-loop fasteners and is tightened by using zip fasteners or a fluidic tightening device.



(57) Zusammenfassung

Der erfindungsgemässe Anzug besteht, nebst einem Futter und einem Überzug, aus einem dazwischenliegenden aktiven Teil. Dieser ist mindestens teilweise aufgebaut aus einer dem Körper zugewandten Schicht (3) und einer ihm abgewandten Schicht (4), beide aus einem flüssigkeitsdichten, wenig dehnbaren textilen Material, die an Verbindungsstellen (6) miteinander durch Kleben, Schweissen oder Nähen verbunden sind und dadurch Hohlräume (5) erzeugen, die durch Ventile (16, 17) mit einer Flüssigkeit gefüllt sind. Zwischen Gebieten, die aus den Schichten (3, 4) bestehen, beispielsweise Oberteile (14) und Vorderteile (15), können Verbindungsteile angeordnet sein, die nur Zugspannung übertragen. Dies baut auf die darunterliegenden Körperteile einen der in der momentanen und lokalen Richtung wirkenden Beschleunigung proportionalen Kompensationsdruck auf und entlastet so den Organismus des Piloten vor den Auswirkungen solcher Beschleunigungen. Geschlossen wird der Anzug durch Reissverschlüsse (11, 12, 13), angepasst an die momentanen Körperbedingungen seines Trägers durch Klettverschlüsse und gespannt durch Reissverschlüsse oder eine fluidische Spannvorrichtung.

Acceleration protection suit

The present invention relates to a suit for protection against the effects of acceleration, such as arise in high performance aircraft when flying in curves, in accordance with the preamble to Claim 1.

Many such protective suits have become known. Those nearest to this invention work on the pressure principle: the body of the pilot - or in the case of multi-seat aircraft naturally the other flying personnel also - is surrounded by a liquid-carrying double layer. The acceleration forces operating on the body's own fluids, predominantly the blood, affect the liquid present in the protective suit in equal measure. Thereby pressure forces are built up on the surface of the body, which correspond to those, which work on the skin from the body fluid. Such a suit is known from EP 0 376 027 B1 D1, which converts the pure pressure principle. This known conversion from D1 requires a relatively large volume of liquid, which is held together on the outside by a low elasticity suit. Although the pilot's body is now released from the pressures on blood vessels, internal organs and skin, on the other hand his body - the skeleton and static musculature - is additionally loaded to a substantial degree by the weight, multiplied by the acceleration factor, of the mass of water carried, which necessitates the application of a supporting corset to remove the loading on the spinal column. Furthermore the application of the protective suit according to D1 has the consequence that the pilot cannot climb into nor leave the aircraft without outside help. The water or general fluid filling can only take place in the aircraft. An emergency exit by means of an ejector seat is inconceivable. Dressing with this quoted protective suit also requires intensive outside assistance.

A further protective suit is known from US 5,153,938 (D2), which essentially builds on the pressure principle. An inner suit, which however leaves large parts of the body uncovered, comprises liquid filled flat bladders. An outer suit, to be worn over it, is essentially inelastic and holds the whole ensemble together. The pressure built up by the bladders is transmitted by the outer suit to the parts of the body unprotected by the inner suit.

Although here by dispensing with the covering of the whole body by the inner suit substantial fluid - and therewith mass and weight - can be saved, the suit claimed in D2 is still heavy. In order to reduce the weight further and to improve freedom of movement, in D2 pressure compensation on the arms is completely dispensed with. It is replaced by elastic armlets; their compensating effect is only so far acceleration dependent, as the volumes of the arms increase with the additional acceleration forces on the blood, and thereby the elastic material of the armlets is additionally tensioned.

A further protective suit on the pure pressure principle is known from CH 687 573 (D3), which however is made in one part, in so far as the unyielding outer skin forms the outer suit. Here also a disadvantage exists in the high weight of the protective suit.

The above discussion of documents, acts, materials, devices, articles and the like is included in this specification solely for the purpose of providing a context for the present invention. It is not suggested or represented that any of these matters formed part of the prior art base or were common general knowledge in the field relevant to the present invention as it existed in Australia before the priority date of each claim of this application.

The aim, which is to be addressed by the present invention, comprises the production of a suit for protection against the effects of the acceleration forces, which arise in curved flight in high performance aircraft, predominantly in the instantaneous and local Z-axis, furthermore the protective suit to be produced should be lighter than those previously known, should make it possible that it can be put on and taken off by the wearer without help and enable him to climb into and leave the aircraft without help and permit the wearer generally to have normal mobility outside the aircraft.

According to the present invention, there is provided a suit for protection against acceleration forces, such as arise in high performance aircraft when flying in curves, whereby at least parts of the suit are made double-walled, and hollow spaces which thereby occur are filled with a fluid, which, when accelerations $\neq$ 1g occur in the momentary and local z-axis, builds up a compensating outer force corresponding to the internal force on the wearer, wherein

- the active part of the suit includes at least in part layers of a watertight and low stretch textile material, joined together so that hollow spaces arise between the connection positions,

- the hollow spaces form a continuous hydrostatic pressure column from the ankles up to the neck of the wearer of the protective suit,

- the inner-lying layer exerts a pressure on the body of the wearer corresponding to the height of the fluid column and the effective acceleration in the momentary and local Z-axis,

- a tensile force is built up in the outer layer due to this pressure,

- the connection positions can be joined to single layer connecting pieces of low stretch textile material outside the hollow spaces, which can transmit the tensile force built up onto the surface of the body of the wearer of the suit,

- the connection positions bordering the hollow spaces are arranged in such structures that the shortening of the separation of neighbouring connection positions effected by the pressure of the fluid present in the hollow spaces can build up the intended tensile force in direction and magnitude and can transmit it to neighbouring elements of the suit,

- the active part of the suit, including the layers and the connecting pieces has means for matching the suit to the current bodily conditions of its wearer,

- this active part of the suit has means for closure, which are simultaneously suited for building up the necessary basic pressure of the suit for straight flight.

Preferred features are defined in the subsidiary claims.

The idea of the invention is more closely explained using the attached drawings. Shown are:

Fig. 1 a cross section through a build up of the layers of the protective suit,

Fig. 2
- a plan view
- b a first section
- c a second section
- d a third section through a first arrangement of connection positions,

Fig. 3 a section through a second arrangement of connection positions,

Fig. 4 a plan view,

b a side elevation of a third arrangement of connection positions

Fig. 5 a fourth arrangement of connection positions,

Fig. 6 a fifth arrangement of connection positions,

Fig. 7 a front view of a first example of construction of the protective suit in two modifications,

Fig. 8 a detail from the rear view of the first example of construction,

Fig. 9 a cross section through a first example of construction of a closure device,

Fig. 10 a cross section through a first modification of Fig. 9,

Fig. 11 a cross section through a second modification of Fig. 9,

Fig. 12 a front view of a second example of construction of the protective suit in two modifications,

Fig. 13 a a longitudinal section,

b a plan view of a modification of construction,

Fig. 14 a cross section through a second example of construction of a closure device,

Fig. 15 a cross section through a third example of construction of a closure device,

Fig. 16 the rear view of Fig. 12,

Fig. 17 a schematic plan view of an addition according to the invention,

Fig. 18 the schematic representation of the pressure breathing system,

Fig. 19 a partly sectioned side view of a detail,

Fig. 20 a schematic representation of a heating and cooling arrangement of a protective suit,

Fig. 21 a schematic side view of a sitting pilot with an additional device,

Fig. 22 a detailed view from Fig. 21.

The protective suit according to the invention basically comprises three pieces of clothing. The innermost comprises, as schematically shown in Fig. 1, a textile lining 1. The actual protective suit is worn over this. This is constructed from an inner layer 3 and an outer layer 4. The layer 3 comprises an armoured watertight plastics material, whereby the armouring comprises a low stretch fibre material such as aramid fibre. The layer 4 is made from the same material as layer 3 and connected to it at various positions. The connection of the layers 3 and 4 occurs for instance by welding, or sewing with a subsequent sealing of the stitching. Since the pattern arising from the connection of the layers 3, 4 is material to the invention, this is discussed separately below. Between the layers 3, 4 a fluid, for instance water, possibly with additives, which influence its fluidity and/or density, is present in the hollow spaces 5 arising from their connection. On the outer side of the layer 4, possibly joined to it over the whole surface or at various positions, there is a robust textile oversuit 2, onto which all the necessary and useful objects and devices for a pilot's suit are fastened.

Whilst of themselves the presence and shaping of the lining 1 and the oversuit 2 are well known, their connection to the ensemble of the layers 3, 4 to form a single item of clothing is part of the idea of the invention. Without departing from the core of the idea of the invention, the lining 1 and the oversuit 2 could also possibly be constructed as separate items of clothing. The active part of the protective suit according to the invention comprises the partially connected layers 3, 4.

Fig. 2a, b, c, d show in detail views the attachment of the connection positions 6 of the layers 3, 4. As already explained, these connection positions can be produced by welding, gluing or stitching. In Fig. 2a is shown a field of for instance six connection positions 6. Each individual connection position has the form of a long thin strip. A section AA according to Fig. 2b shows that the separation between the ends of the strip-shaped connection positions 6 is shortened, as soon as the fluid present in the hollow space 5 between the layers 3, 4 flows in and is put under pressure. The same applies for the lateral separation of the connection positions 6, as is shown in the section BB according to Fig. 2c.

If now a structure formed from the layers 3, 4 - the lining 1 and the oversuit 2 are omitted for the sake of clarity - is placed around a body part, for instance a thigh, then there arises, as is shown schematically in Fig. 2d:

The outer layer 4 is tensioned to a tension force σ, the inner layer lies - essentially tension-free - against the surface of the body; within the hollow space 5 a pressure p applies. This builds up the tension force σ, which is transmitted via the connection positions 6, so that a certain pressure p corresponds to a certain tension force.

If now two - shown in the section - hollow spaces 5 are arranged such that a separation zone 7 lies between them, which contains no hollow spaces 5, then the tensile force σ is propagated essentially without degradation from hollow space 5 to hollow space 5. The degradation of the tensile force, which normally proceeds with a radially included angle α:

$$\sigma(\alpha)=\sigma_0 . e^{-\alpha . f_H}$$

where

σ_0 = initial tension

f_H = coefficient of static friction

applies only for rigid enclosed bodies. Human body tissue is however largely compliant and deformable.

The separation zone 7 can comprise the layers 3, 4 lying on top of each other, or rather a flexible but nevertheless low stretch textile material, for instance the layer 3 or the layer 4 only. The connection points 6 are immediately adjacent to the hollow spaces. They can, as shown in Fig. 1, 2, connect the layers 3, 4, or additionally ensure the connection to the textile material, from which the separation zone 7 is produced.

Fig. 4a, b show the deformation effected by pressure in an arrangement of for instance eight radially applied connection positions 6. In Fig. 4a a plan view is shown, in Fig. 4b a side elevation, partly in section. Since the intervening spaces between the connection positions 6 shorten almost proportionately to the distance between homological points of two connection positions, the arrangement lifts from the level in the shape of a barrel and forms a basket 8.

Such an arrangement is preferably selected at points on the body, where curves have to be enclosed, such as elbows, knees, seat; arrangements according to Fig. 2 are preferably to be selected for more cylindrical or flat parts of the body. Modifications to the arrangement of Fig. 2 are presented in Fig. 5 and 6.

In Fig. 5 the linearly constructed connection positions are arranged in rows displaced from each other. By the application of pressure on the fluid, which is present in the hollow spaces 5 arising between the layers 3, 4, force effects arise on the connection positions 6 (small arrows in Fig. 5). Due to this the existing construction of the layers 3, 4 shortens, preferably in the direction at right angles to the linear connection positions 6 (large arrows 9 in Fig. 5). To a smaller degree, however, there arises from this arrangement a similar shortening in the direction of the linear connection positions 6 (large arrows 10). The tensile forces σ arising therefrom are thus related in the same order, so that $\sigma_{across} > \sigma_{longitudinal}$. The fluid present between the layers 3, 4 has great mobility in this arrangement; it can flow both along as well as at right angles to the direction of the linear connection positions 6.

The arrangement according to Fig. 6 builds up, in contrast to that of Fig. 5, almost isotropic tensile forces, since due to the zig-zag pattern of the connection positions 6 the projections in both coordinate directions in the plane of the layers 3, 4 are almost exactly great, or at least can be exactly great. Thereby an almost isotropic shrinkage of the sizes of the surface areas provided with connection positions 6 can be attained. Instead of the depicted zig-zag pattern with sharp corners a formation with curves is also included in the idea of the invention; instead of a zig-zag pattern in the narrow sense, then, a wave-shaped one arises. All such configurations are included and are to be understood within this concept.

The mobility of the fluid in the hollow spaces 5 between the connection positions 6 according to Fig. 6 is restricted insofar as it is not possible at right angles to the connection positions 6.

Fig. 7 shows the protective suit according to the invention in a first example of construction with modifications with regard to the arrangement of the connection positions 6. In this representation also, the oversuit 2 is omitted. The layers 3, 4 are, as already mentioned, made from essentially non-stretch material. This fact and the requirement on the suit according to the invention, that it lies tightly on the body of the wearer, demands that the suit fulfils this requirement in the sitting position of the wearer. This means - at least for the example of construction shown in Fig. 7 - that the protective suit is cut for each wearer individually. In order to retain the mobility of the wearer until he takes up the sitting position, the example of construction according to Fig. 7 has several zip fasteners 11, 12, 13. The zip fastener 11 runs over the breast and abdomen, opens the protective suit from neck to groin. The two zip fasteners 12 run from the neck over the hips and then to the sides over the thighs and lower legs to the ankles. The two zip fasteners 13 begin at the shoulders and run to the sides over the arms down to the hands. In the example of construction shown, the hands and feet are left uncovered by the protective suit. The protective suit can be put on and partly closed by the zip fasteners 11, 12, 13; definitive closure then follows in the aircraft in the sitting position.

The arrangement of the connection positions 6 represented in Fig. 7 shows a different form of construction according to the invention on the left hand side of the wearer than on the right. In the sense of the configurations in Fig. 2 to 6 all the arrangements are in accordance with the invention, which due to the shortening of the basic material comprising the layers 3, 4 have the effect that a compensatory pressure is built up from outside onto the body surface corresponding to the internal pressure, or that a tensile force σ arises, which immediately causes the outside force mentioned. It is essential to this arrangement that the flow of fluid can occur unhindered, primarily from top to bottom, but also from left to right. Obviously the zip fasteners 11, 12, 13 restrict this cross flow, however not to a decisive degree. Immediately adjacent to each half of each of the zip fasteners 11 to 13 there runs in each case a connection position 6 over their entire length; thereby the zip fasteners 11 to 13 transmit tensile forces, but have however no contact of any sort with the fluid contained in the hollow spaces 5. The protective suit according to Fig. 7 is divided into five independent parts by the arrangement of the zip fasteners: back part (not visible in Fig. 7), left and right upper parts 14, left and right front part 15. For the filling process with the fluid flowing into the hollow spaces 5 and then being held there, each of the parts 14, 15 and the back part has at least two valves 16, 17, whereby the valves 16 are arranged respectively at the lower ends, the valves 17 respectively at the upper end of each part. Obviously the hollow spaces 5 can be filled once for all time. The filling and in all cases the ventilation positions are sealed following the

filling process. Thereby all the valves 16, 17 quoted become redundant.

In Fig. 8 the seat part of the back part designated with the reference 18 is shown. In the upper part the connection positions run essentially vertical; the main tension direction runs horizontal and causes an outside pressure on the organs in the abdominal cavity. Their volume is thereby restricted; the blood cannot collect there. This arrangement shown in the back is continued also at the front (Fig. 7). The seat is covered by structures in accordance with Fig. 4, so that each half of the seat is enclosed for itself under pressure from a hollow shape as shown there.

A zone is connected under this in which the thighs especially are under a pressure working along the circumference of a hollow shape shown there.

Fig. 9 is a sectional representation of a second example of construction of a protective suit. The part at least of the zip fasteners 12 running the length of the legs is here dispensed with. This example of construction has for this an insert 19. For the closure of the part of the protective suit shown this insert which is made without hollow spaces 56 or connection positions 6, but which can comprise both layers 3, 4, is tucked in. For closure a velcro fastener 20 is provided, whose part 21 lying on the body is made wider than its counterpart. With this the suit can be matched to the current condition of the wearer; possibly an extensive making to measure can be avoided for such a protective suit. Although depicted for the leg - thigh and lower leg - the constructions according to Fig. 9 apply also to the arms and the upper body down to and including the belly and abdominal region. Instead of a velcro fastener 20 a closure with adjustable straps can also be provided, in combination with a zip fastener, as shown in Fig. 11. Instead of a continuous velcro fastener 20, it is possible also under the invention to distribute a multiplicity of textile laces, of which each is equipped as a velcro fastener 20 and closes with the continuous part 21, lying against the body.

The detailed representation of Fig. 10 has - supplementary to that of Fig. 9 - a zip fastener 12. With this the suit can from time to time be completely opened, as shown in Fig. 7; the matching to the conditions of the wearer occurs, as shown according to Fig. 9, via the velcro fastener 20, 21.

In the example of construction according to Fig. 11 the matching occurs by means of straps 23 and buckles 22, of which a multiplicity is present over the whole length of the suit. The straps 23 are fastened to a strengthened part 24 of the protective suit. To this, one part of the zip fastener 12 is fastened, whose other part is fastened to the part of the protective suit which is not tucked in. The resolution of the continuous velcro fastener into a multiplicity of laces is also a modification within the sense of the invention.

A third example of construction of the protective suit is shown in Fig. 12. This figure is divided into a left hand side and a right hand side half picture, of which each shows a modification of the example of construction. Common to both modifications is that the main part of the suit or its active part, apart from the lining 1 and the oversuit 2, are made from a low stretch, but air and vapour permeable textile material. This main part carries the reference number 37. Over the whole length of the protective suit a wave-shaped band 38 runs on the left in Fig. 12, a similar one over the whole armlet on the left, with the reference number 39. The bands 38, 39 comprise the layers 3, 4, which are welded glued or sewn in the manner already depicted. The connections of the main part 37 with the wave-shaped bands 38, 39 are effected by sewing and/or welding or gluing. The pressure dependent and anisotropic shrinking of the bands 38, 39, which are each designed as a connecting hollow space 5, is sufficient to build up the necessary pressure over the textile material of the main part via its tensile force. Each band 38, 39 has again a lower valve 16 and an upper valve 17.

The modification on the right of Fig. 12 shows - as the single difference - an extended band 40 along the body, an extended band 41 along the armlet. Both bands 40, 41 carry a pattern of connection positions 6 according to Fig. 5, which similarly effect an anisotropic shrinking. Both shoulder parts 42 of the protective suit, as also the connections 43 of the upper part 14 to the armlets are here made of elastic textile materials, which increases the mobility of the wearer.

In those places where in the sitting position of the wearer there are knees and elbows in the protective suit, it has, according to Fig. 12, in each case an elastic insert 52. Not shown, but nevertheless included in the sense of the invention, there are branching bands 38 to 41 to above and/or below. Thereby the course of the tension and the matching to the anatomy of the wearer can be optimised. Both in the configuration according to

Fig. 7, and also in that according to Fig. 12 or Fig. 16 it is in accordance with the invention that in places where, in the sitting position of the wearer, creased folds occur, for instance in the elbow bends and the groin region, elastic bending but non-kinking elements, for instance small tubes are inserted. Thereby the hydrostatic connection can be still better assured. The wave shaped bands 38, 39, 40, 41 can be divided into independent bands 25. This division is more closely explained below using Fig. 13.

Fig. 13 shows the division of bands 38 to 41, in accordance with the invention, Fig. 13a in cross section, Fig. 13b in a plan view. Although shown here for bands 40, the following description applies in similar manner for the other forms of construction. Band 40 is divided in its length into closed off part bands 25, which each has a lower and an upper valve 16, 17. The part bands 25 are arranged such that overlap over part of their length and are connected together at their connection positions 6 and edges. If now due to acceleration effects the pressure in the upper part band 25 rises, then this increase in pressure is transmitted to the lower part band 25. The advantage of this modification of the solution lies in increased security, since in the event of the destruction of a part band 25 only a partial failure of the whole arrangement occurs, which furthermore can be at least compensated for by the other bands 40, divided into part bands 25. Obviously this modification of the solution can be used in the example of construction according to Fig. 7. The overlapping positions have then simply to be made broader.

This example of construction in Fig. 12 is closed according to the presentation in Fig. 14. This presentation applies on the one hand for arms and legs in the same way, and on the other hand for the closure of the whole protective suit, as shown below. Arm and leg tubes are to be opened completely using the zip fasteners 12, as in accordance with Fig. 12. These are joined with the halves designated 64, 65 by the insert 19, which can comprise a thin textile material, since it is not stressed by tensile forces. The half designated 65 carries a part 21 of the velcro fastener, the other part 20 is fastened to a cloth 66. The velcro fastener 20, 21 serves for the matching to the current situation of the wearer and is adjusted before entering the aircraft. To put on the protective suit all the zip fasteners are open; then the zip fastener 12 is closed; the wearer can move freely. A further zip fastener, whose halves are designated 61a, 61b, bridges the insert. Mobility is thereby somewhat restricted, but climbing into the aircraft is however possible without difficulty, thanks to the elastic inserts 52. Then a further, third zip fastener 62a, 62b is closed. A last, fourth zip fastener 63a, 63b bridges a second smaller insert 19a. The arm tubes have this construction, as do the leg tubes similarly; the zip fasteners 61a, b, 62a, b, 63a, b in the leg tubes however extend from the ankle up to the neck opening, as shown in Fig. 12 using the zip fastener 44. With the closing of the fourth zip fastener 63a, b the wearer is both fixed in the sitting position, and a basic pressure corresponding to straight flight is built up in the protective suit, such that fluid building up the equalising pressure and the equalising tension in the hollow spaces 5 is distributed over the entire body length covered by the protective suit. An opening 46 in the groin of the protective suit can be provided for the genitalia, this can also be closed by an elastic textile material.

Flight trials have resulted in no harmful effects on health due to the opening 46. On the other hand it improves the mobility of the wearer of the protective suit.

A modification of the solution according to Fig. 14 is shown in Fig. 15. Here the fourth zip fastener 63a, b as well as the small insert 19a are omitted. In their place comes a tensioning element, schematically represented as a hollow space analog to the bands 38 to 41. This tensioning element 26 extends over the whole length of the closure shown in cross section in Fig. 15, but can also be divided into several pieces, closed off in themselves.

Following the closure of the zip fasteners 61a, b; 62a, b; and the velcro fasteners 20, 21, the tensioning element 26 is for instance inflated by compressed air, whose pressure is higher than that in the deepest positioned hollow spaces 5 at the greatest possible curved flight acceleration.

By the formation of the width of the tensioning element 26 the basic tension σ can be exactly adjusted to the required necessary value.

Fig. 16 shows again a half of the illustration on the left-hand side and a similar one on the right, each with a modification of the rear side of the protective suit. The concepts "left" and "right" are exchanged with respect to Fig. 14. The two modifications comprise again the insertion of a zig-zag shaped band 38 on the left and an extended band 40 on the right; both bands extend from the shoulder part down to the foot of the wearer. Obviously in an especial form of construction the left and right sides of the front and back parts are produced in the same way, on the other hand the front side can have a different pattern of hollow spaces 5 than the back part.

In the region of the knees both bands 38, 40 are made narrower. Thereby no unduly high tension arises over the knee. Furthermore space is found thereby for the elastic insert 52.

Fig. 16 shows the back view of the example of construction according to Fig. 12, again in two modifications of construction as regards the bands 38, 40. It is similarly in accordance with the invention, for the bands 38, 40 to be varied in their width in order to build up the correct tension.

In the region of the elbows the example in Fig. 16 carries elastic inserts 52.

An extension according to the invention is a fluid-filled insert 67a, b in accordance with Fig. 17. This is worn under the protective suit and is here - as drawn - divided into two halves 67a, b, which however can be connected to each other. Each insert 67a, b is connected to a reservoir 68a, b extending upwards; the two reservoirs 68a, b are however outside the layers 3, 4 comprising the protective suit, nevertheless advantageously worn under the oversuit 2. Thereby only the inserts 67a, b are subject to the ruling tension in the layers 3, 4 and the main part 37. The object of the inserts 67a, b is the production of an equalising pressure on the belly/abdominal region. According to the anatomical characteristics of the wearer the protective suit runs relatively flat between the two intestines. This means that the belly volume can increase relatively strongly, before the internal pressure in the suit is compensated. The consequences of this can on the one hand be an undesirable collection of blood in the abdominal cavity, and on the other a load on the diaphram. The latter makes belly breathing difficult up to the disability to breathe out, which is caused by a loss of tension leading to upwards bulging in the diaphram.

In G loading of the wearer, fluid flows out of the reservoir 68a, b into the inserts 67a, b until the internal pressure of the belly space corresponds to the compensatory pressure built up in the inserts 67a, b and the reservoir 68a, b. The reservoirs 68a, b can be fastened to the protective suit or possibly be carried on a band around the neck. Furthermore it lies within the idea of this extension, that the two inserts 67a, b can be unified into a single volume.

Fig. 18 is the representation of a second example of construction of a pressure loaded belly bladder in analogy to the fluid filled insert 67a, b of Fig. 17. An anatomically shaped bladder 71 of an elastomer is the medium pressure reservoir of an automatic lung, similar to that known from the sport of diving. The bladder is fed via a pressure actuated regulating valve 72 from the on-board high pressure reservoir 73 for breathing air, shown here schematically as a pressure bottle. The regulating valve 72 decreases the pressure of the breathing gas from the high pressure reservoir 73 to a pressure which is a little above the pressure in the lungs. It is controlled via a pressure line 74, which communicates with one of the bands 38, 40. The pressure line 74 opens into the abdominal region at a transfer position 75 in one of the bands 38, 40 and assumes the ruling hydrostatic pressure at the transfer position 75 as the control value. There are two modifications to this: either the regulating valve lies at the same hydrostatic pressure as the transfer position 75 mentioned, then the pressure line 74 can be filled with fluid. Or the pressure line 74 carries air - or more generally: a gas - then the hydrostatic pressure at the transfer position controls a pressure reducing valve (not shown) and with it feeds the pressure line 74 with the pressure originating from the high pressure reservoir 73 and at reduced pressure.

The bladder 71, worn under the protective suit, is on the one hand actuated by its tension σ and by the high pressure, reduced by the regulating valve 72 to medium pressure p_m. Because of the type of the mechanical definition of p_m this corresponds to the hydrostatic pressure in the abdominal region, so that the belly organs are freed from loading and the diaphram is freed from its momentary weight increase. The exact value of p_m is adjustable by the regulating valve 72 for individual cases.

A second regulating valve 76, similarly known from the lung automats in sport diving, which responds to breathing activity, is connected to the bladder 71. Thereby the breath pressure p_a lies only a little below the medium pressure p_m. The regulating valve 76 feeds the breathing tube designated 77 and a breathing mask 78.

On breathing in, the bladder 71 partly empties by a volume, which is smaller than the volume of the breath. In order to make these volumes the same, the second regulating valve 76 can have an overflow device, which blows off a predetermined adjustable portion of the breathing air directly via the regulating valve to the outside.

In the flying helmet (not shown) or separated from it, the pilot carries a shell-shaped headphone harness 80, which lies tightly against the head. From this to the breathing mask 78 leads on each side a connecting tube 79. With this it can be ascertained that both sides of the eardrum are under the same pressure - the breathing pressure. The breathing mask 78 and the earphones 80 are anyway part of the pilot's equipment; the only additions are the two connecting tubes 79.

Fig. 19 shows a flying boot 48 in side view, partly cut away. Between the foot of the wearer - provided with the reference number 49 - and a normal tongue 50 fastened to the boot 48, a double-walled, second tongue, again composed of layers 3, 4, is inserted, which has a fluid filled hollow space 5. The second tongue 51 is, with reference to all the previously described examples of construction of the protective suit, provided as a continuation of the leg part; the hollow space 5 communicates with that of the leg part.

When the aircraft engine is running, even on the ground, the adjustment and maintenance of a comfortable temperature in the cockpit is generally no problem. In the preparation phase, when the pilot is already sitting in the cockpit, but the engine is still stationary, it can be either very hot or uncomfortably cold according to the situation. Naturally this is also the case if the air conditioning in the cockpit is insufficient or fails. A device, which is a component of the protective suit, is shown schematically in Fig. 20. It shows a part of the lining 1. This comprises for instance two layers of a weft, joined by means of a known bonding technique for textiles. Between the layers, of which the inner layer is referenced 48, there is an arrangement of Peltier effect elements 49. These are all connected electrically conducting to a conductor 50, of which one pole leads to a d.c. voltage - or to a conductor connected to it - , as also to a conductor 51 leading to the other pole or to one connected to it. The conductors 50, 51 are taken together into a connector socket 52, which is taken through the outer layer (not shown) of the lining 1 and corresponds to a suitable mating part (not shown) in the active part of the protective suit and the oversuit 2.

In accordance with the adjusted polarity of the d.c. voltage - and therewith the direction of current flow of the direct current passing through the Peltier elements 49 - the heat energy flow changes direction from or to the Peltier elements 49. With the same device it is possible thus to heat or to cool. The high temperature reservoir in the heating setting, the low temperature reservoir in the cooling setting of the device according to Fig. 20 are located on the aircraft side.

The conductors 50, 51 are made highly flexible and insulated. The connection to the Peltier elements 49 is performed by a well known solder-free connecting technique. Semiconductor Peltier elements with high thermal efficiency are available. The arrangement of Peltier elements 49 is shown schematically in Fig. 20, for the front side of the upper body. Obviously it is possible to carry this out in the same or a suitable manner for the back area and the extremities. By the use of diodes it is possible to set up certain areas of the arrangement of Peltier elements 49 only for heating or only for cooling. Such diodes 53 are drawn in in Fig. 20 for the abdominal region as representative.

Furthermore, the Peltier elements can be arranged in several independent circuits, whereby the possibility arises of heating or cooling certain parts of the body selectively. The connector socket has then the corresponding number of connections.

Fig. 21 is the schematic representation of an additional device to the previously described protective suit, and shows a pilot 91 from the side sitting on a pilot's seat 92 with a seating surface 93. On this seating surface 93 there is a cushion 94, for instance fixed by buckles, which is shown in detail in Fig. 22. The cushion 94 comprises in the representation in Fig. 22 three essentially independent layers 95, 96, 97, each of which is individually enclosed in a textile and low stretch material. The layers 95, 96, 97 internally each comprise an open pored plastics foam material 98, 99, 100. These are preferably of different hardness, such that the hardness increases from the uppermost layer 95 to the lowest layer 97. Each airtight enclosed layer has a connection 101, 102, 103 leading to the outside for instance in the form of a tube. The three connections 101 to 103 open into a ventilation valve 104, whose method of operation is further described below. There is an outlet 105 and a flooding entry 106.

The outlet 105 is for instance connected with the tensioning element 26 according to Fig. 15. Alternatively it can also be connected to inside of the hollow space 5 - in its formation as bands 38 to 41.

The filling of the layers 95 to 97 is in the first case preferably air, in the second case either the same fluid as is in the hollow spaces 5, or likewise air. The connection of the hollow spaces 5 to the outlet 105 must be made, if air represents the filling of the layers 95 to 97, at the highest point of the bands 38 to 41.

If now the pilot 91 - or in the case of a multi-seat aircraft another member of the flying personnel, as already mentioned - sits on the cushion 94, then the plastics foam materials 98 to 100 are set up such that they are essentially not compressed. Inside the layers 95 to 97 the same pressure applies, as in the tensioning elements or of that of the highest point of the bands 38 to 41.

If the pilot 91, who in Fig. 22 is included only symbolically as a mass 107, experiences an additional acceleration, then the plastics material foam 98 in the uppermost layer 95 is compressed and the air escaping from this layer builds up an additional tension in the tensioning elements 26 or an additional pressure in the hollow spaces 5, which increases the tension σ in the textile main parts 37 of the protective suit, in addition to the component generated by the increased hydrostatic pressure.

If the force exerted by the pilot 91 - or by the mass 107 - creates a mass which exceeds that by which the layer 95 is already squashed together, the plastics foam material 99 in the layer 96 starts to be compressed. A similar thing occurs with the still harder plastics foam material 100 in the layer 97.

After the release of the G loading the plastics foam materials 98 to 100 take up air again and recover their original shape, and the pre-tensioned pressure in the tensioning elements returns to the original value.

After the pilot 91 climbs out, the output side of the ventilation valve 104 is without pressure; this opens the flooding input 106 and the inside of the layers 95 to 97 and thereby the plastics material foam 98 to 100 is in pressure equilibrium with the environment.

What has been described here for three layers 95 to 97, can also be done with fewer and thereby wider spaced stages with two layers 95, 96, or without graduation using a single layer 95 of the cushion 94.

Alternatively to Fig. 22 the cushion 94 can be spatially divided: the layer 95 can be integrated in the acceleration protective suit - inside or outside -, the layer 96 can be buckled onto the outside of the protective suit, the third layer 97 - if present - can be a component of the seating surface 93. The connections 101 to 103 are then preferably constructed as pluggable quick connectors, similarly the connection of the outlet 105 to the valves of the tensioning elements 26 or the hollow spaces 5.

If the layers 95 to 97 are fluid filled, then the flooding input 106 can be dispensed with in the form shown and is replaced by a separate filling valve.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A suit for protection against acceleration forces, such as arise in high performance aircraft when flying in curves, whereby at least parts of the suit are made double-walled, and hollow spaces which thereby occur are filled with a fluid, which, when accelerations ≠ 1g occur in the momentary and local z-axis, builds up a compensating outer force corresponding to the internal force on the wearer, wherein

- the active part of the suit includes at least in part layers of a watertight and low stretch textile material, joined together so that hollow spaces arise between the connection positions,
- the hollow spaces form a continuous hydrostatic pressure column from the ankles up to the neck of the wearer of the protective suit,
- the inner-lying layer exerts a pressure on the body of the wearer corresponding to the height of the fluid column and the effective acceleration in the momentary and local Z-axis,
- a tensile force is built up in the outer layer due to this pressure,
- the connection positions can be joined to single layer connecting pieces of low stretch textile material outside the hollow spaces, which can transmit the tensile force built up onto the surface of the body of the wearer of the suit,
- the connection positions bordering the hollow spaces are arranged in such structures that the shortening of the separation of neighbouring connection positions effected by the pressure of the fluid present in the hollow spaces can build up the intended tensile force in direction and magnitude and can transmit it to neighbouring elements of the suit,
- the active part of the suit, including the layers and the connecting pieces has means for matching the suit to the current bodily conditions of its wearer,
- this active part of the suit has means for closure, which are simultaneously suited for building up the necessary basic pressure of the suit for straight flight.

2. A suit for protection against acceleration forces according to Claim 1, wherein it essentially covers the whole body with the exception of the neck, head, hands and feet.

3. A suit for protection against acceleration forces according to Claim 1 or Claim 2, wherein a lining and an oversuit are present, whereby the lining is worn under, the oversuit outside the active part of the suit.

4. A suit for protection against acceleration forces according to Claim 3, wherein the lining and the oversuit are partly joined to the active part of the suit.

5. A suit for protection against acceleration forces in accordance with Claim 1 or Claim 2, wherein the hollow spaces and the connection positions dividing them extend completely over the whole suit and only the places where there are means of matching and closing the suit are excepted therefrom.

6. A suit for protection against acceleration forces in accordance with Claim 1 or Claim 2, wherein the hollow spaces and the connection positions dividing them are arranged in bands, which extend over the whole length of the suit.

7. A suit for protection against acceleration forces in accordance with Claim 5 or Claim 6, wherein the individual connection positions lie essentially on lines parallel to each other, and the separation of the connection positions lying on an individual line corresponds somewhat to their lateral separation, and this arrangement of connection positions can be applied where tensional forces mainly perpendicular to the direction of the connection positions are to be generated.

8. A suit for protection against acceleration forces according to Claims 5, or Claim 6, wherein

- the connection positions are in straight lines, which run essentially parallel to each other, whose lengths correspond to their lateral separation,
- the individual connection positions lie essentially on two groups of parallel lines, which are displaced from each other by about half the lateral

separation of two adjacent connection positions, and the connection positions lying on the displaced parallel lines lie somewhat symmetrically to the gaps of the connection positions on the non-displaced parallel lines, and this arrangement of connection positions can be applied where tensional forces mainly perpendicular to the direction of the connection positions, in a small measure also in their direction, are to be generated.

9. A suit for protection against acceleration forces according to Claim 5, or Claim 6, wherein the individual connection positions are in straight lines which are arranged essentially radial to a point and this arrangement of connection positions can be applied, both where tensional forces are to be built up on circulating lines and also a basket-shaped deformation of the mutually connected layers is to be effected.

10. A suit for protection against acceleration forces according to Claims 6 and 7 or 8, wherein the bands extending over the whole length of the suit are formed in a wave shape.

11. A suit for protection against acceleration forces according to Claim 6, wherein the bands extending over the whole length of the suit are formed in a wave shape.

12. A suit for protection against acceleration forces according to Claim 6 and 7 or 8, wherein the bands extending over the whole length of the suit are formed essentially in an elongated shape.

13. A suit for protection against acceleration forces according to Claim 1 or Claim 2, wherein the means for matching the suit to the current bodily conditions of its wearer include straps and buckles, which are arranged over the whole length of the suit.

14. A suit for protection against acceleration forces according to Claim 1 or Claim 2, wherein the means for matching the suit to the current bodily conditions of its wearer include velcro fasteners, which extend over the entire length of the part of the suit to be closed.

15. A suit for protection against acceleration forces in accordance with Claim 14, wherein the velcro fasteners include a multiplicity of straps.

16. A suit for protection against acceleration forces in accordance with Claim 1 or Claim 2, wherein the means for closing include zip fasteners.

17. A suit for protection against acceleration forces according to Claims 1 or 2 and 16 wherein the means of matching the suit to the current bodily conditions of its wearer include pneumatic tensioning elements, which extend over the whole length of the zip fasteners and are arranged parallel to them

- the tensioning elements are made from a low-stretch and airtight textile material and can have connection positions along their length,
- the tensioning elements can build up the basic tension σ of the suit due to a fluid under pressure.

18. A suit for protection against acceleration forces according to any one of Claims 13 to 15, wherein the suit has an insert along the means of closure and the means of closure are arranged such that the insert is bridged over in the closure so that the tension in the suit runs via the means of closure and the insert is fully unloaded by it.

19. A suit for protection against acceleration forces according to any one of Claims 14 to 16 and 18, wherein a first zip fastener is present, which closes the insert and the velcro fastener is so arranged that its fixed part lies against the body, its movable part is fixed to the end of the insert, thus the closed velcro fastener bridges the insert and the zip fastener.

20. A suit for protection against acceleration forces according to any one of Claims 14 to 16 and 18, wherein

- a first zip fastener is present, which closes the part of the suit to be closed,
- a second zip fastener is present, bridging the insert,
- a third zip fastener is present, of which one half is fastened to the part of the suit to be closed, and the other half is fastened to the end of the cloth, which extends over the whole length of the suit to be closed,
- the cloth itself has a second insert extending over its whole length of the part of the suit to be closed,
- a fourth zip fastener is present, which bridges the second insert and with which the necessary basic tension can be provided in the suit,
- the velcro fastener joins the cloth to the part of the suit to be closed.

21. A suit for protection against acceleration forces according to any one of Claims 14 to 18, wherein

- a first zip fastener is present, which closes the part of the suit to be closed,
- a second zip fastener is present bridging the insert,
- a third zip fastener is present, whose one half is fastened to the part of the suit to be closed and whose other half is fastened to the end of a cloth, which extends over the whole length of the part of the suit to be closed,
- the pneumatic element is inserted in the cloth,
- the velcro fastener joins the cloth with the part of the suit to be closed.

22. A suit for protection against acceleration forces according to Claim 5 or Claim 6, wherein

- the layers containing a fluid in the hollow spaces structured by the connection positions and arising from them are formed in height as enclosed regions, of which each has valves for filling and ventilation,

- these regions are arranged to overlap in the suit, so that the hydrostatic pressure in the outer region can be transmitted to the outer part of the inner region.

23. A suit for protection against acceleration forces according to Claim 1 or 2 or 3 or 4, wherein it

- has a fluid filled insert, which is arranged inside the suit in the belly/abdominal region and can be joined externally to the suit,

- the insert is connected to a reservoir, extending upwards, which is arranged outside the suit and is joined to it, which reservoir is similarly filled with fluid, whereby, under an increase in the loading due to acceleration, fluid can flow back from the reservoir into the insert and increase the pressure on the belly/abdominal region.

24. A suit for protection against acceleration forces according to any one of the Claims 1 to 22, wherein

- an anatomically shaped bladder made from an elastomer is present, which is arranged inside the suit in the belly/abdominal region and can be joined externally to the suit,

- the bladder has an entrance and an exit, each of which opens outside the suit and are each closed by a regulating valve,

- the first regulating valve reduces the pressure of breathing air from a high pressure supply to a medium pressure,

- the control valve, which is the ruling hydrostatic pressure at a predetermined position in the hollow space of the suit, can be transmitted to the first regulating valve by means of a pressure line,

- a breathing mask is present and is worn by the wearer of the suit,

- the outlet of the second regulating valve, which can reduce the medium pressure to breathing pressure, opens into the breathing tube.

25. A suit for protection against acceleration forces according to Claim 24, wherein at a suitable position between the second regulating valve and the breathing mask and connected to both, an over flow device is present.

26. A suit for protection against acceleration forces according to Claim 24, wherein an earphone harness is present and is worn by the wearer of the suit, which by means of connecting tubes is connected to a position carrying the breathing pressure, so that on the outer side of the eardrum the same pressure is effective, as on its inner side.

27. A suit for protection against acceleration forces according to any one of Claims 1 to 12, wherein the connection positions are formed by gluing.

28. A suit for protection against acceleration forces according to any one of Claims 1 to 12, wherein the connection positions are formed by welding.

29. A suit for protection against acceleration forces according to any one of Claims 1 to 12, wherein the connection positions are formed by sewing and sealing.

30. A suit for protection against acceleration forces according to any one of Claims 6, 7, 8, 10, 11, 12, wherein the bands are branched.

31. A suit for protection against acceleration forces according to Claim 5 or Claim 6, wherein at creasing positions of the active part of the suit soft bending but kink-resisting elements are inserted in the hollow spaces.

32. A suit for protection against acceleration forces according to Claims 17 or 21, wherein

- a cushion is present, which can be divided into several layers, whereby each layer is individually sealed to be water and air tight and contains an open pored plastics material foam,
- each layer has a connection, which can optionally be connected to the tensioning elements or the hollow spaces of the suit,

- the cushion is inserted between the body of the wearer and a seating surface of a pilot's seat and optionally fastened to the suit or to the pilot's seat,
- the layers are filled optionally with air or fluid,
- whereby in the presence of accelerations >g an additional pressure can be exerted on the fluid or gas bearing parts of the suit.

33. A suit according to Claim 32, wherein the cushion has only one layer.

34. A suit according to Claim 33, wherein the plastics foam material is filled with air and the connection is inserted between the layer and the tensioning elements of the suit.

35. A suit according to Claim 33, wherein the plastics foam material is filled with air and the connection is inserted between the layer and the hollow spaces of the suit, such that it is introduced at the highest possible point of the hollow spaces.

36. A suit according to Claim 33, wherein the plastics foam material is filled with fluid and the connection is inserted between the layer and the hollow spaces.

37. A suit according to Claim 33, wherein the cushion has two layers with plastics foam material, each layer includes a connection to the suit, and the lower plastics foam material is harder than the upper plastics foam material.

38. A suit according to Claim 37, wherein the two layers are filled with air.

39. A suit according to Claim 38, wherein the connections are inserted between the layers and the tensioning elements.

40. A suit according to Claim 38, wherein the connection is inserted between the layer and the tensioning elements, the connection is inserted between the layer and the hollow spaces of the suit, such that it is introduced at the highest possible point of the hollow spaces.

41. A suit according to Claim 38, wherein both the layers are filled with fluid and the connections are inserted between the layers and the hollow spaces.

42. A suit according to Claim 37, wherein the cushion has three layers with plastics foam material and each layer includes a connection to the suit, the lowest plastics foam material is harder than the middle plastics foam material and this is harder than the uppermost plastics foam material.

43. A suit according to Claim 42, wherein all three layers are filled with air.

44. A suit according to Claim 42, wherein the upper two layers are filled with air, the lowest layer with fluid.

45. A suit according to Claim 42, wherein the uppermost layer is filled with air, the lower two layers with fluid.

46. A suit according to Claim 42, wherein the connections can be connected optionally to the tensioning elements or to the hollow spaces of the suit.

47. A suit according to any one of the embodiments substantially as herein described and illustrated with reference to the accompanying drawings.

DATED: 13 April 2000
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Attorneys for:
LSS LIFE SUPPORT SYSTEMS AG

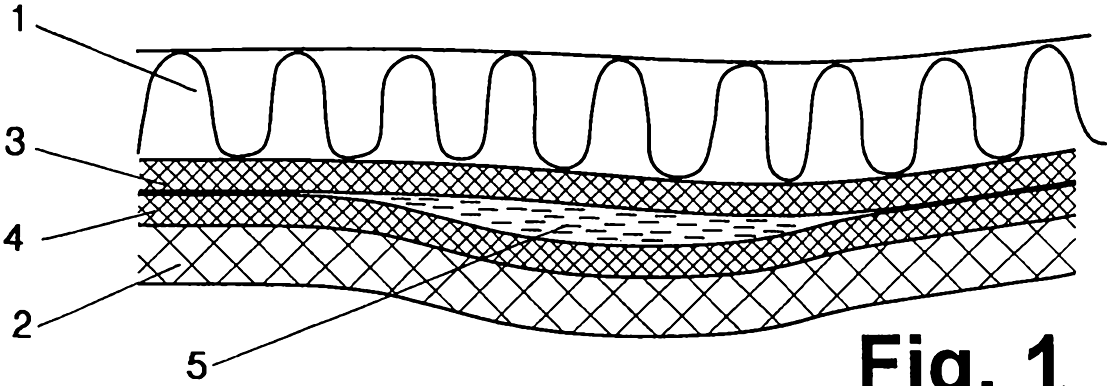

Fig. 1

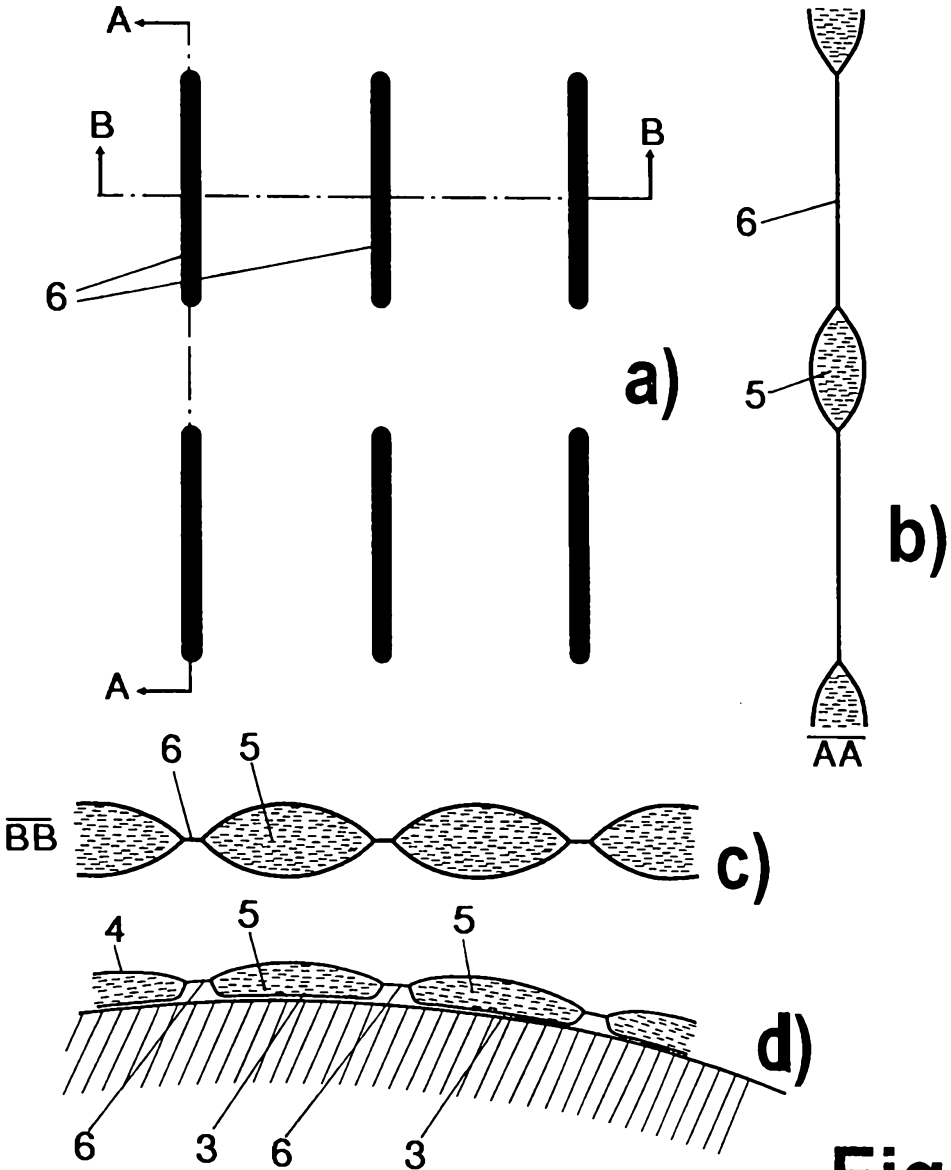

Fig. 2

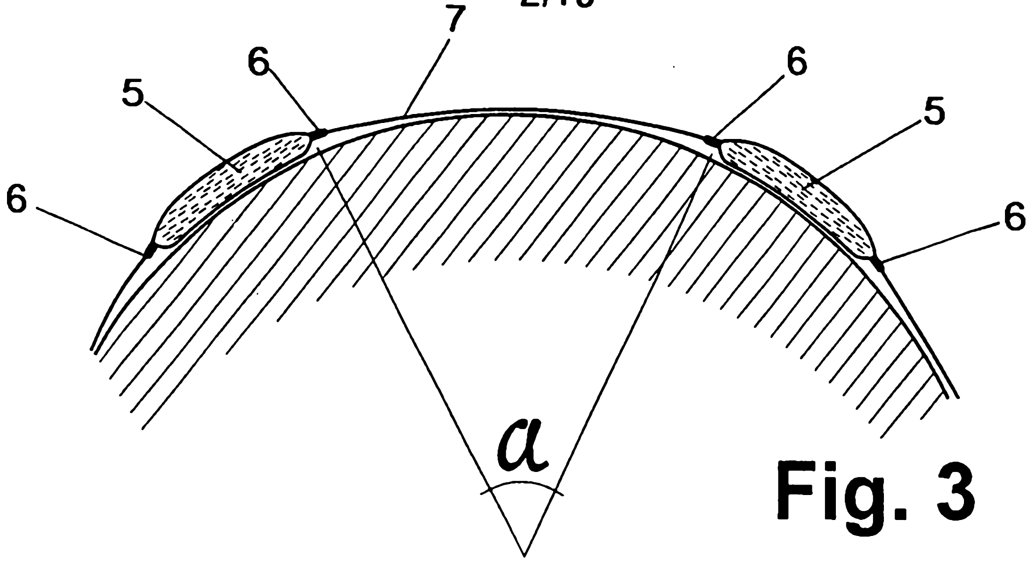

Fig. 3

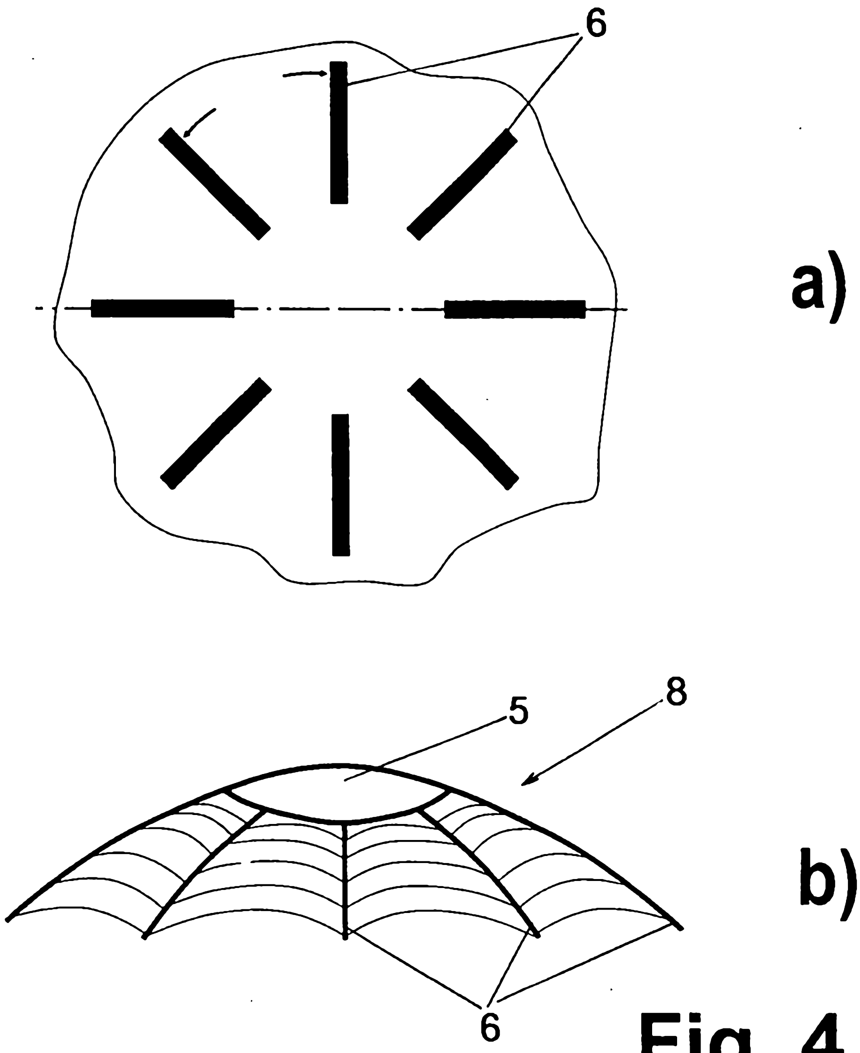

Fig. 4

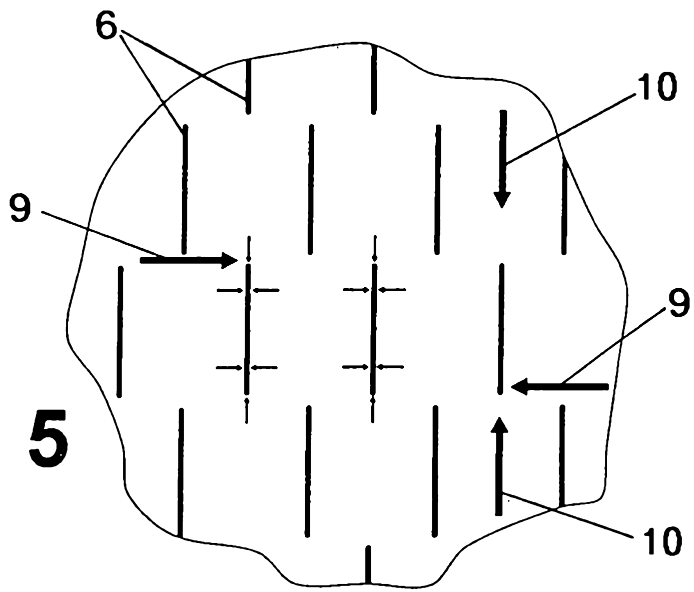

Fig. 5

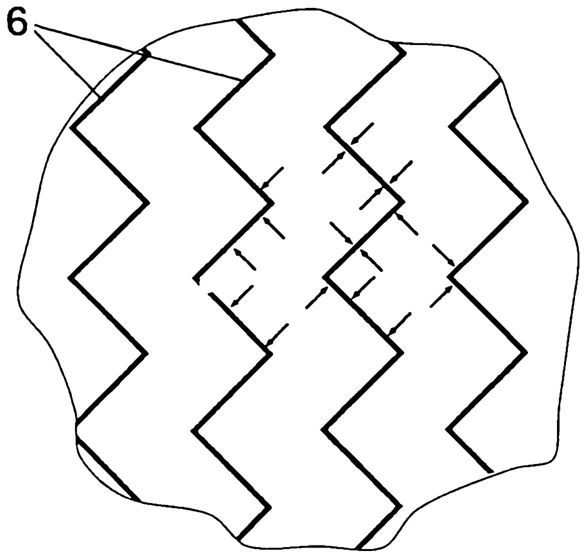

Fig. 6

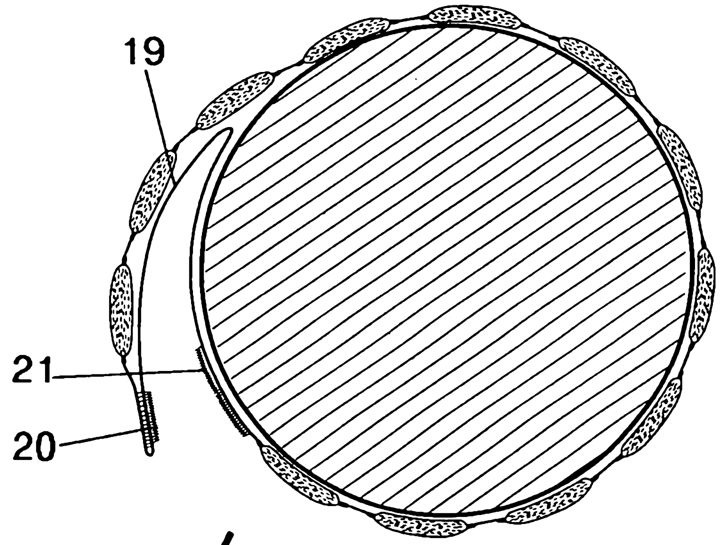

Fig. 9

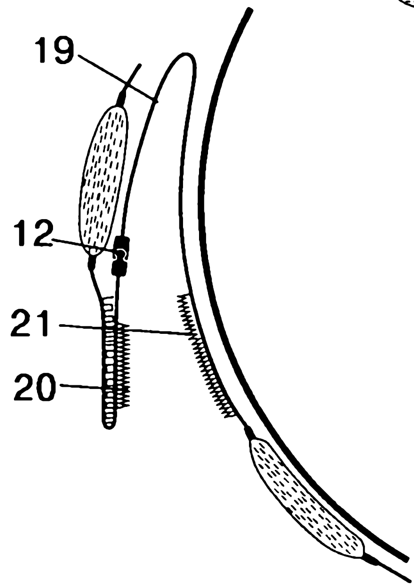

Fig. 10

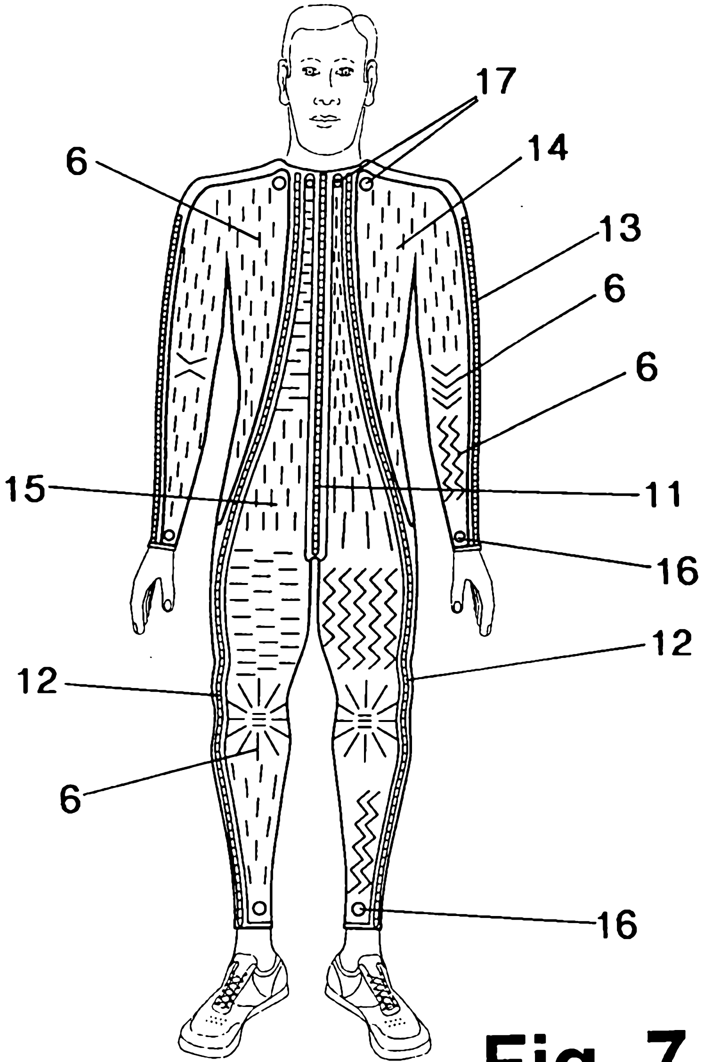

Fig. 7

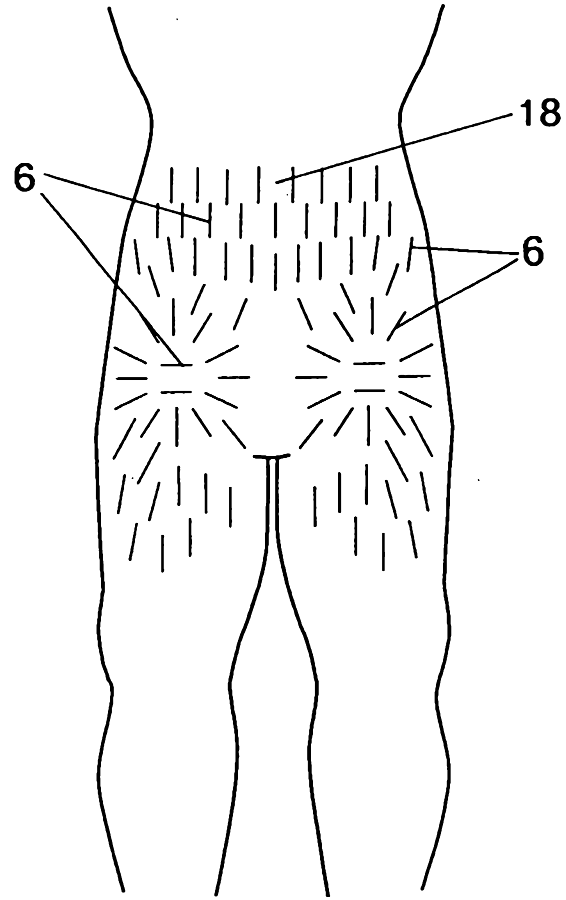

Fig. 8

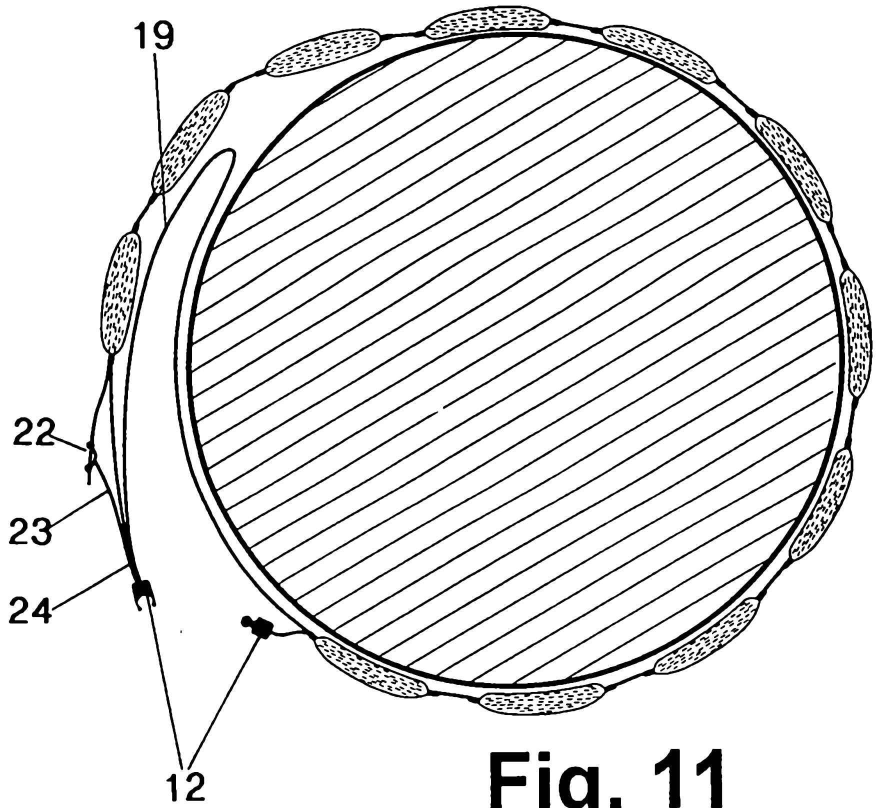

Fig. 11

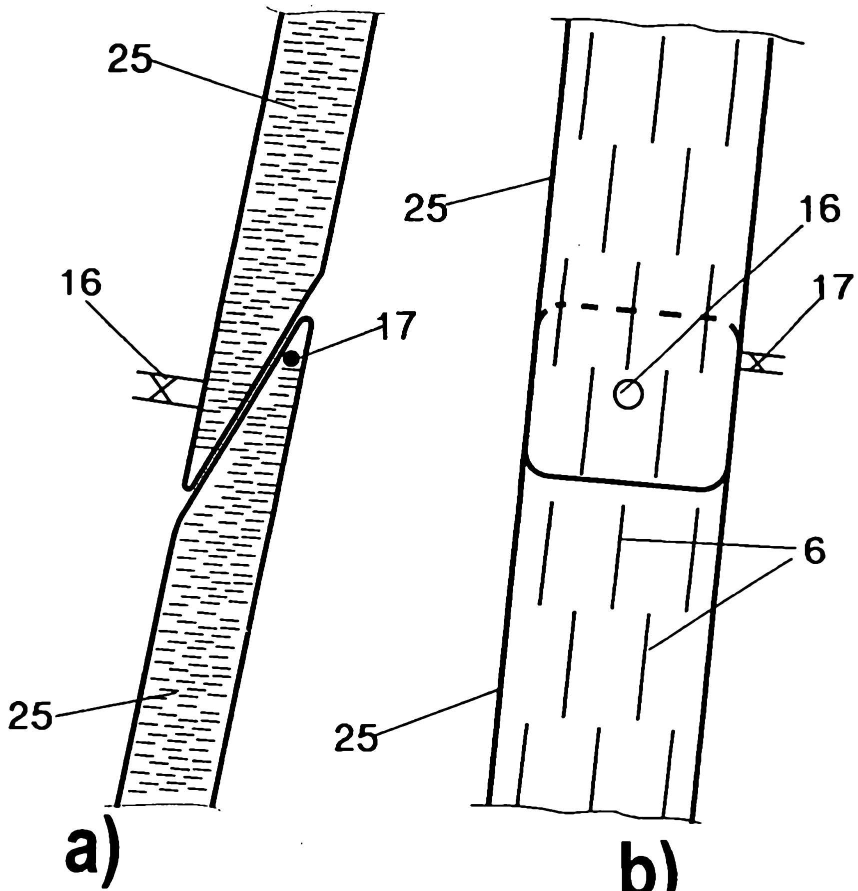

Fig. 13

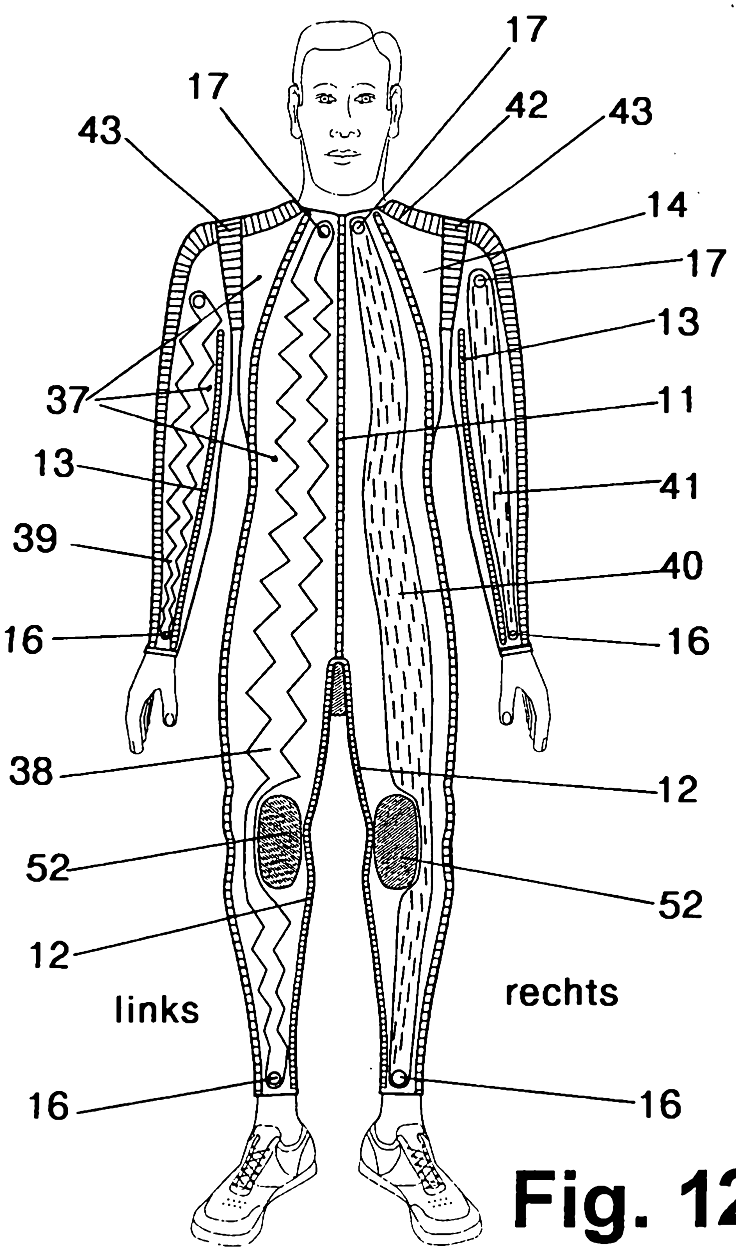
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Fig. 12

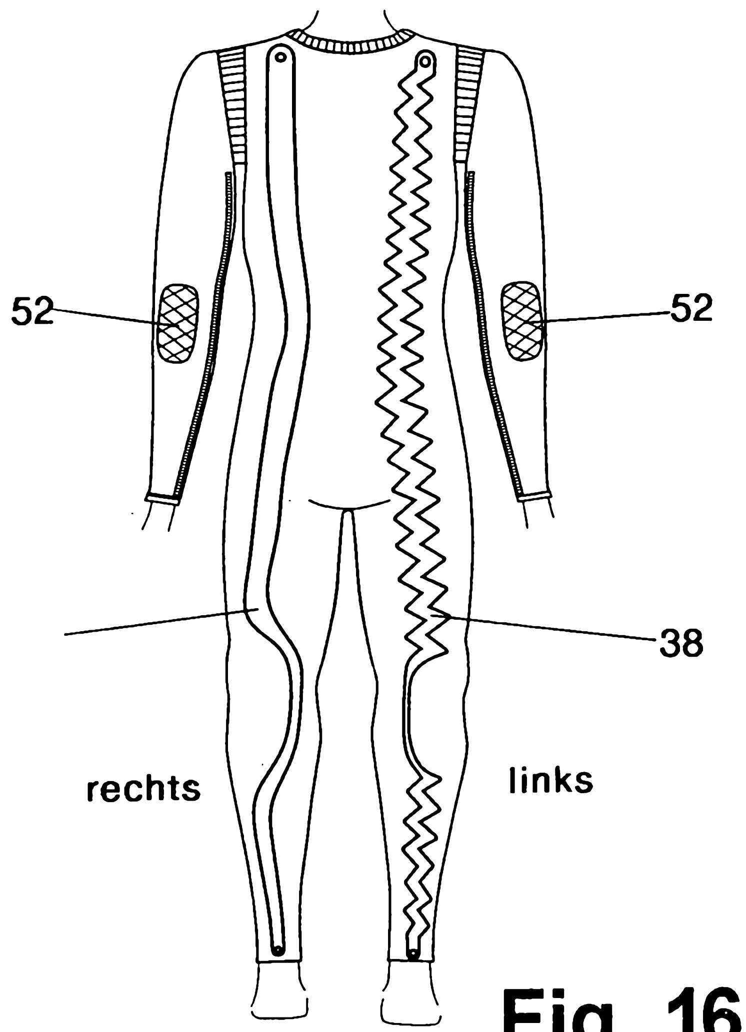
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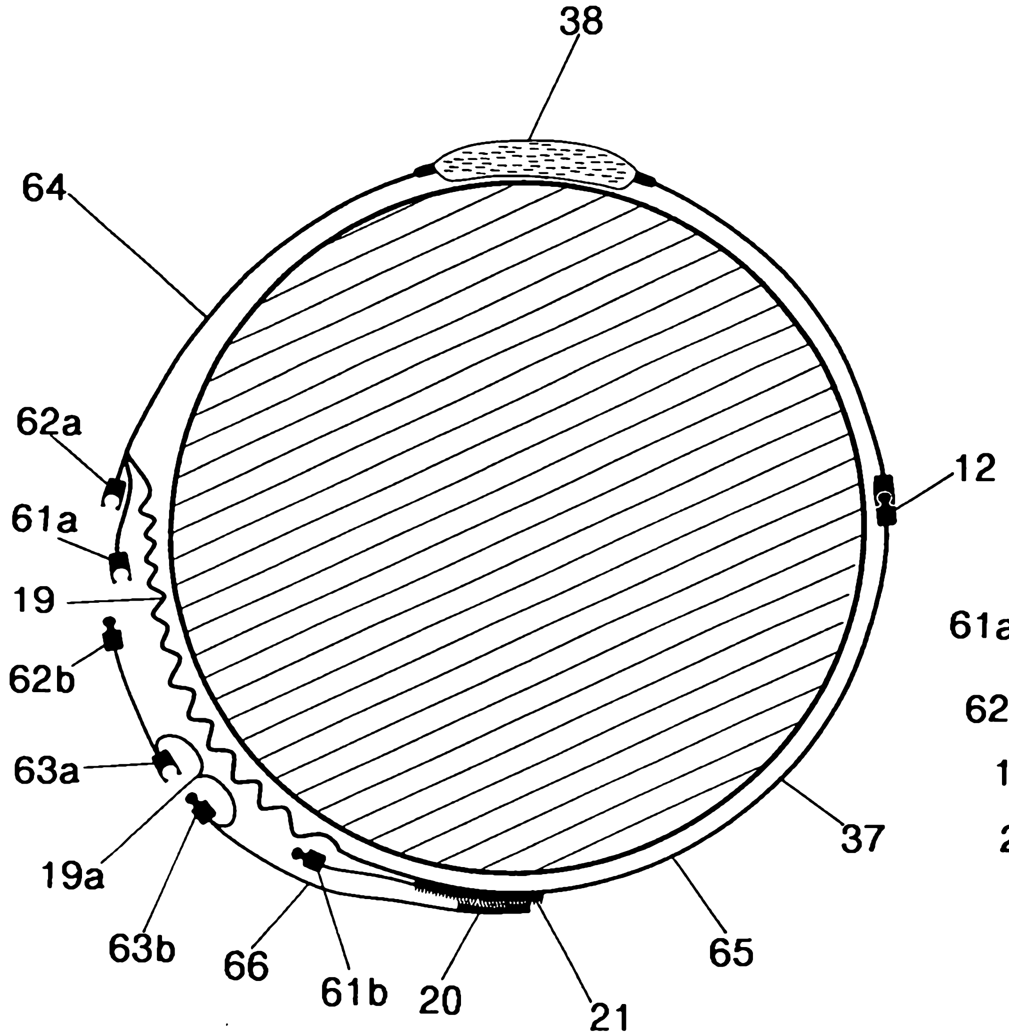
Fig. 16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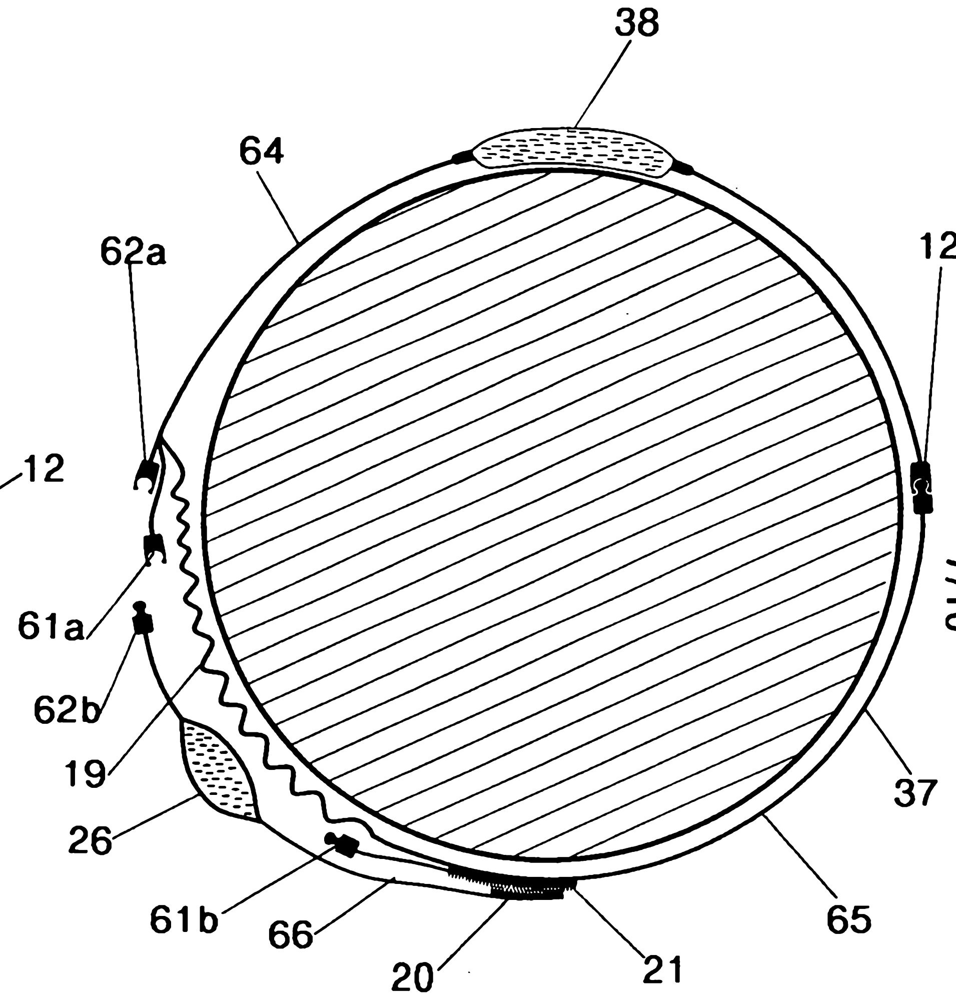
12

Fig. 14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62b
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61b
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20
21
65
37

Fig. 15

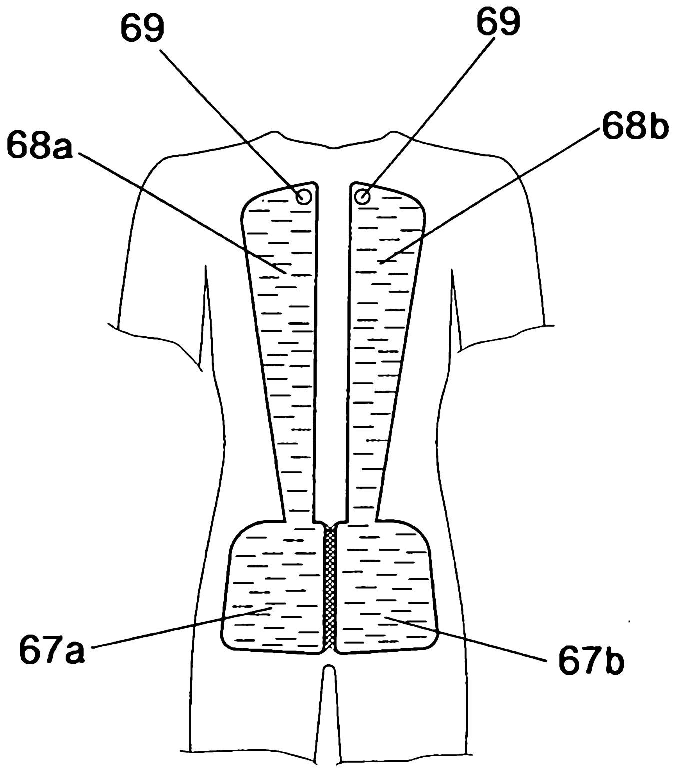

Fig. 17

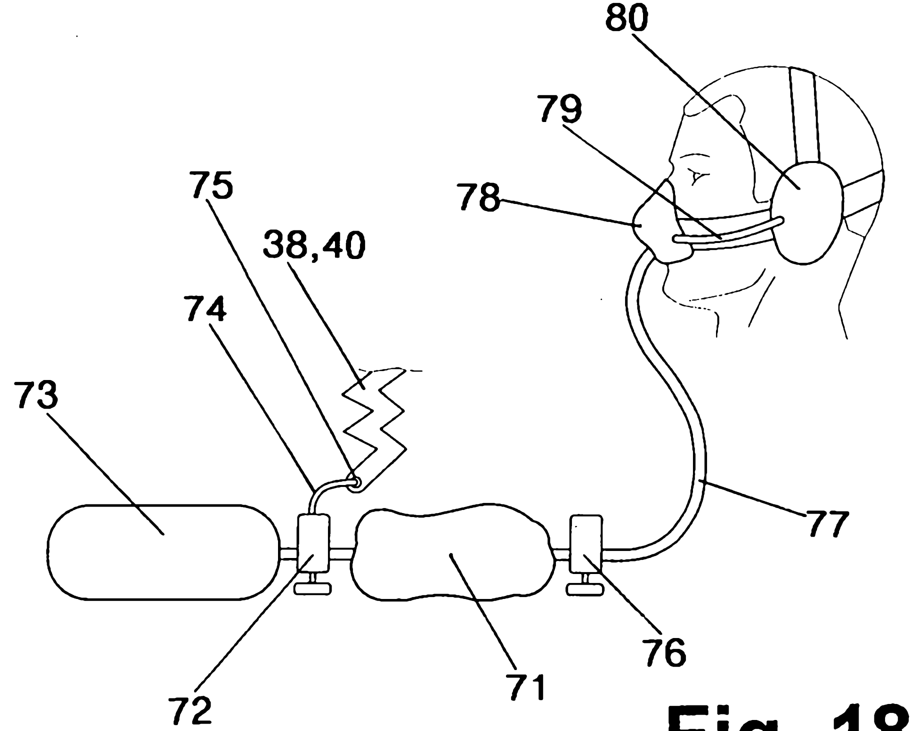

Fig. 18

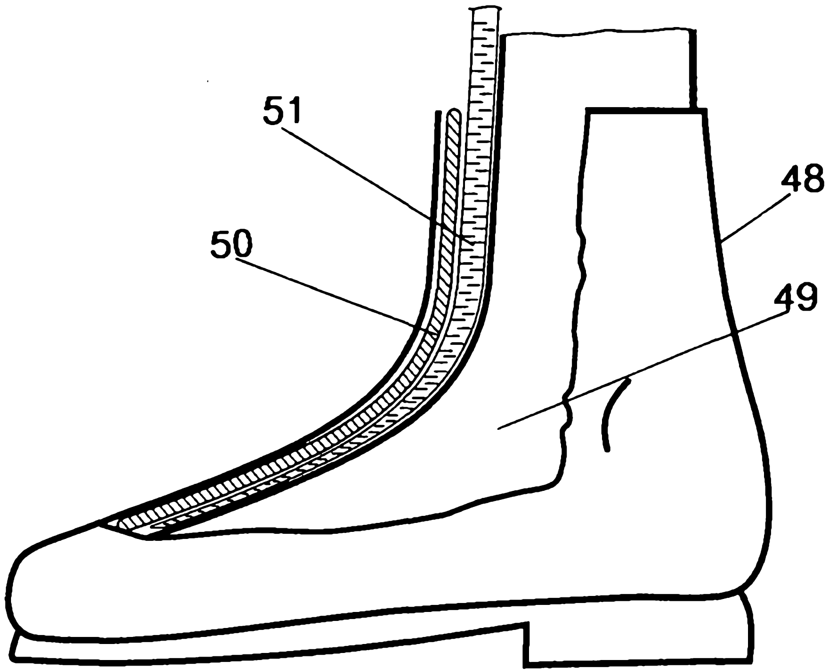

Fig. 19

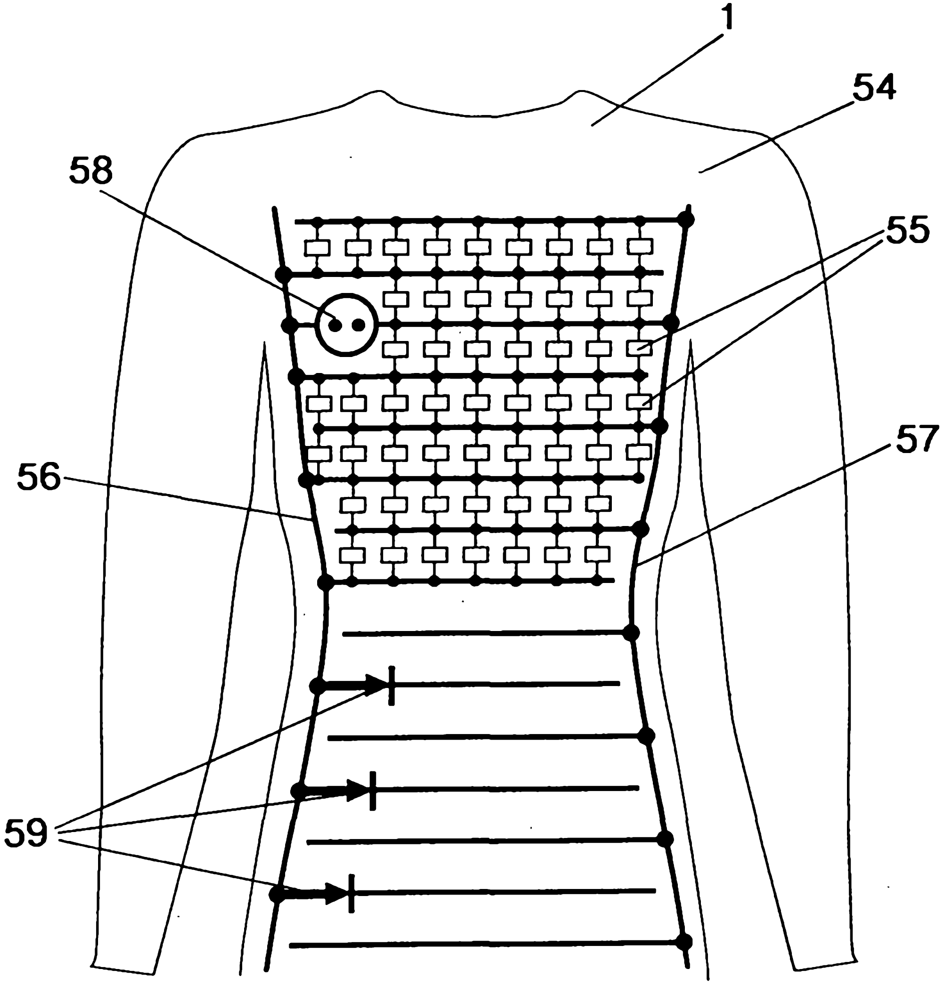

Fig. 20

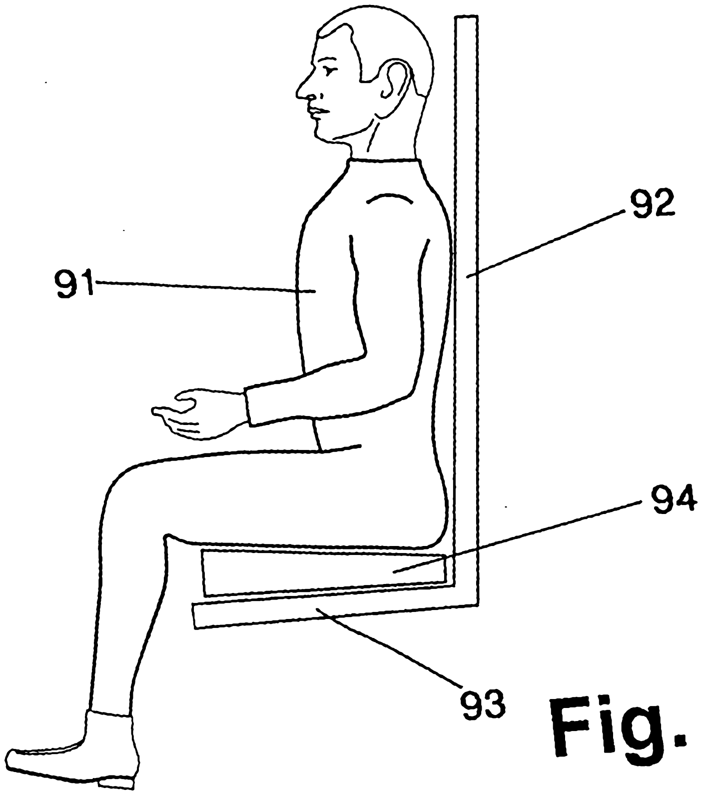

Fig. 21

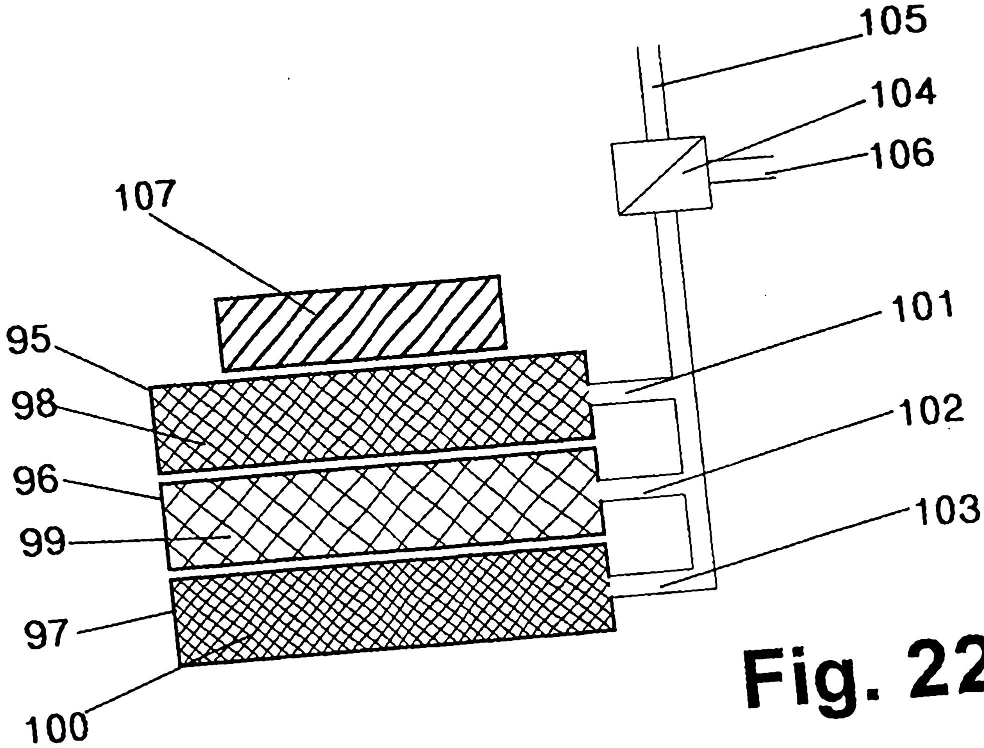

Fig. 22