

[54] INFLATABLE SHAPED STRUCTURES

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[51] Int. Cl. A61f 5/02

[58] Field of Search 128/78, 87, DIG. 20, 83,
128/84; 2/DIG. 3, 2.1

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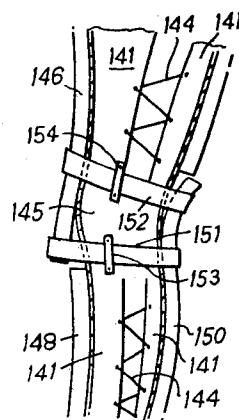
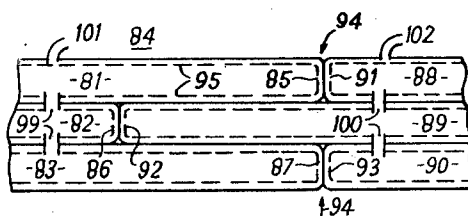
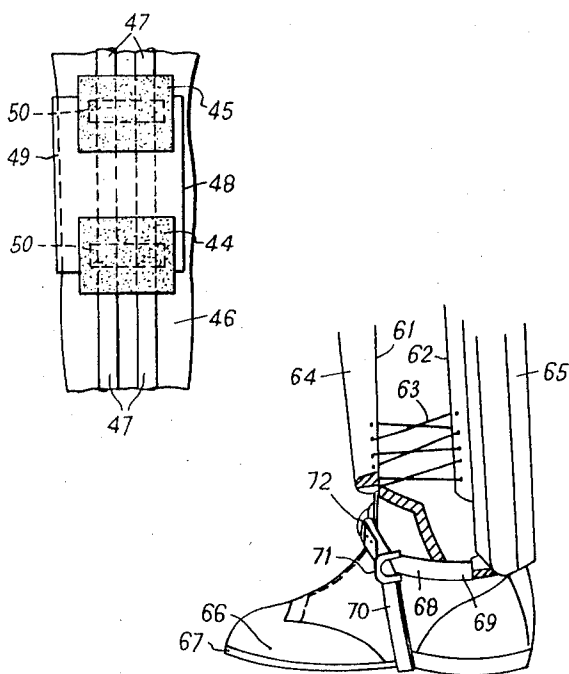
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[57]

ABSTRACT

An inflatable structure has at least two elongated fabric pipes of substantially square cross-section disposed in parallel relationship, each pipe including opposed plane side walls and having a base constituted by a portion of a sheet of air-permeable fabric to which said side walls are secured along their one longitudinal edge, the adjacent respective side walls of each adjacent pair of pipes being secured together substantially along their other longitudinal edge, and an inflatable tube of gas-tight resilient material in each said pipe, and this disclosure concerns its application to orthopaedic clothing, to orthopaedic devices for emaciated limbs, to orthopaedic boots for the support of weak ankle joints, and to orthopaedic devices adapted to facilitate bending of an articulated limb, especially the knee joint.

13 Claims, 15 Drawing Figures



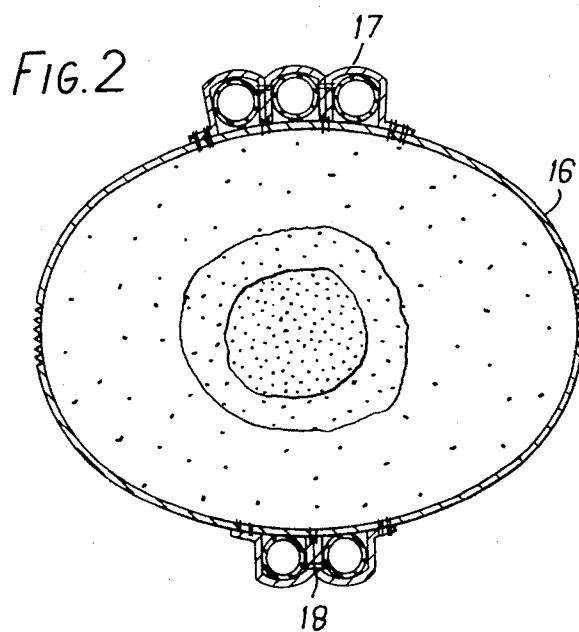
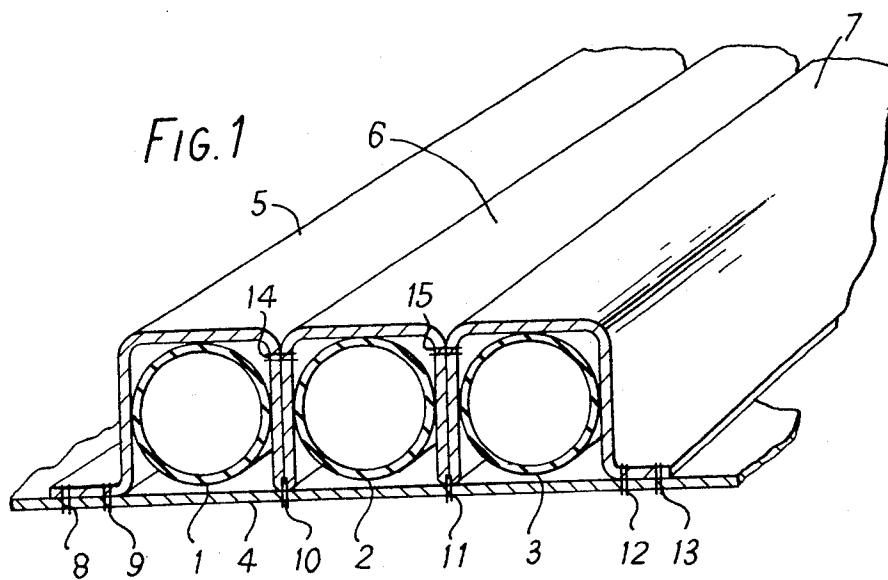


FIG. 3

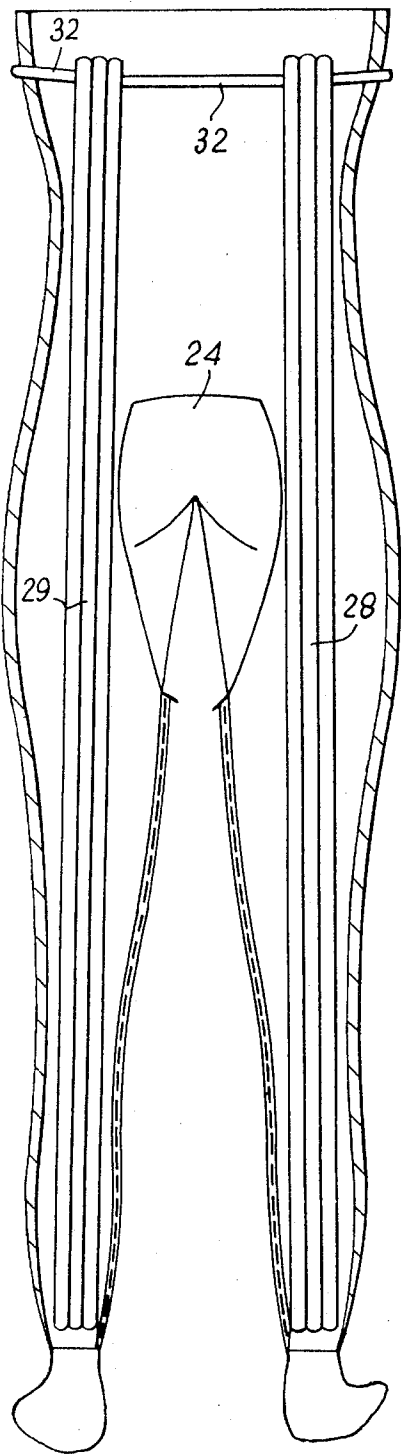


FIG. 4

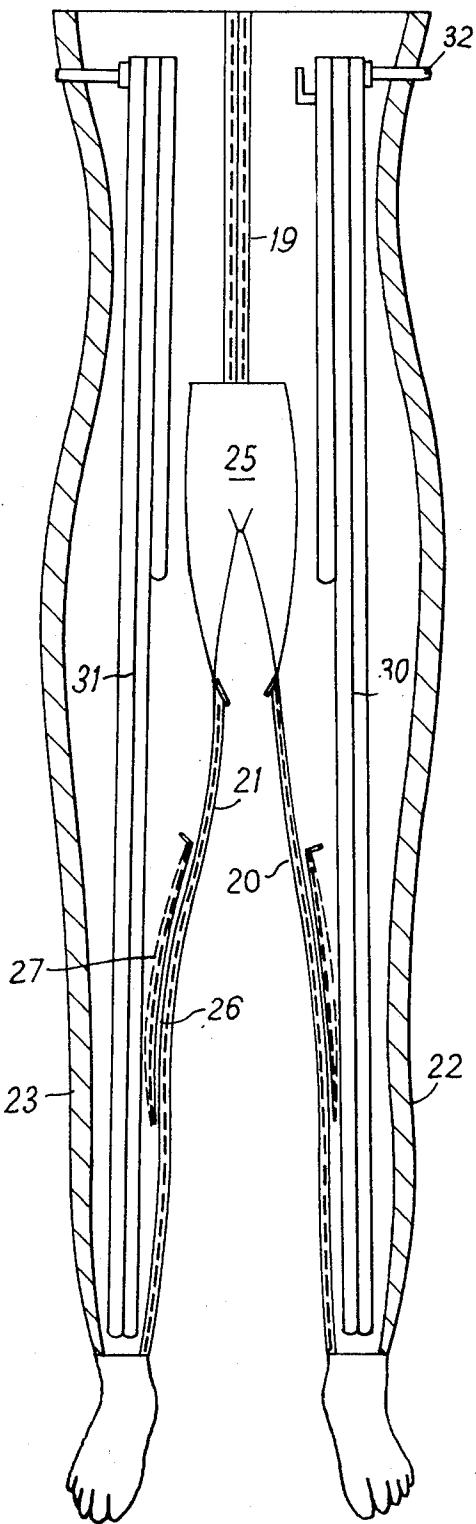


FIG. 5

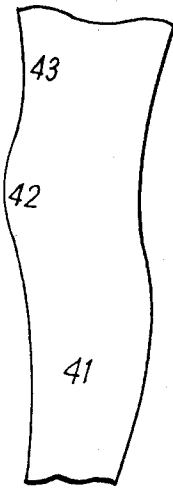


FIG. 6

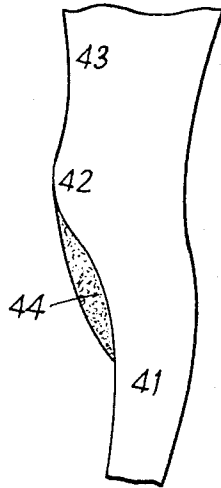


FIG. 7

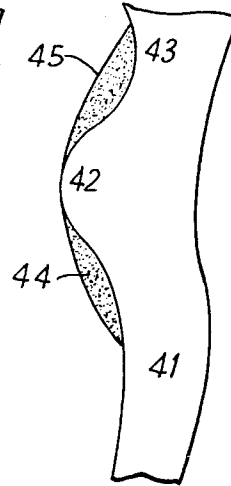


FIG. 8

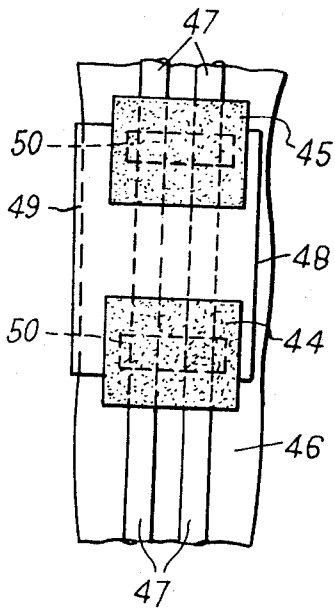


FIG. 9

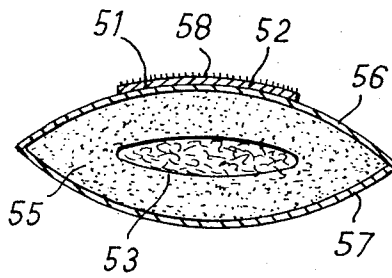
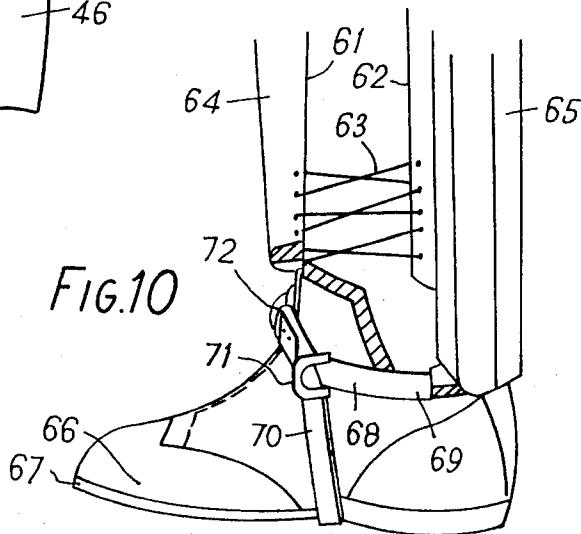


FIG. 10



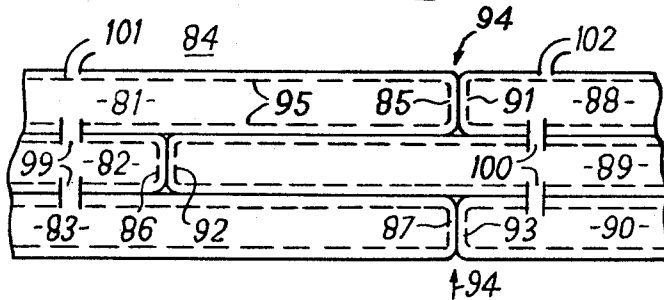


FIG. 11

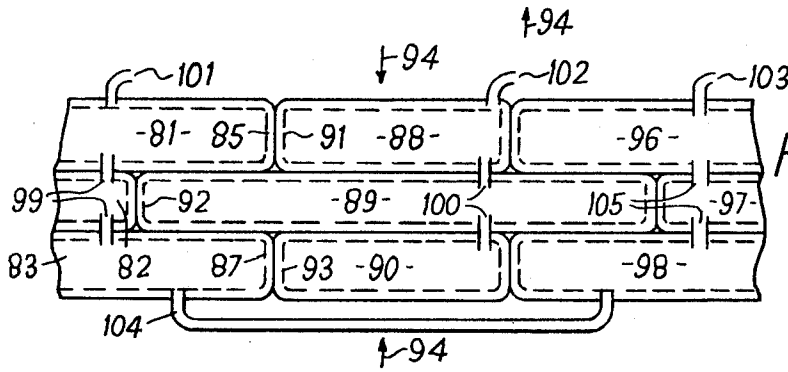


FIG. 12

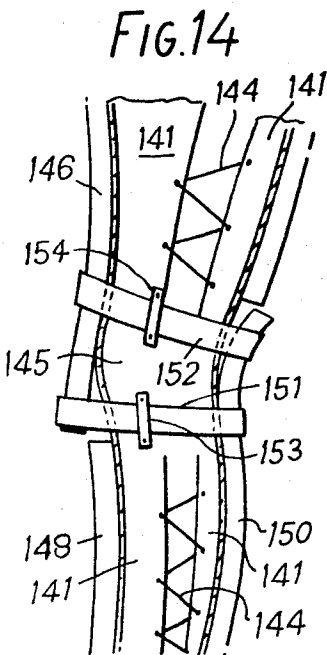


FIG. 14

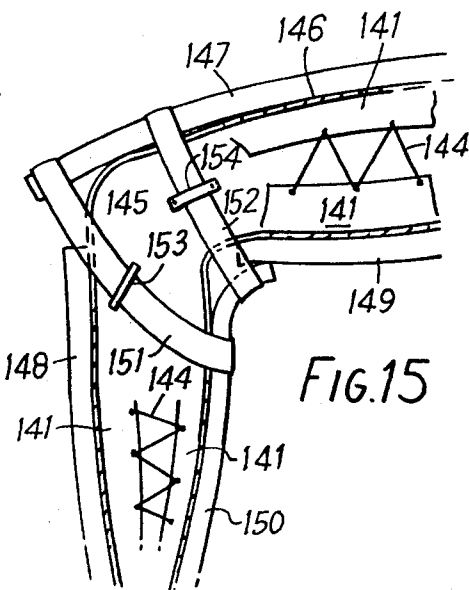


FIG. 15

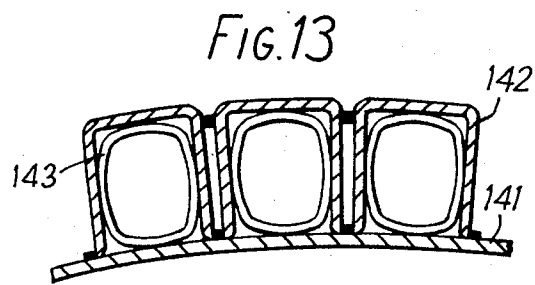


FIG. 13

INFLATABLE SHAPED STRUCTURES

This is a continuation-in-part to my co-pending U.S. Pat. application Ser. No. 267,162 filed 28 June 1972 now U.S. Pat. No. 3,823,711.

A first object of this invention is to provide, in combination with an inflatable shaped structure, one or more cushions to compensate for emaciation of a limb of an individual when the inflatable structure is used for support of parts of the human body.

A second object is to provide orthosis constructions having an inflatable structure associated with a boot in order to counteract insufficient support of the foot, e.g., so that an ankle may have transverse support, and so that a club foot may be corrected, e.g., the deformation of a hanging foot without the strength to lift itself.

A third object is to provide means for adaptation of an orthopaedic device, comprising an inflatable profiled structure, to articulated joints and more especially to the knee joint.

The inflatable structure utilised in the invention is shaped only on one side, which enables it to make continuous contact with a body of predetermined form. In particular, it can act as a support for certain parts of the human body, which parts are held firmly but without constricting the patient.

Some pneumatic mattresses are made of two layers of fabric water-proofed with latex and stuck together along parallel lines in order to form several inflatable cylinders, but such a structure will only support relatively weak inflation pressures, of the order of 200 g/cm² (2.84 pounds per square inch) for example, and provides no continuous plane surface.

The structure utilised in the invention can support inflation pressures which may reach for example several kg/cm², (one kg/cm² 14.2 pounds per square inch).

According to a first aspect of the invention an orthopaedic device is characterised by an inflatable structure having at least one removable cushion fixed inside at right angles to an emaciation of the leg.

According to a second aspect of the invention an orthopaedic device is characterised by means of connection between the lower part of an inflatable structure and a boot, so as to maintain the sole in a direction largely at right angles to the tibia and thereby opposing the transverse rocking of the ankle.

According to a third aspect of the invention, the possibility is obtained, when such an orthopaedic device is secured on an articulated limb, of bending a joint by deflating temporarily a portion of an inflatable structure and then re-inflating it to regain the necessary rigidity.

According to a fourth aspect of the invention there is obtained the possibility of bending an articulated joint of an inflatable structure without deflation, by releasing one or more straps.

The various aspects of the invention will be better understood with the help of the following description.

In the accompanying drawings:

FIG. 1 is a perspective view, in transverse section, of a preferred inflatable structure utilised in the invention;

FIG. 2 is a section of a leg dressed in an orthopaedic costume using such a structure;

FIG. 3 is a back view of such a costume, and

FIG. 4 is the front view;

FIG. 5 shows the outline of a normal leg;

FIG. 6 shows the outline of a leg which is wasted at the bottom part;

FIG. 7 represents the outline of a leg that is emaciated at the bottom and the top;

FIG. 8 shows a front view of the fixing of two cushions;

FIG. 9 shows a section through a cushion;

FIG. 10 is a lateral view of a leg encased in an appliance;

FIG. 11 represents a frontal view of an inflatable structure, comprising three contiguous pipes, separated into two sub-assemblies, in the vicinity of the axis of bending of a joint;

FIG. 12 is a frontal view of an inflatable structure, comprising three contiguous pipes, separated into three subassemblies, one of which is central in the vicinity of the bending axis of a joint;

FIG. 13 shows in section the pipes of an inflatable structure;

FIG. 14 represents a profile view of the structure surrounding a limb in the extended position, but not fastened;

FIG. 15 represents a profile view of the structure surrounding a limb in the bent position.

FIG. 1 shows part of an elongated section comprising, by way of example, three latex tubes 1-3 contained in a fabric casing.

The latter consists of a plane side 4 and three parts 5-7 forming pipes. The parts 5-7 are stitched to the side 4 at 8, 9, 10, 11, 12 and 13. They also are stitched to each other, both in the vicinity of the longitudinal edge 4 (at 10 and 11 for example), and at their other longitudinal edge (at 14 and 15 for example). This results in the adjacent plane sides of the pipes being in mutual contact and acting as braces.

Zip fasteners, not shown, may be provided to allow the tubes to be inserted easily in the casing, previously sewn so as to be an integral part of the assembly to which they are applied.

By way of example, FIG. 2 shows a leg of an orthopaedic costume in which each leg is provided with two sections 17 and 18. The section 17 comprises three tubes and is intended for application to the back of the patient's leg, while the section 18, with only two tubes, is applied to the front part of the leg.

It can be seen that the sections 17 and 18 form an integral part of the leg of the costume, the fabric wall 16 closing the pipes of the two structures. In this connection the circumferential wall of each tubular cell has a length which upon inflation of the inflatable tubes 1, 2 and 3 minimizes any tightening of the fabric wall 16 enclosing the lower extremity. Yet because of the adjacent wall structures in contact relation one with the other, as well as the spaced stitching 8, 9, 10, 11, 12 and 13 securing the tubular wall structures to the fabric wall 16, they do indeed form the needed, integral, bracing means.

When the tubes 1, 2, 3 are inflated they completely fill the interior space of the pipes, slightly rounding their exterior walls, and the adjoining walls stretch and become rigid. Each section thus forms a homogeneous structure in which the stretched adjoining walls act as stiffening braces, and has considerable rigidity.

The rigidity is very much greater than would be the case if the pipes were completely separated from each other.

It is preferred that the adjoining walls of the pipes be joined by at least two lines of stitching in order to form stiffening braces after inflation. However, where less rigidity is needed a single line of stitching will suffice to prevent the pipes from separating during inflation.

The fabric used is an air-permeable linen and preferably fire-proofed. The structure is then permeable to air, which is important in the case of an orthopaedic costume. It is clearly much lighter and more flexible than a metal or plastic frame, yet possesses sufficient rigidity to replace them in most cases.

The orthopaedic costume shown in FIGS. 3 and 4, made from a light strong fabric, air-permeable and preferably fire-proof, consists of a garment fitted around the legs and the body up to a certain height. It is supported by shoulder-straps or other means, not shown, and can be put on easily by means of zip fasteners 19, 20 and 21 (FIG. 3) or other quick fastenings, so positioned that it can be laid flat when the fasteners are open; the user can then lie on the costume and put it on unaided.

Suitably positioned lacings 22, 23 allow adjustment for differing body sizes, so as to fit closely without impeding the circulation.

Two openings, posterior 24, and anterior 25, are provided so that the femoral artery will not come under any pressure, which would cause serious problems in the case of prolonged wearing of the costume.

A gusset 26, by a zip fastener 27, gives fullness to the garment at knee level to allow the wearer to sit down when the strengthening sections are deflated.

The tubular sections are visible at 28 and 29 (rear view, FIG. 3) and at 30 and 31 (front view, FIG. 4).

In the preferred form described, these sections follow closely the anterior and posterior axes along the legs and thighs and rise to the level of the dorsal vertebrae, at a variable height according to the case being treated. This arrangement is not limitative; nor is the number of pipes which comprise each section. The anterior sections (FIG. 4) are shown with three pipes in their upper part and two pipes in their lower part. It may be preferable in some cases to prolong the third pipe to the bottom of the section.

The tube of each pipe is closed each end, as is the pipe, and the tubes joined to each other and to the tubes of the other sections of the costume by a flexible tube 32 (FIGS. 3 and 4).

A feeding device (not shown) comprises preferably a micro-valve, a striker and a valve fixed to the tube 32.

A bottle of carbonic gas or a compressor with a pressure-reducer may be joined to the valve to ensure inflation.

When the user has no such source available, he operates the striker which opens a cartridge of carbonic gas (not shown), which may also be joined to the valve. The micro-valve is to allow decompression.

The inflation pressure needed to ensure bodily support for an adult is of the order of 2 bars, or 29.4 pounds per square inch.

The costume thus inflated exerts a light pressure on the members, which suppresses hypotension.

It goes without saying that the number and the size of the tubes, and the different details of the construction described, are not limitative.

It is advisable to note here that, in the costume described and shown, a continuous and substantially uniform support is given along the length of the patient's

body, with the result that his bones are put under pressure and the body support is effected normally by bone pressure.

In particular cases where it would be useful, a ground support could nevertheless be provided.

FIG. 5 shows at 41 the calf of a normal leg, at 42 the knee and at 43 the thigh.

FIG. 6 shows a leg which is very emaciated and deformed in the lower part below the knee 42. A compensating cushion 44 is then provided.

FIG. 7 shows a leg which is very wasted above and below the knee. Two compensating cushions are then provided respectively in the positions 44 and 45.

FIG. 8 is a front view, seen from inside, of a leg section 46 as described above, showing by way of example three vertical contiguous pipes 47. A supporting tab of the same fabric as the orthosis is stitched to the section only on the lateral line 49 to allow it greater freedom of adaptation after the manner of a mobile flap. This flap has one or two "velvet surfaces" 50, stitched and self-adhesive, allowing easy and stable fastening with other "velcro" strips 51 stitched at 52 to the removable cushions represented in FIG. 9.

The cushion represented in section has a core 53 of synthetic or other felt, round which is held a synthetic foam 55 enclosed between two thicknesses 56 and 57 of the same orthosis fabric. The "velcro" strips are stitched with their "hooked" surface outside, as on the supporting flap, so as to allow self-adhesion.

Each of the removable cushions can thus be placed exactly in the right compensating position.

The principal role of the cushions is to allow the section to adapt itself, at the inside, to the shape of the limb to be supported, while displaying on the outside a regular shape and having only slight curvatures. This arrangement is in fact essential to avoid the risk of flexion in the strength of the materials, where incipient flexion of the inflatable pipes would at once entail their total flexion with loss of support of the orthosis.

FIG. 10 is a side view of a leg encased in an appliance. There will be seen at 61 and 62 the lateral edges of the sections joined by laces 63. In front of the leg the section has two inflatable pipes 64, and at the back three pipes 65, of the same structure.

At 66 will be seen a boot with sole 67. A strap 69 is fixed similarly to a cavalry spur to a lower part of the section and is connected to the inflatable pipes.

A belt 70 fixed on each side of the sole near the middle of the foot, passes through a loop 71 and is fastened at 72, and is adjusted to the size of the foot.

It will be seen that such a connection between the boot and the section provides a satisfactory support for the foot which is lifted and held in a normal horizontal position and is held securely in such a way as to oppose all transverse flexion of the ankle.

There will be seen in FIG. 11 three contiguous pipes 81, 82, 83 stitched to the fabric 84 of the structure. Broken lines denote the inflatable inner tubes. These pipes have end walls 85, 86, 87, the end walls 85 and 87 being situated in the same position, while the end wall 86 is offset by a distance of the order of ten centimetres. There will also be seen three other contiguous pipes 88, 89, 90 extending the pipes 81, 82, 83 respectively. The ends of the pipes 81, 82, 83 come respectively into contact with the said end walls 85, 86, 87. There will also be seen at 94 an arrow representing the position of the joint, and particularly the knee joint.

According to the first aspect of the invention described hereinabove, the pipes **81, 82, 83** have their two common walls stitched together, at least on a level with the fabric **84** of the structure and for preference also at a higher level up the wall, see FIG. 1. The same applies to the pipes **88, 89, 90**. In this improvement of FIG. 11, the pipe **89**, throughout its hatched portion overlapping the pipes **88** and **90** and up to a zone **96** near the arrow **94**, is stitched to the fabric **84**, but not laterally to the pipes **81** and **83**, to allow it to be flattened near the arrow **94**.

Two separate supply conduits **101** and **102** for compressed air are provided, one for the pipes **81, 82, 83**, whose inflatable tubes communicate through lateral openings **99**, the other for the pipes **88, 89, 90**, whose tubes communicate through openings **100**. By deflating these latter pipes, it will be seen that the hatched portion of the pipe **89** loses its extreme adherence to the parts of the pipes **81** and **82** which enclose it, and that bending of the orthopaedic device can take place round the axis at the arrow **94**.

In FIG. 12 is seen a variation of construction of the principle that has just been described by way of example. There will be seen on the left the references from **81** to **87**, relating to the first inflatable structure described of three contiguous shaped pipes. There will also be found three contiguous pipes **88, 89, 90** coming into contact at **91, 92, 93** with the elements **81, 82, 83**. However, these pipes **88, 89, 90** are limited and largely symmetrical in relation to the line **94** of the bending of the joint. Pipes **96, 97, 98** are also symmetrical to the pipes **81, 82, 83**.

Each of the three assemblies of three pipes comprises internal openings respectively **99, 100, 105**, and a separate supply conduit, respectively **101, 102, 103**. It is possible for preference to replace the supply conduit **103** by a connection **104** between the pipes **81, 82, 83** and **96, 97, 98**.

It will then be seen that by deflating the intermediate pipes **88, 89, 90** the two main pipe sections **81, 82, 83** and **96, 97, 98** remain rigid, and the device can be bent at right angles to the axis **94** provided opposite the joint. It will be seen that the intermediate pipe section **88, 89, 90** can bend in its central region to an extent equal to that of its pipes **88** and **90**, even having been stitched to the fabric **84**, as well as its pipes with one another.

Bending takes place thanks to the bringing together of the upper and lower parts of the pipes which can flatten after deflation. It will be seen that the deflation of the intermediate pipe produces of its own accord the straightening of the joint and restores rigidity to the whole of the three pipe sections.

The invention also covers structures of more than three pipe sections and it may have different variants as regards the connection of the pneumatic tubes with one another.

There will be seen in FIG. 13 the fabric **141** of the structure, three fabric pipes **142** of square section which are contiguous and are stitched to the fabric **141** and between one another laterally; and tubes **143** of elastomer, which are inflatable by means of valves that are not shown.

There will be seen in FIG. 14 the structure surrounding a leg and lacing **144**, non-extensible or resiliently extensible, by means of which bending will be possible round the knee joint **145**. At **146** is shown a partial sec-

tion of the fabric. At **147** and **148** there are seen, in cross-section, two sections of three contiguous pipes enclosing three tubes of inflatable elastomer, placed in front of the leg. There will be seen at **149** and **150** two similar sections placed on the back of the leg. The section **147**, stops lower than the knee, as an extension of the section **148** when the strap **151** surrounding the leg is tightened on it. The section **150** rises at the back above the knee, but the upper part is not fixed to the structure. It can rest behind the leg, as an extension of the section **149**, when a strap **152** surrounding the leg is clamped against it. When the two straps are tightened, the sections **147** and **148** in front have become contiguous and with the sections **149** and **150** at the rear impart to the orthopaedic device great rigidity so that the leg is fully supported.

When the straps are slackened, it will be seen from FIG. 15 that it becomes possible to bend the leg. The extremity of the section **147** remains lifted above the knee, while the extremity of the section **150** resumes the curvature provided for, and rests resiliently on the extremity of section **149**.

When straightening the leg, it suffices to retighten the two straps to regain the desired rigidity. The straps pass through slides such as **153, 154** and their securing is effected in front by well known means (not shown), such as a buckle or velcro arrangement.

The invention extends to all equivalent variants relating to the position of the straps and the form of attaching and closing them.

In particular, the straps and belts can be replaced by zip fasteners, arranged on either side at the front and back of the section.

I claim:

1. An orthopaedic device comprising, in combination, (i) an inflatable structure having at least two elongated fabric pipes of substantially square cross-section disposed in parallel relationship, each pipe including opposed plane side walls and having a base constituted by a portion of a sheet of air-permeable fabric to which said side walls are secured along their one longitudinal edge, the adjacent respective side walls of each adjacent pair of pipes being secured together substantially along their other longitudinal edge, and an inflatable tube of gas-tight resilient material in each said pipe, and (ii) at least one removable cushion secured on a face of said structure and at right angles thereto for presenting towards an emaciation of the leg.

2. The orthopaedic device of claim 1 comprising a movable flap secured along an inner lateral vertical line of said shaped structure, at least one self adhesive strip on said flap, a corresponding number of other adhesive strips secured to said removable cushion, said flap strips and said cushion strips being adapted to coact with each other for securing said cushion removably in position.

3. The orthopaedic device of claim 2, wherein said removable cushion has a felt core surrounded by synthetic foam enclosed between two layers of fabric forming two sides of the cushion.

4. An orthopaedic device comprising in combination, (i) an inflatable structure having at least two elongated fabric pipes of substantially square cross-section disposed in parallel relationship, each pipe including opposed plane side walls and having a base constituted by a portion of a sheet of air-permeable fabric to which said side walls are secured along their one longitudinal

edge, the adjacent respective side walls of each adjacent pair of pipes being secured together substantially along their other longitudinal edge, and an inflatable tube of gas-tight resilient material in each said pipe, and (ii) a boot, and means for connection between a lower part of said structure and said boot to maintain the sole of said boot in a direction substantially at right angles thereto, whereby when the device is fitted to the leg the boot is maintained substantially at right angles to the tibia and opposes transverse rocking of the ankle.

5. The orthopaedic device of claim 4 further comprising a strap secured on said boot to pass about the ankle, said strap being connected to the lower part of said inflatable structure, and a belt fixed on the sole and passed through loops of said strap, in the centre of the foot, and to fasten above the boot.

6. An inflatable structure having at least two elongated fabric pipes of substantially square cross-section disposed in parallel relationship, each pipe including opposed plane side walls and having a base constituted by a portion of a sheet of air-permeable fabric to which said side walls are secured along their one longitudinal edge, the adjacent respective side walls of each adjacent pair of pipes being secured together substantially along their other longitudinal edge, and an inflatable tube of gas-tight resilient material in each said pipe, the pipes having at least one discontinuity disposed in the vicinity of a zone of articulation of a limb on which the structure is provided, said discontinuity resulting in at least two distinct sub-assemblies of pipes which are each inflatable and deflatable independently of the other, each pipe of one of the sub-assemblies being an extension of an associated pipe of the other sub-assembly, and the portion where two associated pipes are separated being, for each pair of associated pipes, offset longitudinally of the structure with respect to the position of separation of each alternate pair of associated pipes.

7. The structure of claim 6 wherein the section to be secured along a limb has two adjacent discontinuities one at each side of the zone of articulation of the limb, the pipes between the said discontinuities forming an intermediate section whose inflation imparts rigidity to the entire assembly of sections and whose deflation permits the bending of the structure about the articulation of the limb whilst the outermost sections remain inflated.

8. The structure of claim 7 wherein the intermediate section and the outermost sections are each formed by three contiguous pipes, the central pipe of the intermediate section being longer than the two pipes at each side of it.

9. The structure of claim 8, wherein the two outermost sections are coupled pneumatically by an external flexible conduit, only one of said sections being fed with fluid under pressure.

10. An inflatable structure having at least two elongated fabric pipes of substantially square cross-section disposed in parallel relationship, each pipe including opposed plane side walls and having a base constituted by a portion of a sheet of air-permeable fabric to which said side walls are secured along their one longitudinal edge, the adjacent respective side walls of each adjacent pair of pipes being secured together substantially along their other longitudinal edge, and an inflatable tube of gas-tight resilient material in each said pipe, there being provided on the fabric adapted to surround the limb on which the structure is secured, about the zone of articulation of the limb, a first section of said structure for disposing on that side of said zone on which the limb is attached to the body, a second section extending the first section towards the extremity of the limb, inside the zone of articulation a third section disposed on that side of the zone on which the limb is attached to the body, a fourth section disposed as an extension of the third section and positioned towards the extremity of the limb, the first section overlapping the zone of articulation of the limb and the fourth section extending beyond the zone of articulation and not being stitched at its upper part, means being provided to enable the ends of the first and fourth sections to be secured together and released at each side of zone of articulation of the limb.

11. The inflatable structure of claim 10, wherein the securing means are two straps, arranged one at each side of the zone of articulation of the limb, secured on the inner side of the zone of articulation and fastenable outside the zone of articulation.

12. The inflatable structure of claim 11 wherein each of said straps pass through at least one slide and to fasten in front by a buckle.

13. the inflatable structure of claim 11 wherein each of the straps is adapted to fasten by means of a velcro surface.

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