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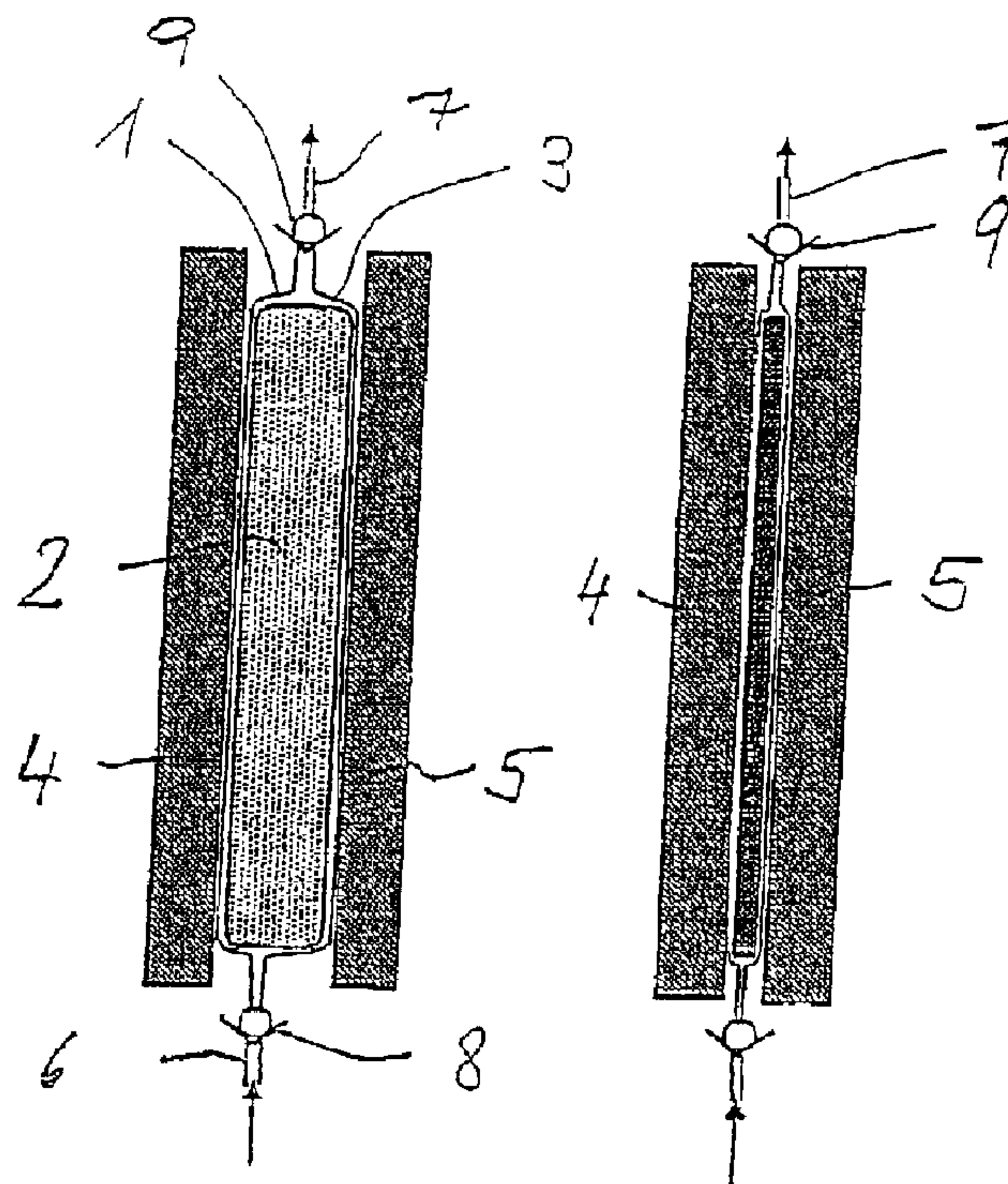
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(54) Title: PUMP COMPRISING A MOVING WALL AND USE OF A PUMP OF THIS TYPE



(57) Abrégé/Abstract:

A vacuum pump comprising a wall configured to form a closed-off fluid volume, the wall being movable by means of a first force for producing a volume reduction of the closed-off fluid volume and, after a preceding volume reduction, the wall being movable by means of a second force for producing a volume increase in the closed-off fluid volume; an inlet port in fluid communication with the closed-off fluid volume, the inlet port having an inlet valve arranged to be connected to a vacuum space; an outlet port in fluid communication with the closed-off fluid volume, the outlet port including an outlet valve arranged to exhaust external to the closed-off fluid volume; and an elastically deformable material compressible by the first force and upon expansion, after termination of the first force, produces the second force, wherein the first force exhausts fluid from the closed-off fluid volume through the outlet port and the second force draws fluid from the vacuum space through the inlet port into the closed-off fluid volume.



ABSTRACT

5 A vacuum pump comprising a wall configured to form a closed-off fluid volume, the wall being movable by means of a first force for producing a volume reduction of the closed-off fluid volume and, after a preceding volume reduction, the wall being movable by means of a second force for producing
10 a volume increase in the closed-off fluid volume; an inlet port in fluid communication with the closed-off fluid volume, the inlet port having an inlet valve arranged to be connected to a vacuum space; an outlet port in fluid communication with the closed-off fluid volume, the outlet
15 port including an outlet valve arranged to exhaust external to the closed-off fluid volume; and an elastically deformable material compressible by the first force and upon expansion, after termination of the first force, produces the second force, wherein the first force exhausts fluid
20 from the closed-off fluid volume through the outlet port and the second force draws fluid from the vacuum space through the inlet port into the closed-off fluid volume.

PUMP COMPRISING A MOVING WALL AND USE OF A PUMP OF THIS TYPE

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TECHNICAL FIELD

The invention relates to a pump comprising a wall which forms a closed-off fluid volume and which can be moved by means of a first external force in the direction of a volume
10 reduction and by means of a second force, after a preceding volume reduction, in the direction of a volume increase, and with an inlet valve which communicates with an inlet port and with an outlet valve in an outlet line in the fluid volume.

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The invention relates, furthermore, to a use of a pump of this type.

BACKGROUND

20 Pumps of this type are known, for example, as hose pumps, in which the fluid is expressed from a fluid-filled hose by means of pressure rollers pressing the hose together and moved in a longitudinal direction of the hose. As a result of the movement of the roller, the upstream end of the hose
25 is filled with fluid again when this end is connected to a fluid supply. The propulsive force for moving the rollers is generated by a motor which may be designed, for example, as an electric or hydraulic motor. Pumps of this type are used for conveying a volume in the pressure direction.

Another kind of pump of the type initially mentioned is diaphragm pumps, in which the fluid volume is reduced by the diaphragm and moved back and forth by means of a connecting rod and is subsequently increased again. The connecting rod
5 thus transmits both the first force for the volume reduction and the second force for the volume increase.

In many instances, it is merely necessary to call up a pumping power only in specific operating states when
10 movements, the force flux of which can be used for actuating a pump, take place in a device. Thus, it is known, for example, to evacuate the interspace between a patient's amputation stump and an airtight liner arranged above it, in order, by means of the vacuum formed, to ensure a firm fit
15 of the liner connected to a prosthesis. For this purpose, a piston pump is used, which, when the patient treads on the ground by means of the prosthesis, exerts an evacuation stroke and is returned by means of a return spring. Pumps of this type are relatively bulky particularly because of the
20 return mechanism required.

SUMMARY

An object on which the described embodiments are based is, therefore, to design a pump of the type initially mentioned
25 such that it can be implemented in a small space.

Certain exemplary embodiments can provide a vacuum pump comprising: a wall configured to form a closed-off fluid volume, the wall being movable by means of a first force for
30 producing a volume reduction of the closed-off fluid volume

and, after a preceding volume reduction, the wall being movable by means of a second force for producing a volume increase in the closed-off fluid volume; an inlet port in fluid communication with the closed-off fluid volume, the inlet port having an inlet valve arranged to be connected to a vacuum space; an outlet port in fluid communication with the closed-off fluid volume, the outlet port including an outlet valve arranged to exhaust external to the closed-off fluid volume; and an elastically deformable material compressible by the first force and upon expansion, after termination of the first force, produces the second force, wherein the first force exhausts fluid from the closed-off fluid volume through the outlet port and the second force draws fluid from the vacuum space through the inlet port into the closed-off fluid volume.

Certain exemplary embodiments can provide a component for attachment to a lower extremity of a prosthetic device, the component comprising: a. a pressure element; b. a vacuum pump having (i) a closed-off fluid volume adjacent the pressure element and (ii) an elastically deformable material forming a wall defining the closed-off fluid volume, wherein the pressure element is movable toward the closed-off fluid volume by application of a first force that causes compression of the elastically deformable material to produce a volume reduction of the closed-off fluid volume and wherein the pressure element is movable away from the closed-off fluid volume by a second force caused by expansion of the elastically deformable material to produce a volume increase in the closed-off fluid volume; c. an outlet port in fluid communication with the fluid volume for

evacuating fluid from the closed-off fluid volume in response to the first force; and d. an inlet port in fluid communication with the fluid volume for drawing fluid into the closed-off fluid volume in response to the second
5 force.

Certain exemplary embodiments can provide a component for attachment to a lower extremity of a prosthetic device, the component comprising: a. pressure element; b. a vacuum pump
10 having (i) a closed-off fluid volume adjacent the pressure element and (ii) an elastically deformable material disposed in the closed-off fluid volume, wherein the pressure element is movable toward the closed-off fluid volume by application of a first force that causes compression of the elastically
15 deformable material to produce a volume reduction of the closed-off fluid volume and wherein the pressure element is movable away from the closed-off fluid volume by a second force caused by expansion of the elastically deformable material to produce a volume increase in the closed-off
20 fluid volume; c. an outlet port in fluid communication with the fluid volume for evacuating fluid from the closed-off fluid volume in response to the first force; and d. an inlet port in fluid communication with the fluid volume for drawing fluid into the closed-off fluid volume in response
25 to the second force.

Other embodiments provide a pump of the type initially mentioned is characterized in that it is designed as a vacuum pump, the volume of which can be reduced by means of the external first force against an elastically deformable
30 material, the return force of which forms, after the

termination of the external force action, the second force acting counter to the generated vacuum.

In the pump according to various described embodiments, the working stroke by which the fluid, in particular air, is sucked away from a closed-off volume, is brought about by the return force of the elastically deformable material. Previous deformation for reducing the volume of the fluid material takes place by means of a first force acting externally. The pump according to the described embodiments thus makes it possible to have a very uncomplicated and small-volume design, by means of which a low to medium vacuum can be generated.

15 In a first embodiment, the wall has two rigid walls lying opposite one another, the elastically deformable material being arranged in the interspace formed by the walls. In this case, the elastically deformable material may be formed by a sealing insert running around the edge and delimiting the fluid volume. This embodiment affords the advantage that the external force can act directly on one of the rigid walls.

25 In another embodiment likewise having advantages, the wall is designed flexibly, the elastically deformable material bearing, preferably over a large area, against the flexible wall. In this case, a high return force sufficient for many applications can be generated by means of a relatively thin material layer.

The elastic material may be an open-pored foam which is arranged within the fluid volume and which exerts the return force after a volume reduction has been carried out. The fluid, which is preferably air, accordingly flows through
5 the foam. In this embodiment, the generation of the return force does not take up any additional space at all, since the fluid volume itself is utilized for this purpose. In this case, it is expedient if the foam completely fills the fluid volume, with the exception of residual volumes as a
10 consequence of construction. An alternative elastic material which is capable of throughflow and which can be used is a wide-mesh knitted fabric.

The pump according to the described embodiments is
15 implemented in a simple way if the elastic material is surrounded on all sides by the flexible wall. It is also possible, however, for the wall to be partially of rigid design and for a part of the wall such as is required for the volume reduction to be made flexible.

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The pump according to the invention can preferably be produced with a preferred large-area extent and with a thickness which is small, as compared with this, and can therefore in many instances be integrated into the structure
25 of a device without difficulty.

To press together the fluid volume, at least one pressure element bearing against the flexible wall over a large area is provided. In particular, the fluid volume with a flexible
30 wall may be arranged between two large-area pressure elements.

The valves may be arranged on the corresponding narrow sides of the flexible wall, but are preferably also arranged in recesses of one of the pressure elements or of both pressure
5 elements, with the result that flexing actions of the flexible wall are reduced.

The pump according to the invention can advantageously be integrated in the force flux of a system in which forces
10 arise which are utilized to exert one of the two forces. The pump according to the invention is suitable particularly as a vacuum pump.

In a special application, the pump constitutes part of a
15 prosthesis for a lower extremity. Preferably, in this case, the force occurring due to body weight when a patient treads on the ground is utilized as the first force. The pump may be employed, in particular, for the vacuum assistance of a suction well of the prosthesis, in particular for evacuating
20 the interspace between a liner and the prosthesis shank. A preferred place of use for the pump according to the invention is an artificial foot which makes it possible particularly effectively to have the large-area design of the pump perpendicularly to the force flux occurring during
25 load caused by the body weight.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be explained in more detail below by means of exemplary embodiments illustrated in the drawing in
30 which;

Figure 1 shows a diagrammatic illustration of a pump in the initial state according to a first embodiment;

5 Figure 2 shows the pump according to Figure 1 in the compressed state;

Figure 3 shows a pump in an initial state according to a second embodiment;

10 Figure 4 shows a pump in a third embodiment which is integrated into an artificial foot;

15 Figure 5 shows an arrangement of an elastically deformable material consisting of two layers with profilings which point toward one another and in the nonloaded state form a fluid space;

20 Figure 6 shows the arrangement according to Figure 5 in a loaded state in which the compressed material of the layer completely fills the fluid space;

25 Figure 7 shows an embodiment of a pump according to the invention with two rigid plates lying opposite one another and with an insert running around at the edge and consisting, of an elastically deformable material, in the nonloaded state;

Figure 8 shows the arrangement according to Figure 7 in the loaded state.

DETAILED DESCRIPTION

The pump illustrated in Figure 1 has a closed fluid volume 1 which is filled virtually completely with an elastic material in the form of an open-pored elastic foam 2. The foam 2 has a substantially large-area extent with a small width. It is surrounded on all sides by a flexible wall 3 which thus has four narrow sides and two large-area sides with large dimensioning, as compared with these. Two large-area pressure elements 4, 5 bear against the large-area sides.

The flexible wall 3 has on opposite narrow sides a tubular or hose-shaped feed 6 and a tubular or hose-shaped outlet 7. Both the feed 6 and the outlet 7 are provided in each case with a nonreturn valve 8, 9.

For the pumping operation, the pressure elements 4, 5 are moved relatively toward one another, as illustrated in Figure 2. The fluid volume 1 together with the foam 2 contained in it is thereby pressed together, with the result that fluid, preferably air, escapes via the nonreturn valve 9 and the outlet 7. When the pressure force of the pressure elements 4, 5 ceases, the elastic return force of the foam 2 ensures that the fluid volume 1 returns to the initial state of Figure 1, fluid being sucked into the fluid volume 1 via the inlet 6 and the nonreturn valve 8.

In the modification of the pump, as illustrated in Figure 3, the pressure plate 5' is provided with recesses 10 in which the nonreturn valves 8, 9 are arranged. The flexing actions of the flexible wall 3 in the region of the nonreturn valves 8, 9 are thereby markedly reduced.

Figure 4 shows an example of the use of a pump of the type described in Figures 1 to 3. The pump is in this case integrated into an artificial foot 11, the functional set-up of which is connected to a lower-leg tube 12 of a lower-leg prosthesis. The functional part of the artificial foot consists of an S-shaped spring insert 13, the free ends of which form an upper junction limb 14 and a lower sole limb 15. Between these is located an essentially horizontal intermediate piece 16 which is connected to the junction limb 14 and to the sole limb 15 in each case by means of a curved transition piece 17, 18 such that the essentially horizontal intermediate piece 16 can spring in relation to the sole limb 15 of the insert 13 under the action of a weight. Under the action of the weight of the prosthesis wearer when the latter puts his foot onto the ground, therefore, the distance between the intermediate piece 16 and the sole limb 15 is reduced. This distance reduction is utilized for the pump employed according to the invention, in that the intermediate piece 16 is connected to a pressure element 5''. The pressure element 5'', of large area per se, is adapted in its form to the form of the intermediate piece 16 and of the curved transition 17, in order to make it easier to position the pressure element 5''. The fluid volume 1 filled by the foam 2 is located, within the

flexible wall 3 surrounding the foam 2 on all sides, between the pressure element 5'' and the sole limb 15 functioning here as a counterpressure element 4. One of the connections 6, 7 is indicated merely diagrammatically, said connection extending through a recess 10 of the pressure element 5'' and being connectable, for example as an inlet 6, via a hose line to the interspace between an amputation stump and a liner surrounding the amputation stump, in order to evacuate this interspace.

10

The functioning of the pump inserted into the foot 11 corresponds fully to the functioning explained with reference to Figures 1 to 3. The load on the artificial foot 11 due to the body weight acts as a pressure force for the pressure element 5'', with the result that the intermediate piece 16 is pressed downward in the direction of the sole limb 15 and thus presses together the fluid volume 1 and the foam 2. Air thereby escapes from the fluid volume 1. When the artificial foot 11 is relieved, at the latest when the foot 11 is lifted off from the ground for the next step, the foam 2 causes the pump to return to the initial position illustrated in Figure 4. In this case, air is sucked via the inlet 6 into the fluid volume 1 out of the interspace between the amputation stump and the surrounding liner, that is to say a desired vacuum which stabilizes the fit of the liner on the amputation stump is generated in the interspace.

It can be seen that an artificial foot 11 is suitable for integrating the pump according to Figure 4, because it is easily possible to have a large-area design of the fluid

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volume 1 and of the foam 2 perpendicularly to the (vertical) force flux because the anatomy of the foot 11 likewise tends to extend over a large area. It is nevertheless also possible, of course, to arrange a corresponding pump in
5 other prosthesis parts which execute a relative movement with respect to one another, for example in a knee joint.

Figures 5 and 6 show an exemplary embodiment in which the elastically deformable material is formed by two layers 21,
10 22 which point toward one another in each case with a profiled surface 23, 24. The profiled surfaces are in this case formed by projections 25, the width of which is smaller than a recess 26 between the projections 25. The tips 25 of the layer 21 accordingly project into the recesses 26 of the
15 layer 22, and vice versa, thus giving rise to the spaces which form the fluid space 1 and which are not filled by the elastically deformable material.

If, then, a pressure causing compression is exerted onto
20 layers 21, 22 the tips 25 are compressed in the height direction and the material is deflected into width, so that the spaces between the tips 25 and the recesses 26 are filled, ideally completely, as illustrated in Figure 6. When the external force pressing the layers 21, 22 against one
25 another ceases, the initial situation of the layers 21, 22, as is illustrated in Figure 5, is established. The return causes fluid, in particular air, to be sucked in from a vacuum space connected to the fluid space 1.

The layers 21, 22 may be formed from a plastic having stability such that the layers 21, 22 at the same time form the wall 3. Alternatively, however, the layers 21, 22 may also cooperate with pressure plates 4, 5, such as are
5 illustrated in the embodiments according to Figures 1 to 3.

In the exemplary embodiment illustrated in Figures 7 and 8, the fluid space is delimited by two rigid walls 31, 32 parallel to one another and by an insert 33 which runs
10 around and connects the edges of the rigid walls 31, 32 sealingly to one another and which consists of an elastically deformable material. The insert 33 is in this case a channel-like profile consisting of a stable fluidtight material which is connected, fluidtight, to the
15 walls 31, 32 by adhesive bonding or the like.

By means of an external first force F , the rigid walls 31, 32 are pressed against one another, as indicated in Figure 8. The fluid space 1 is thereby reduced to a
20 maximum, with the result that the fluid contained in the fluid space 1 escapes through the outlet 7. When the external force F ceases, the state illustrated in Figure 7 is reestablished due to the return force of the insert 33, with the result that fluid is sucked into the fluid space 1
25 via the feed 6.

It can be seen that the exemplary embodiments illustrated in Figures 5 to 8 can be employed in the same way as the exemplary embodiments according to Figures 1 to 3, that is
30 to say, in particular, also in an artificial foot or the like.

The pumps according to the invention may be used, in particular, in prosthesis parts also for other purposes, for example as a hydraulic pump for the control of dynamic
5 functions, for example for the control of hydraulic damping cylinders or for the movement of structural elements of the prosthesis, for example from an uncoupled to a coupled state, in order to carry out dynamic adaption to the situation of use.

CLAIMS:

1. A vacuum pump comprising:

5 a wall configured to form a closed-off fluid volume,
the wall being movable by means of a first force for
producing a volume reduction of the closed-off fluid volume
and, after a preceding volume reduction, the wall being
movable by means of a second force for producing a volume
10 increase in the closed-off fluid volume;
an inlet port in fluid communication with the closed-off
fluid volume, the inlet port having an inlet valve arranged
to be connected to a vacuum space;
an outlet port in fluid communication with the closed-
15 off fluid volume, the outlet port including an outlet valve
arranged to exhaust external to the closed-off fluid volume;
and
an elastically deformable material compressible by the
first force and upon expansion, after termination of the
20 first force, produces the second force, wherein the first
force exhausts fluid from the closed-off fluid volume
through the outlet port and the second force draws fluid
from the vacuum space through the inlet port into the
closed-off fluid volume.

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2. The vacuum pump of claim 1, wherein the wall includes
two opposing rigid walls defining a region for receiving the
elastically deformable material.

3. The vacuum pump of claim 2, wherein the elastically deformable material is formed by a sealing insert arranged to delimit the closed-off fluid volume.

5 4. The vacuum pump of claim 1, wherein the wall is flexible and the elastically deformable material is bearable against the flexible wall.

10 5. The vacuum pump of claim 4, wherein the elastically deformable material includes a material that is capable of throughflow and is arranged within the closed-off fluid volume.

15 6. The vacuum pump of claim 5, wherein the material is an open-pored foam.

7. The vacuum pump of claim 6, wherein the material fills the closed-off fluid volume.

20 8. The vacuum pump of claim 7, wherein the material is surrounded by the flexible wall.

25 9. The vacuum pump according to any one of claims 4 to 8, wherein the material is designed with a large-area extent and with a thickness that is small relative to the large-area extent.

30 10. The vacuum pump according to any one of claims 1 to 9, wherein the elastically deformable material includes two layers bearing against one another and having profiles

pointing toward one another and forming interspaces that are reducible by means of application of the first force.

11. The vacuum pump of claim 10, wherein the interspaces
5 between the two layers can be eliminated by means application of the first force.

12. The vacuum pump of any one of claims 4 to 11, further comprising at least one pressure element bearing against the
10 flexible wall over a large area.

13. The vacuum pump of any one of claims 1 to 12, wherein the inlet valve and the outlet valve are located on narrow sides of the wall.

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14. The vacuum pump of claim 13, wherein the inlet valve and the outlet valve are arranged on narrow sides of the wall lying opposite to one another.

20 15. The vacuum pump of claim 12, wherein the inlet valve and the outlet valve are arranged in recesses in at least one pressure element.

25 16. The vacuum pump of claim 12, wherein the inlet valve and the outlet valve are arranged in recesses in more than one of the pressure elements.

17. Use of a vacuum pump according to any one of claims 1 to 16 as part of a prosthesis for a lower extremity.

18. Use of a vacuum pump according to claim 17, wherein the first force is a force generated due to body weight of a patient exerted on a ground surface.

5 19. Use of a vacuum pump according to claim 17 or 18, wherein the prosthesis includes a prosthetic socket into which a residual limb is received and the vacuum pump applies a vacuum to a space between the prosthetic socket and the residual limb.

10 20. A component for attachment to a lower extremity of a prosthetic device, the component comprising:

a. a pressure element;

b. a vacuum pump having (i) a closed-off fluid volume

15 adjacent the pressure element and (ii) an elastically deformable material forming a wall defining the closed-off fluid volume, wherein the pressure element is movable toward the closed-off fluid volume by application of a first force that causes compression of the elastically deformable material to produce a volume reduction of the closed-off fluid volume and wherein the pressure element is movable away from the closed-off fluid volume by a second force caused by expansion of the elastically deformable material to produce a volume increase in the closed-off fluid volume;

20 c. an outlet port in fluid communication with the fluid volume for evacuating fluid from the closed-off fluid volume in response to the first force;

25 and

30

d. an inlet port in fluid communication with the fluid volume for drawing fluid into the closed-off fluid volume in response to the second force.

5 21. A component for attachment to a lower extremity of a prosthetic device, the component comprising:

a. pressure element;

10 b. a vacuum pump having (i) a closed-off fluid volume adjacent the pressure element and (ii) an elastically deformable material disposed in the closed-off fluid volume, wherein the pressure element is movable toward the closed-off fluid volume by application of a first force that causes compression of the elastically deformable material to produce a volume reduction of the closed-off
15 fluid volume and wherein the pressure element is movable away from the closed-off fluid volume by a second force caused by expansion of the elastically deformable material to produce a
20 volume increase in the closed-off fluid volume;

c. an outlet port in fluid communication with the fluid volume for evacuating fluid from the closed-off fluid volume in response to the first force;
and

25 d. an inlet port in fluid communication with the fluid volume for drawing fluid into the closed-off fluid volume in response to the second force.

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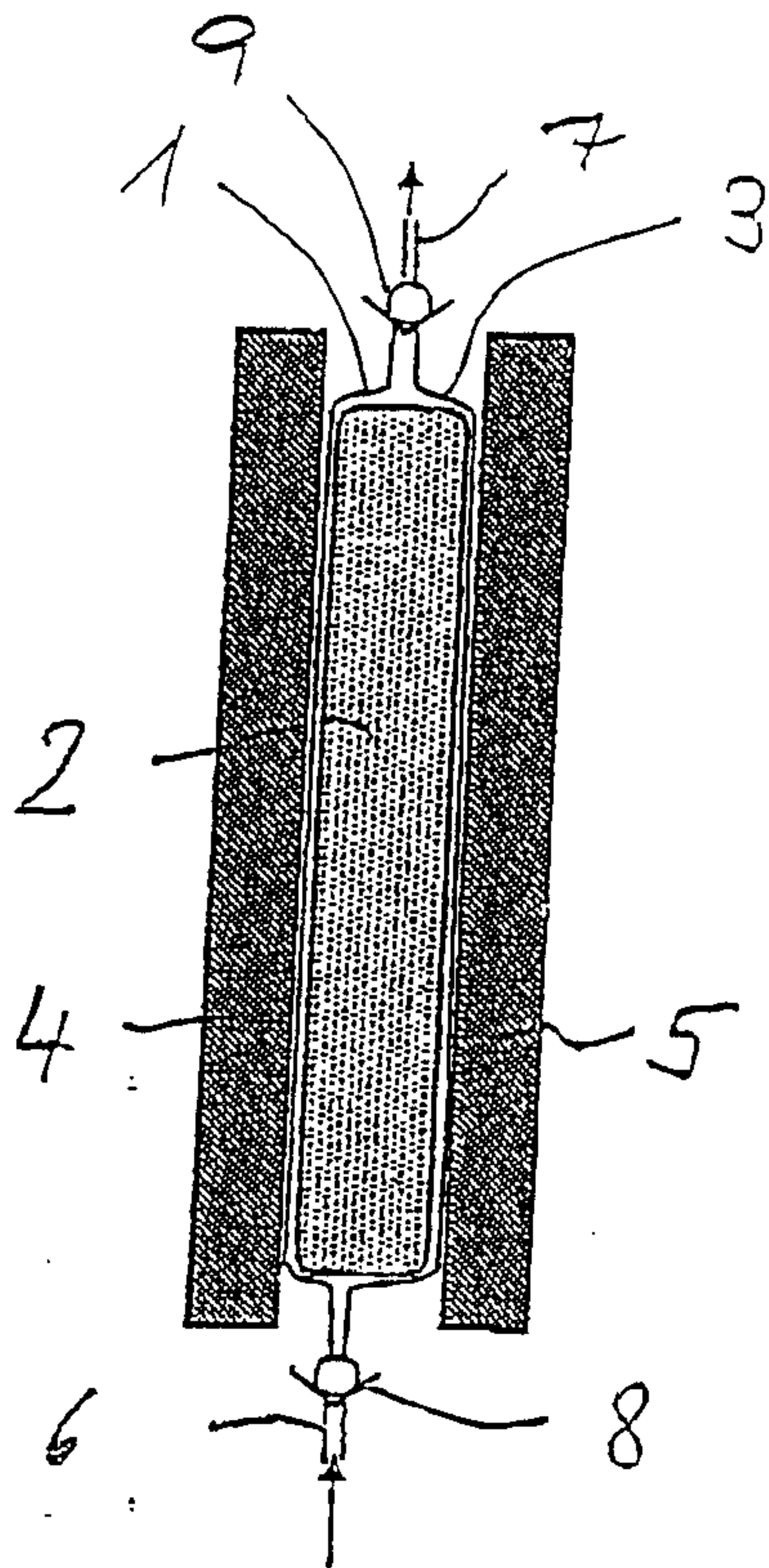


Fig. 1

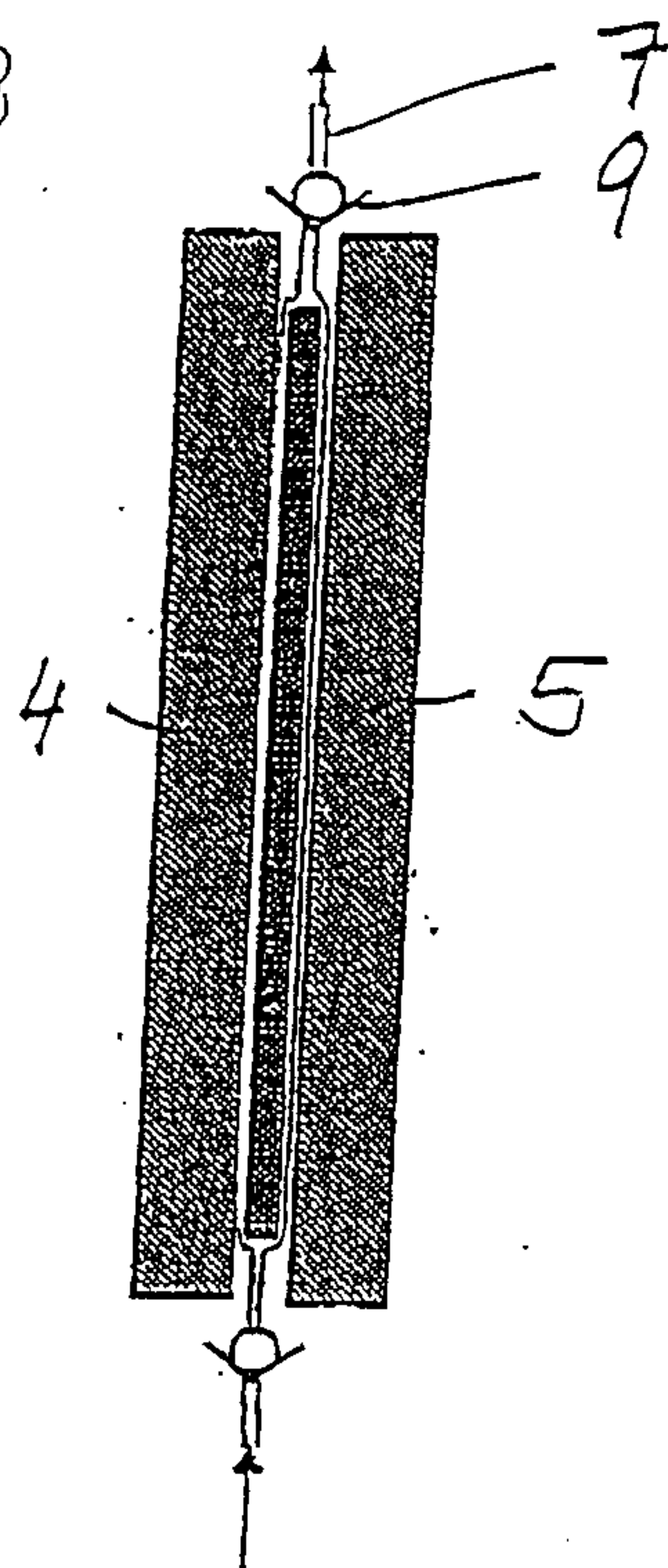


Fig. 2

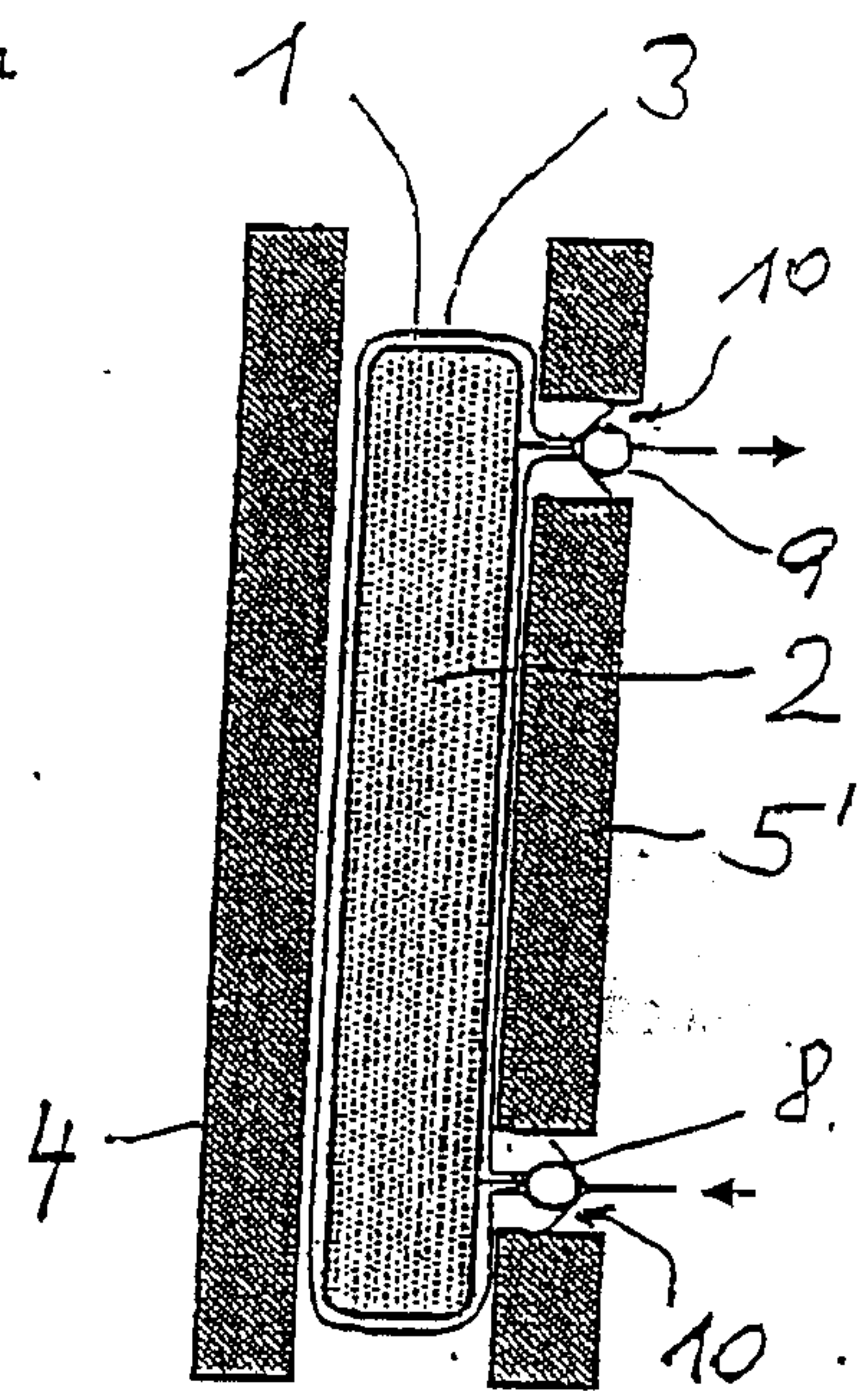


Fig. 3

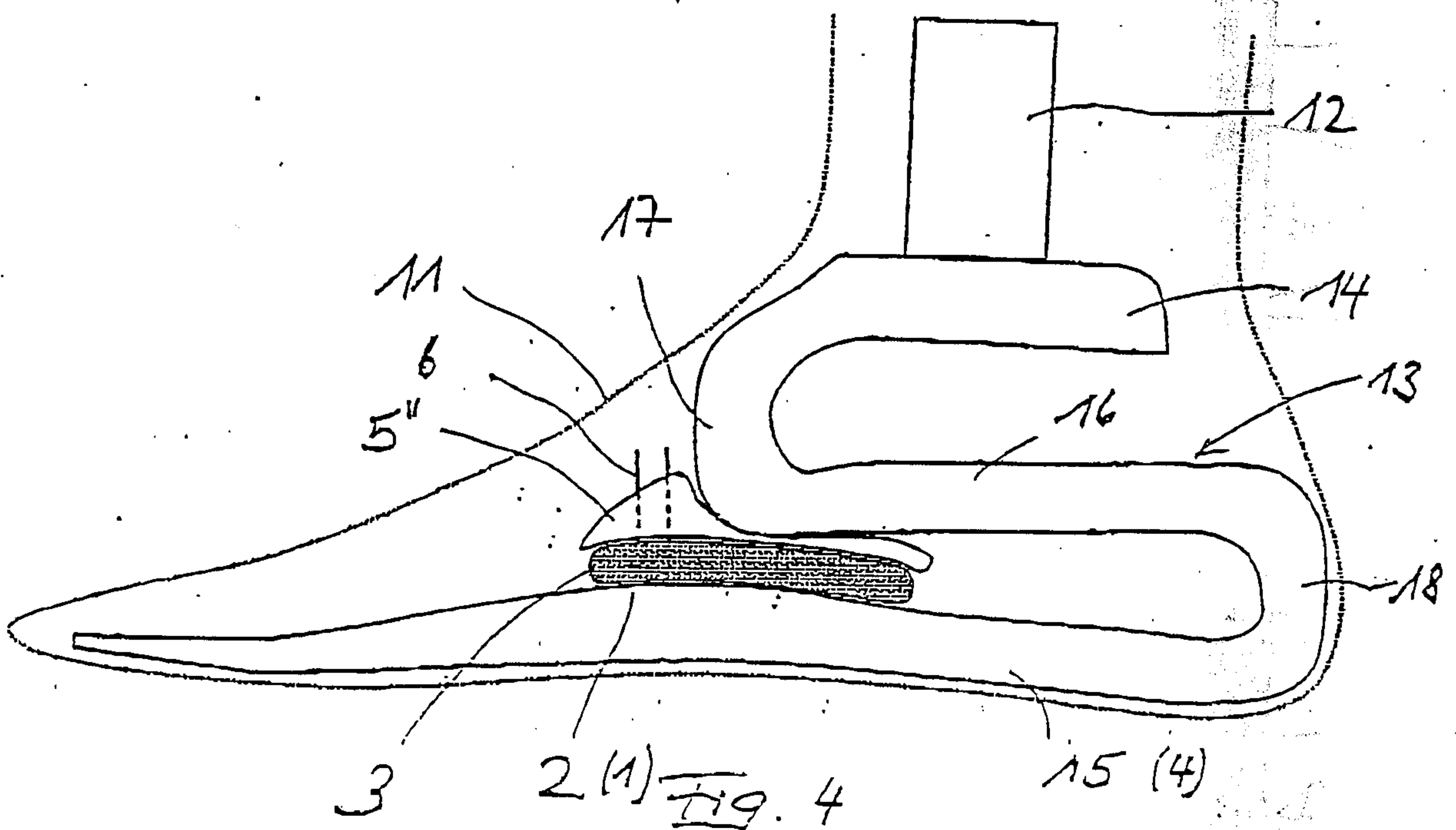


Fig. 4

