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MESSIOU(10) **Pub. No.: US 2010/0218301 A1**(43) **Pub. Date: Sep. 2, 2010**(54) **GARMENT VENTILATION STRUCTURE**

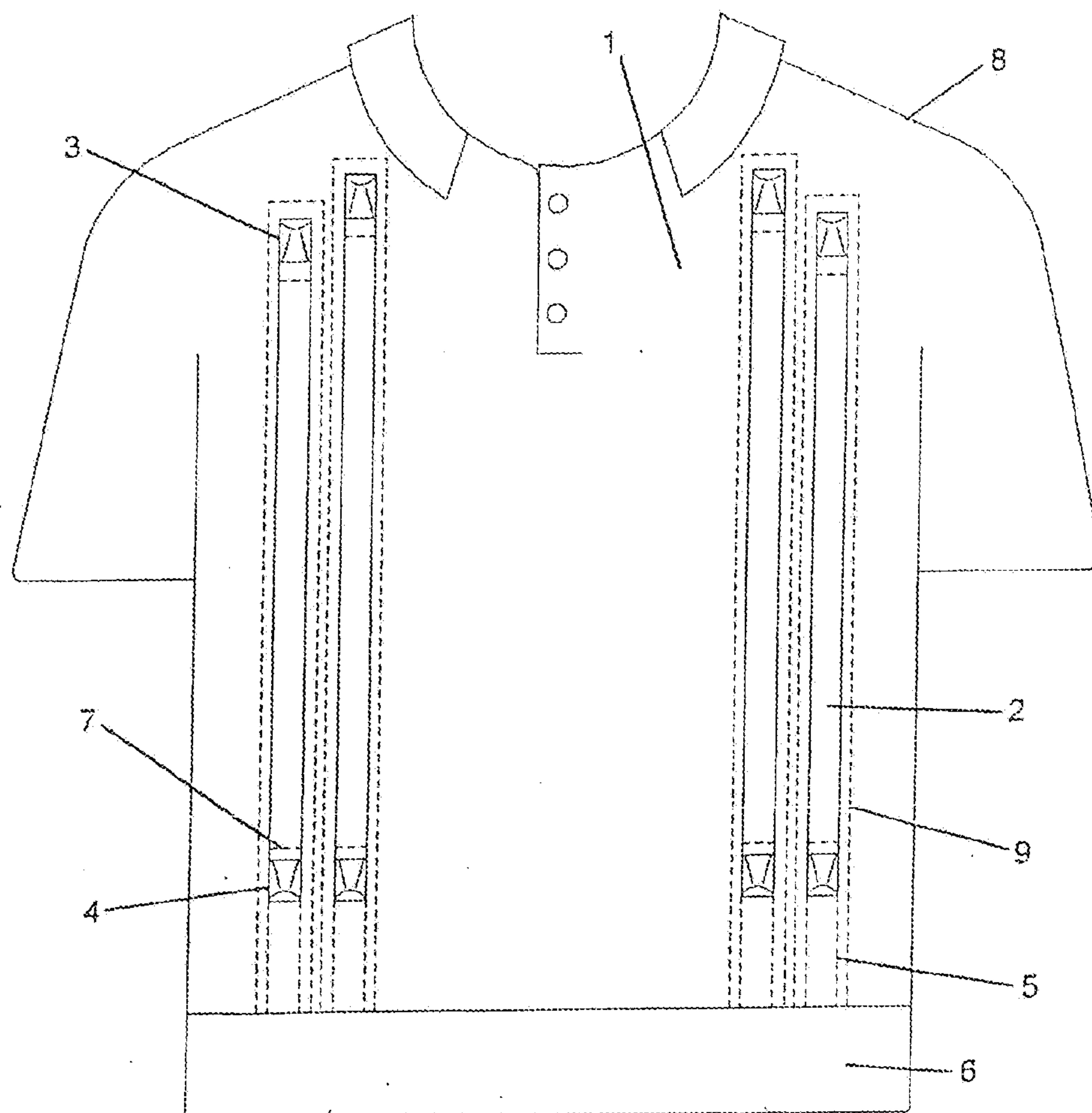
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(57) **ABSTRACT**

A garment such as a sports shirt has concealed ventilation channels, which provide a continuous air channel between permanent openings. In one embodiment, the channels are flexible and non-intrusive and the openings are maintained by springy eyelets. The eyelets and channels are attached to the main fabric of the garment, providing a robust and a streamlined construction. Another embodiment incorporates active ventilation structures within the channels, the structures having a natural vibration frequency matched to a motion frequency spectrum of the wearer. In a further embodiment, the ventilation channels are made of shape memory polymer and change shape in response to changes in temperature.



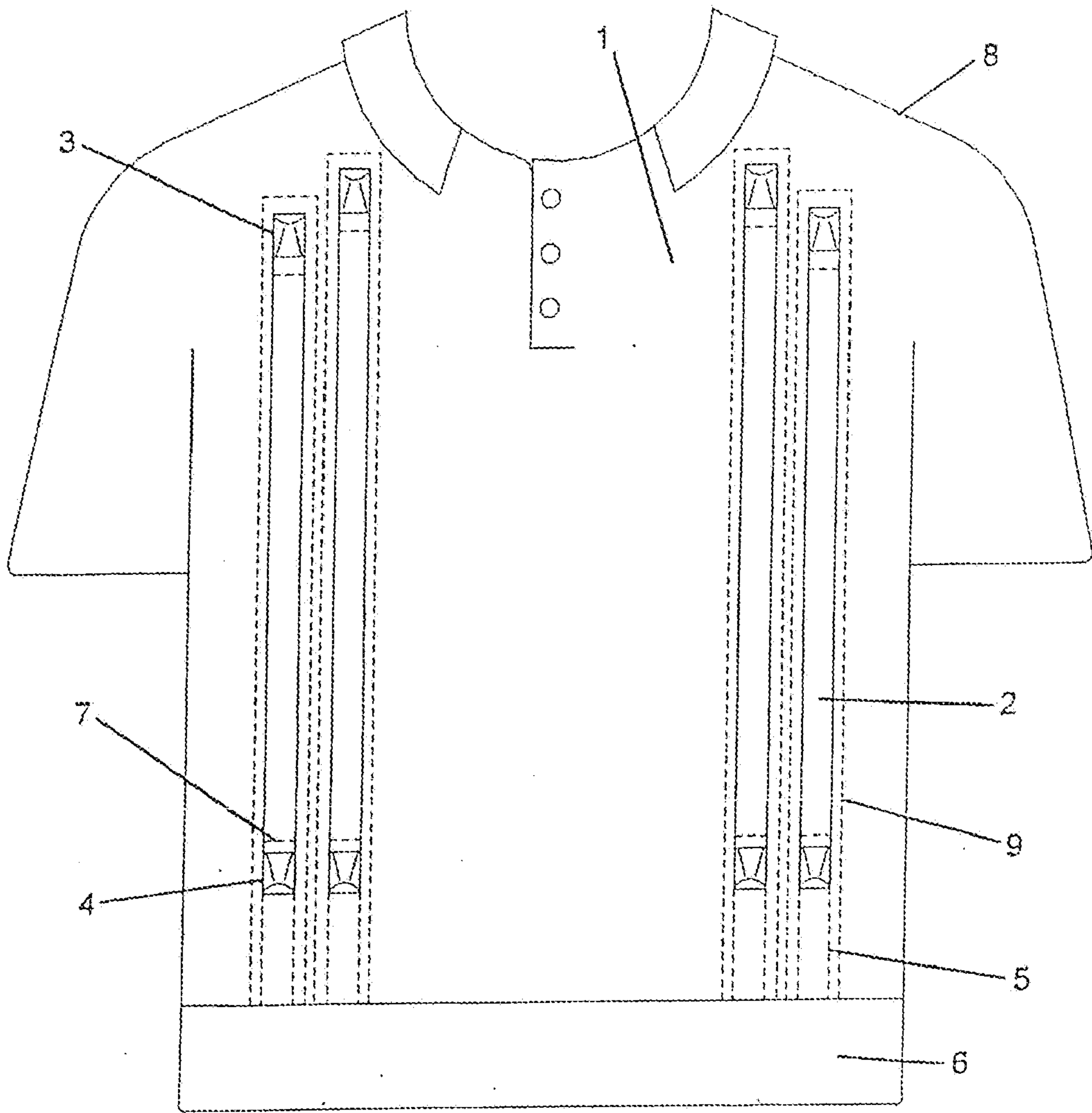


Figure 1

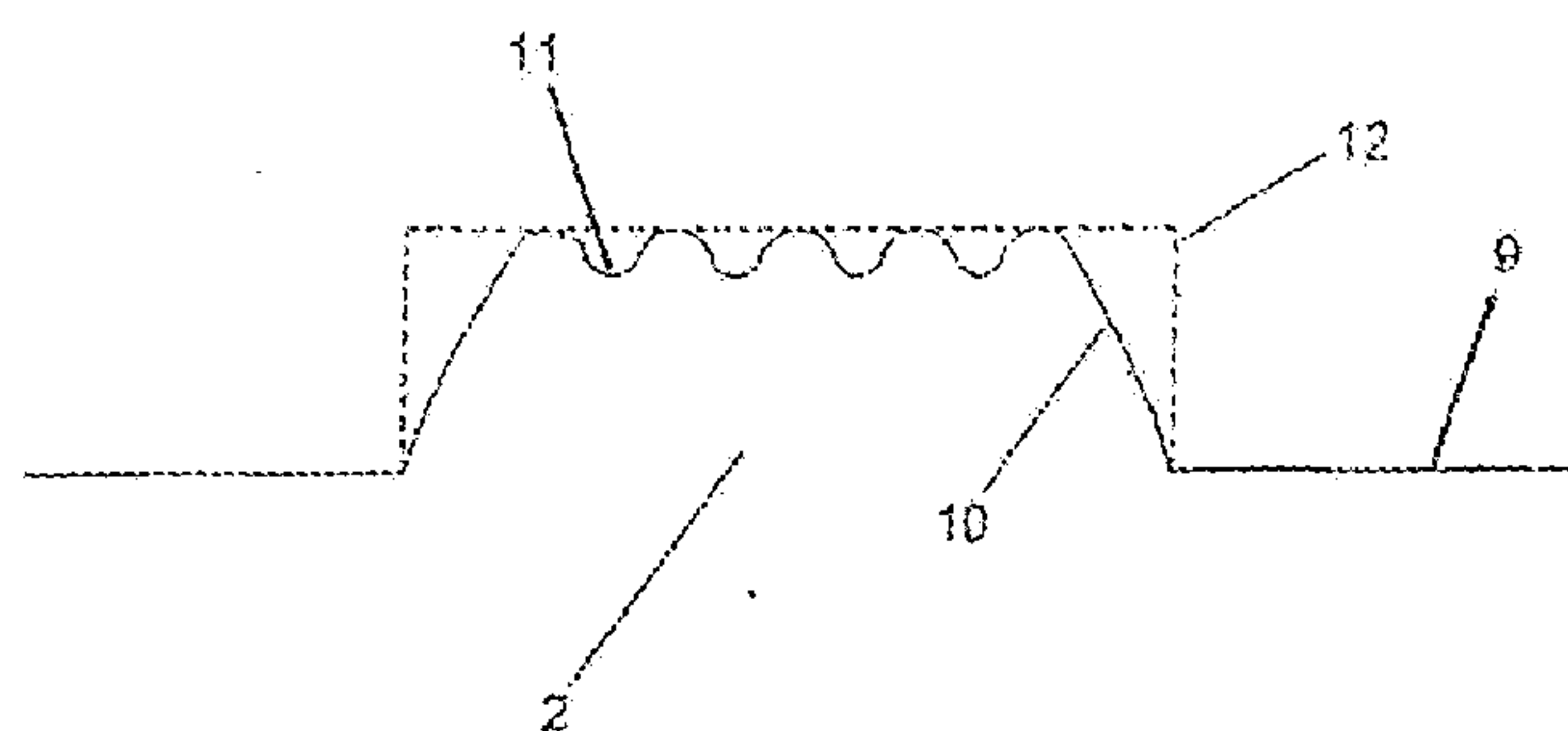


FIGURE 2

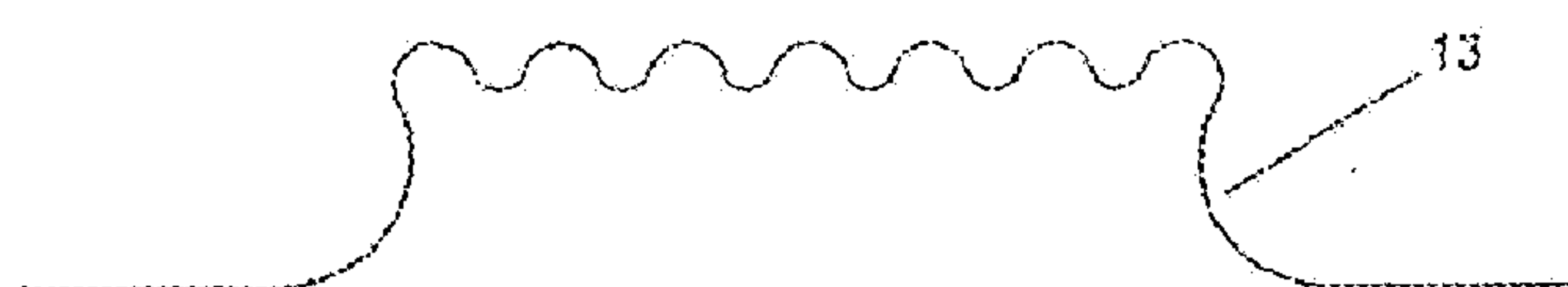


FIGURE 3

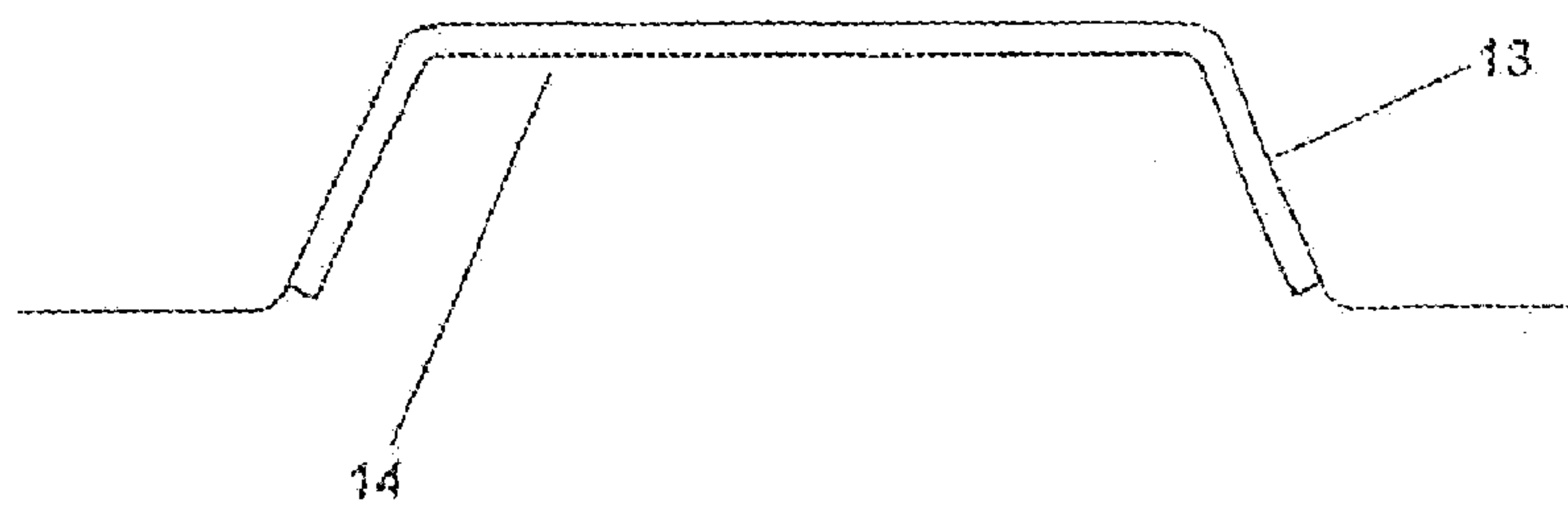


FIGURE 4

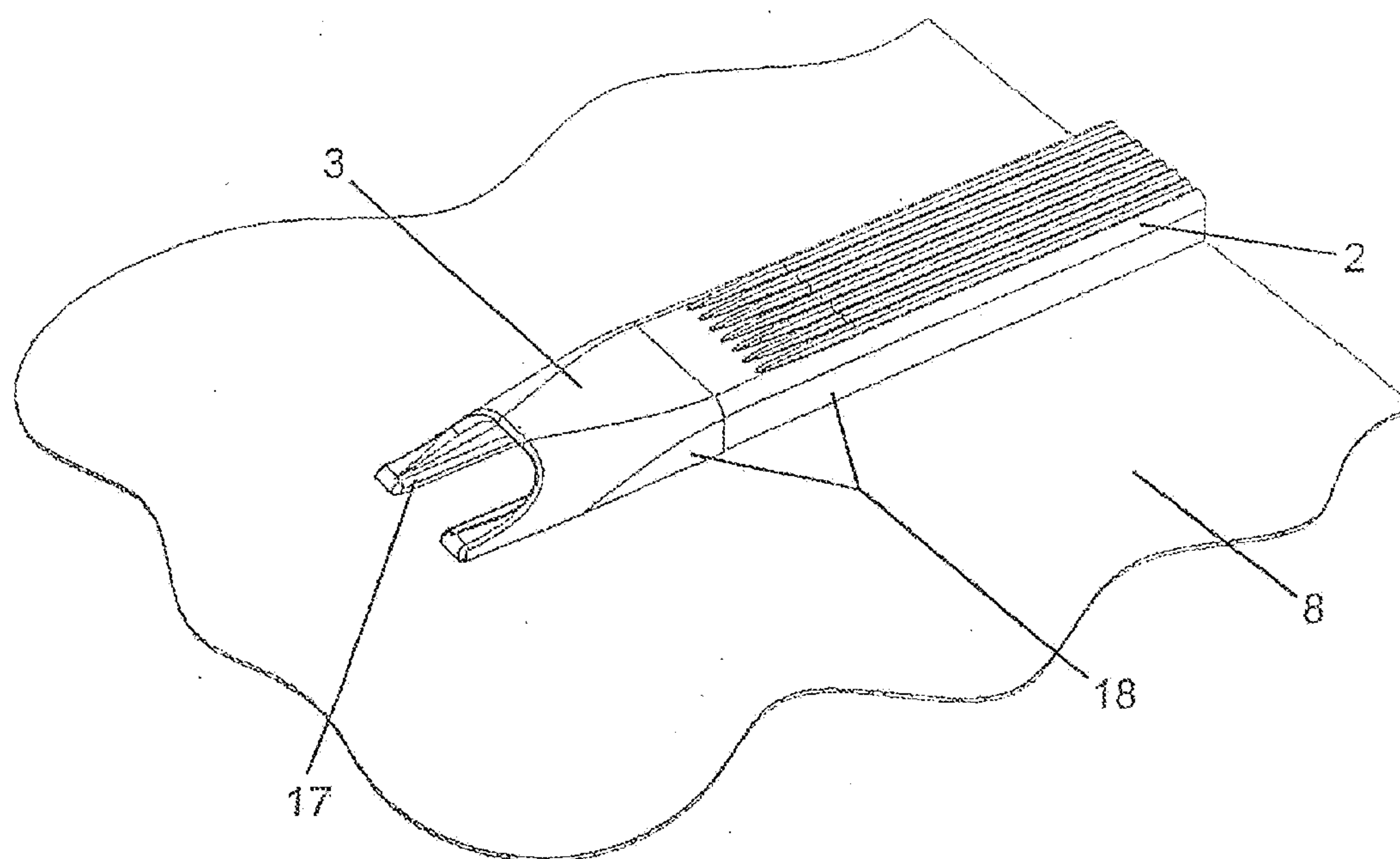


FIGURE 5

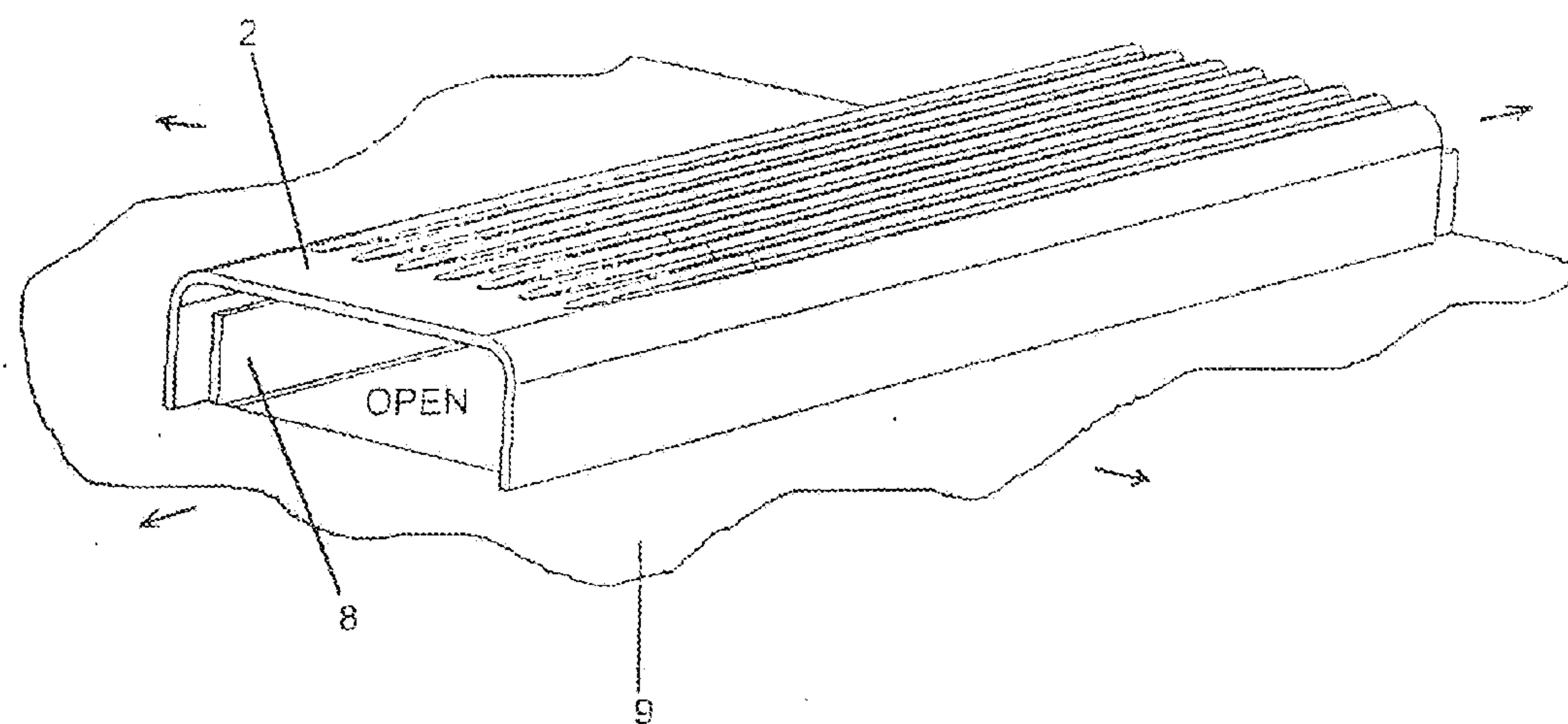


FIGURE 5 a)

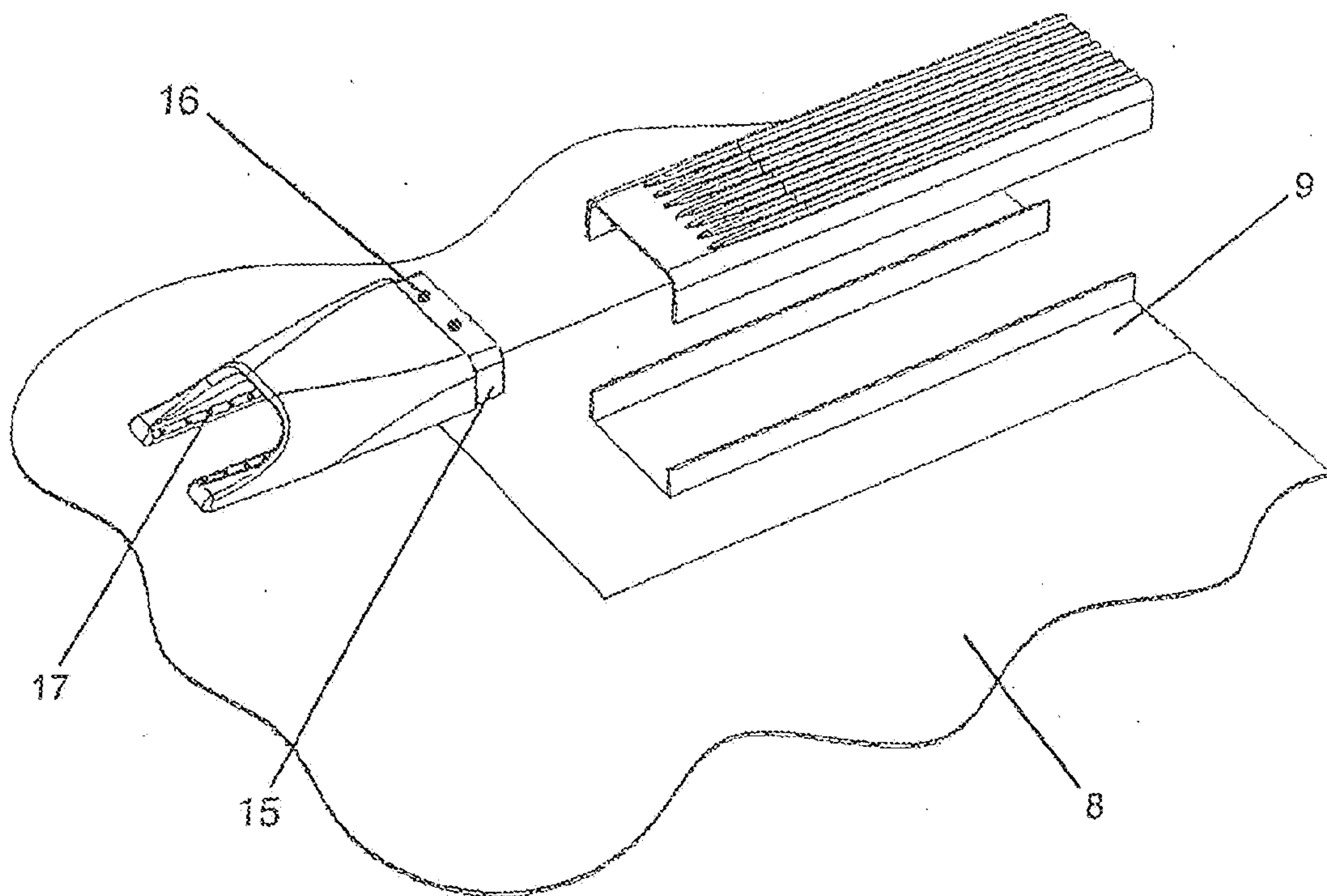


FIGURE 5 b)

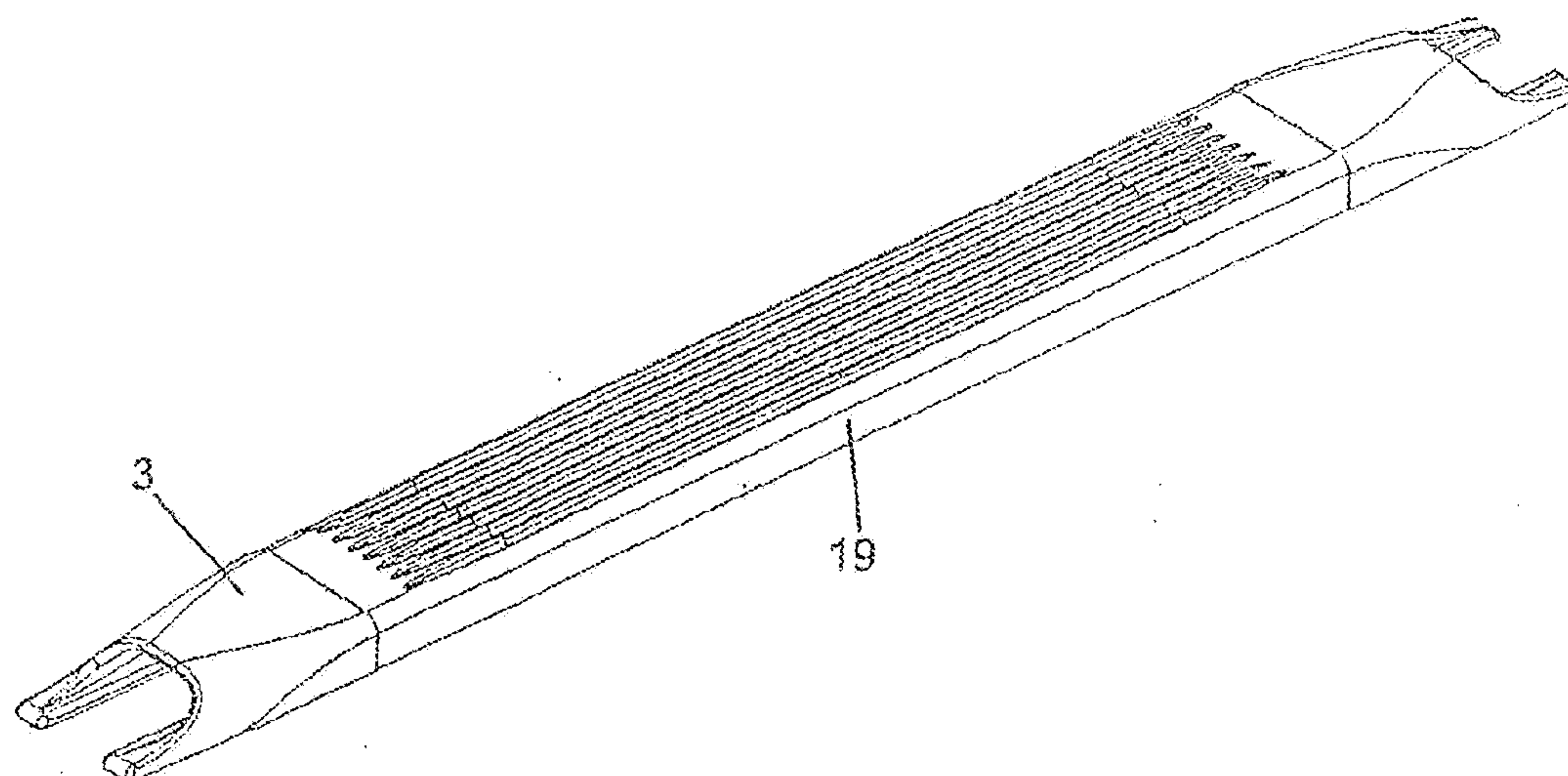


FIGURE 6

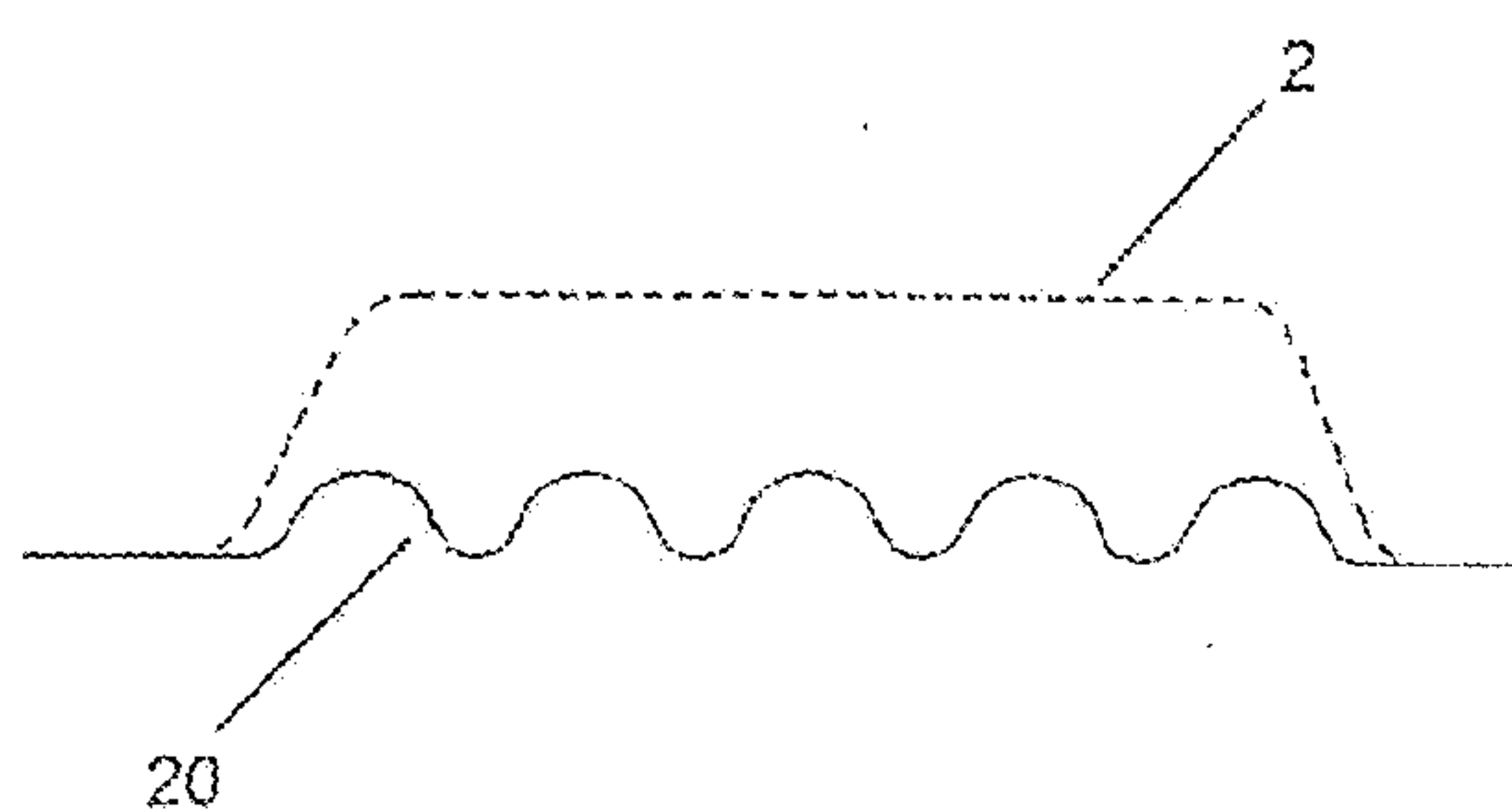


FIGURE 7

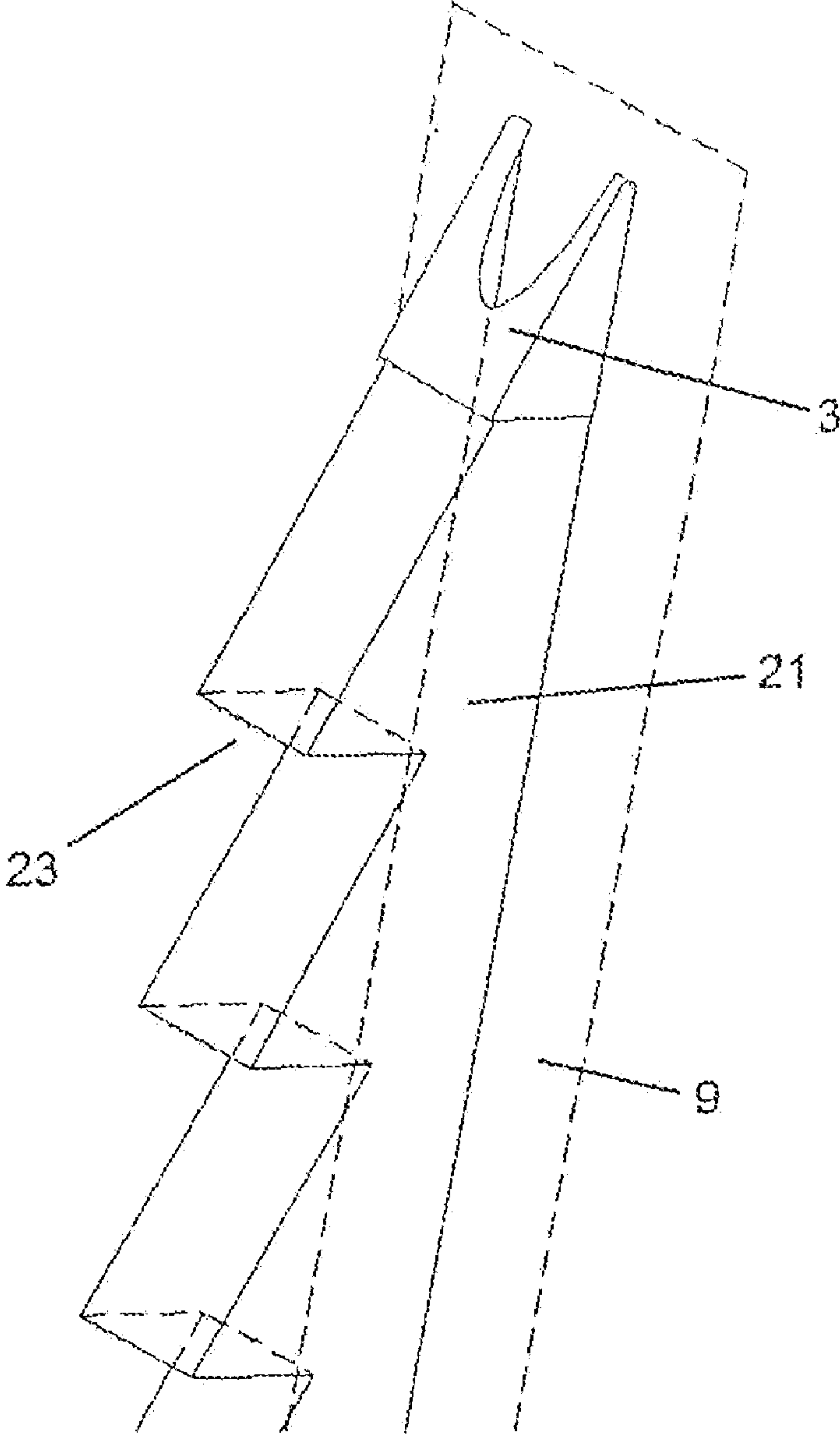


FIGURE 8

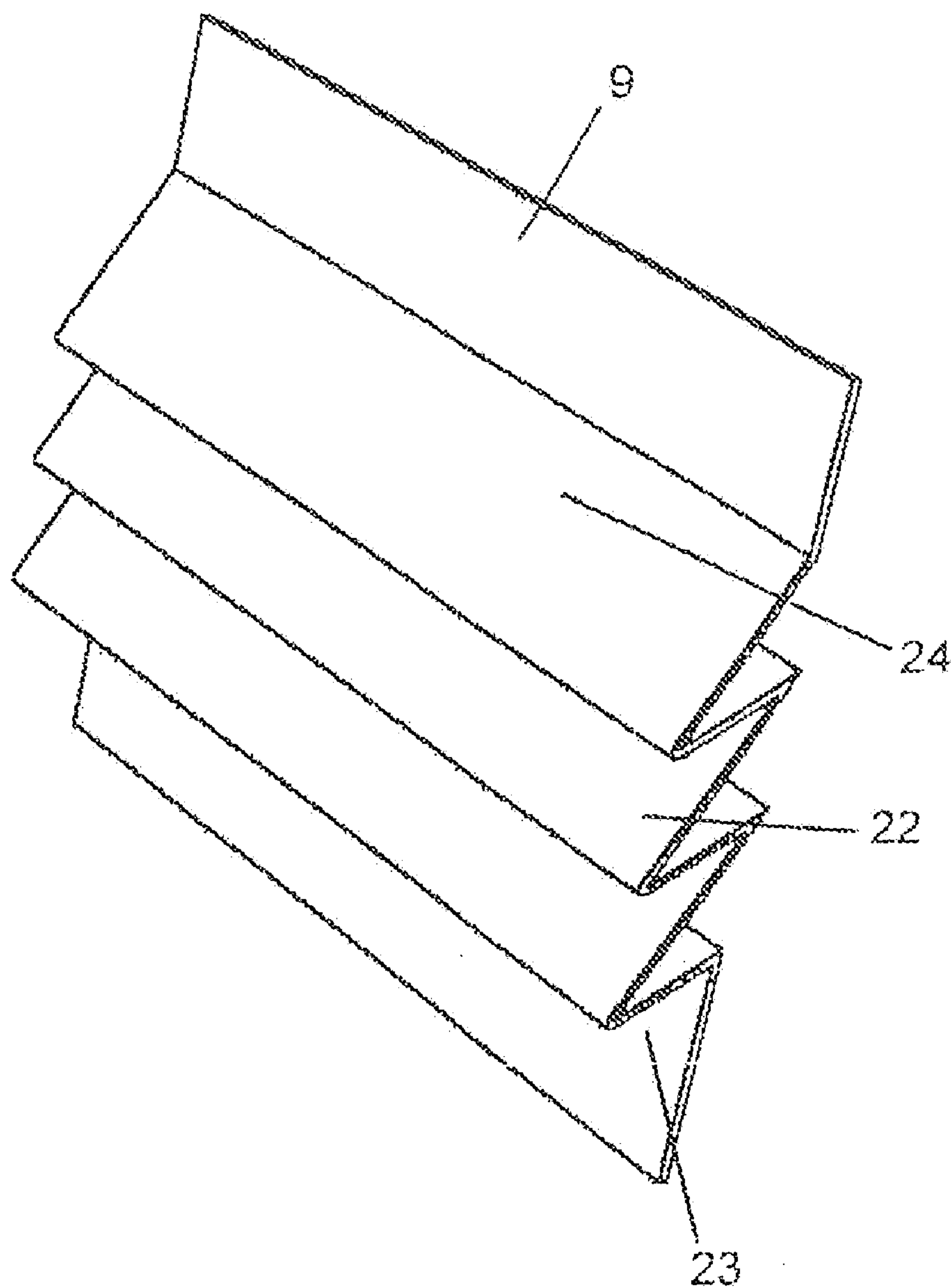


FIGURE 9

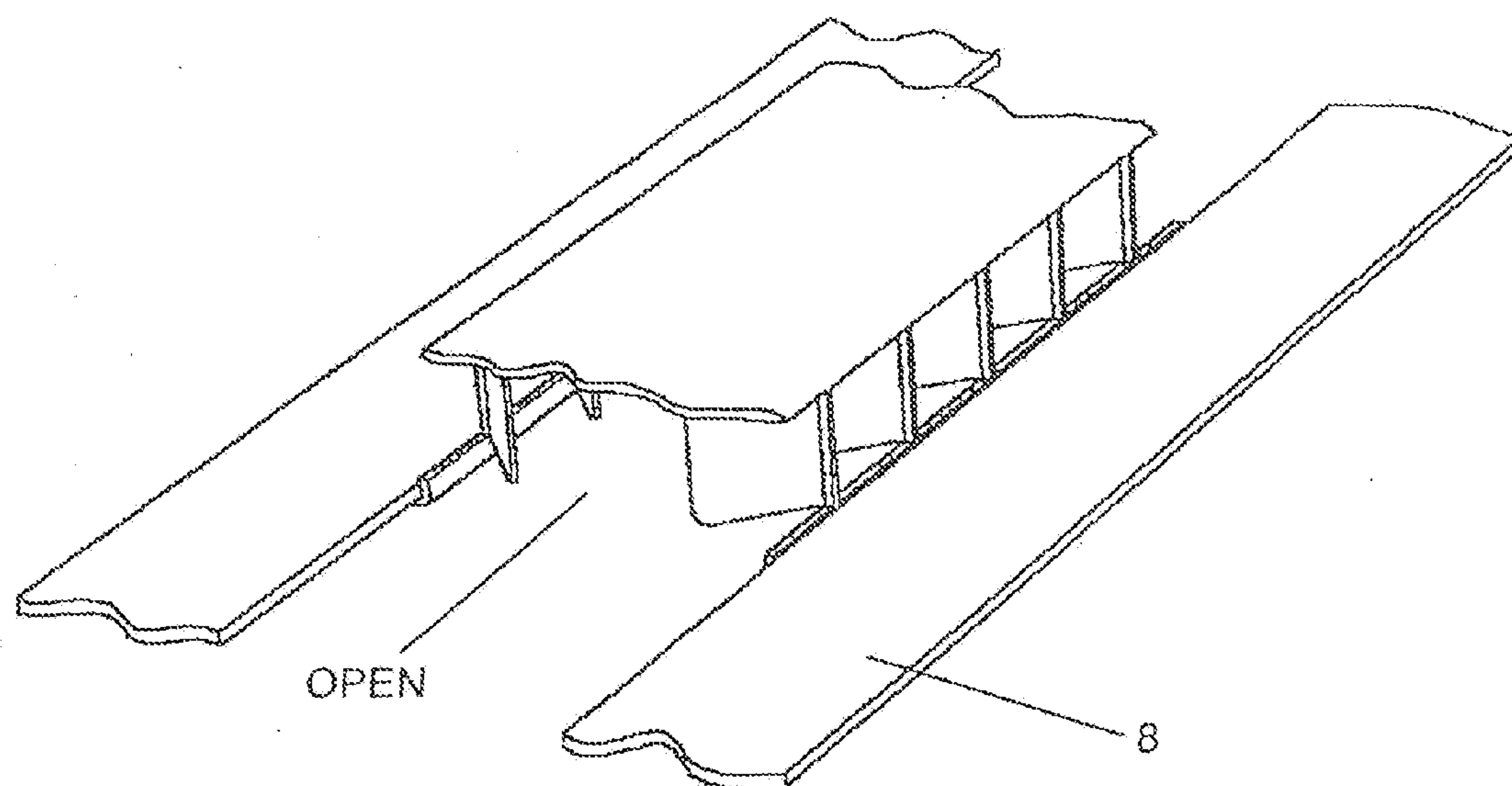


FIGURE 10

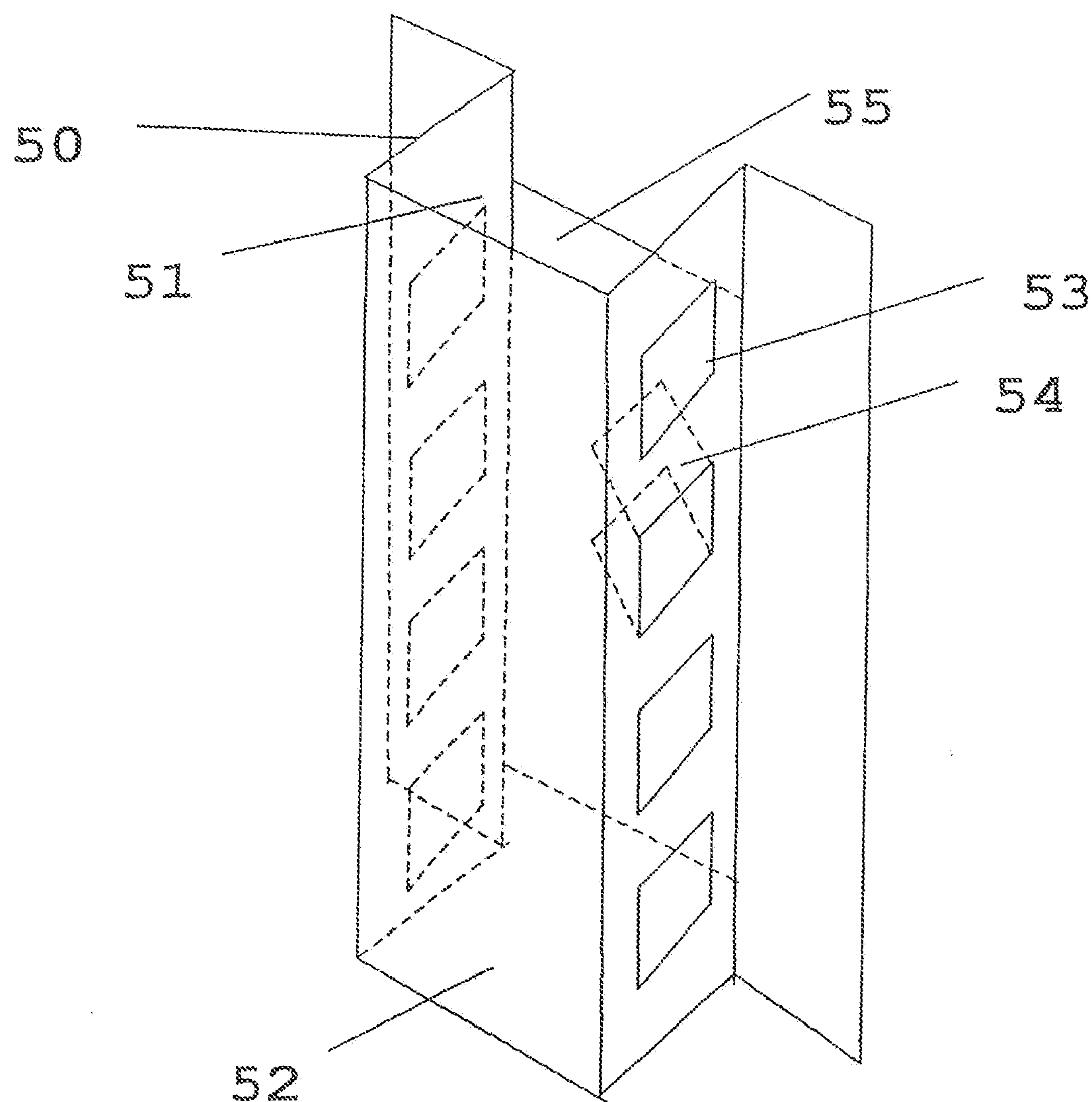


Figure 11

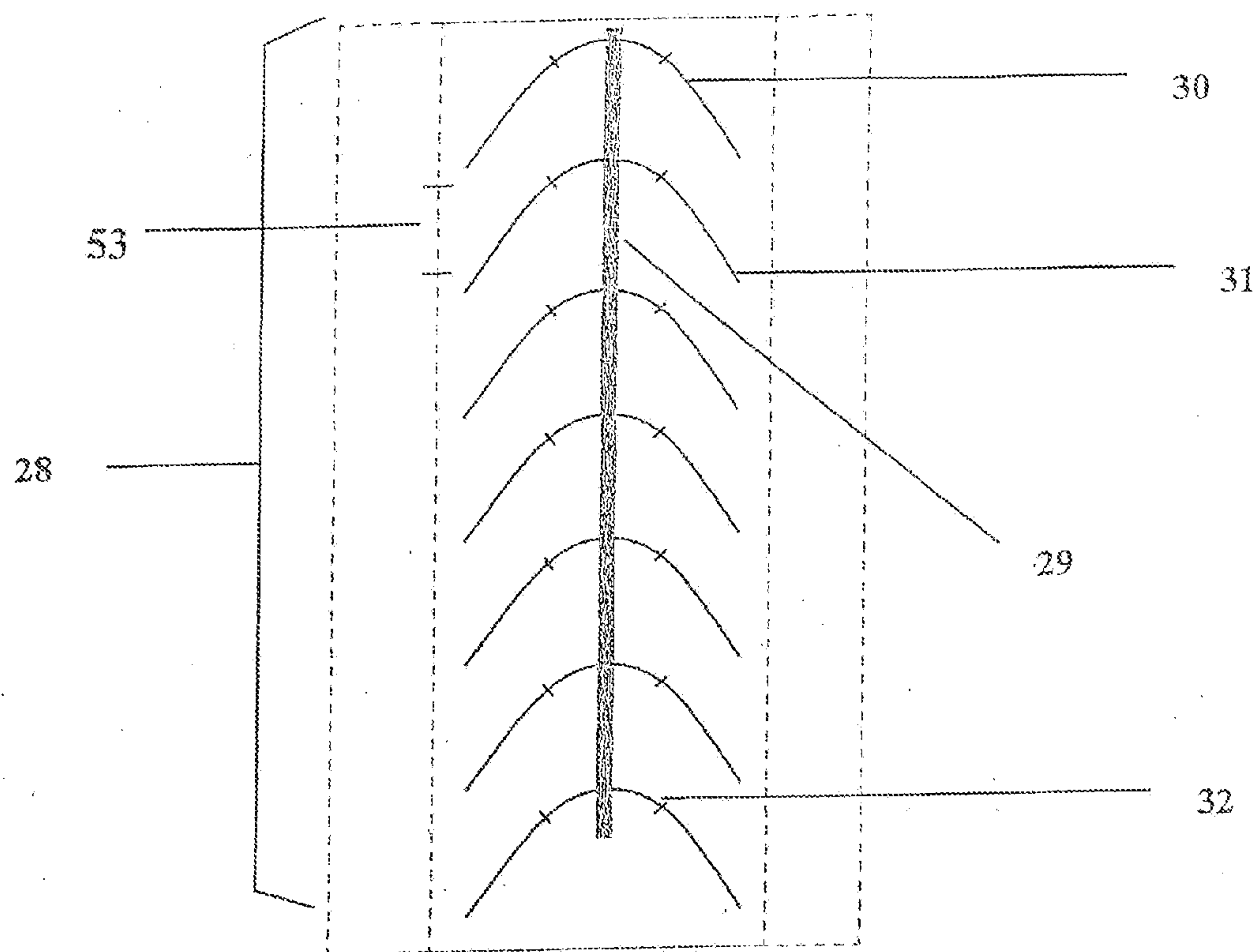


Figure 12

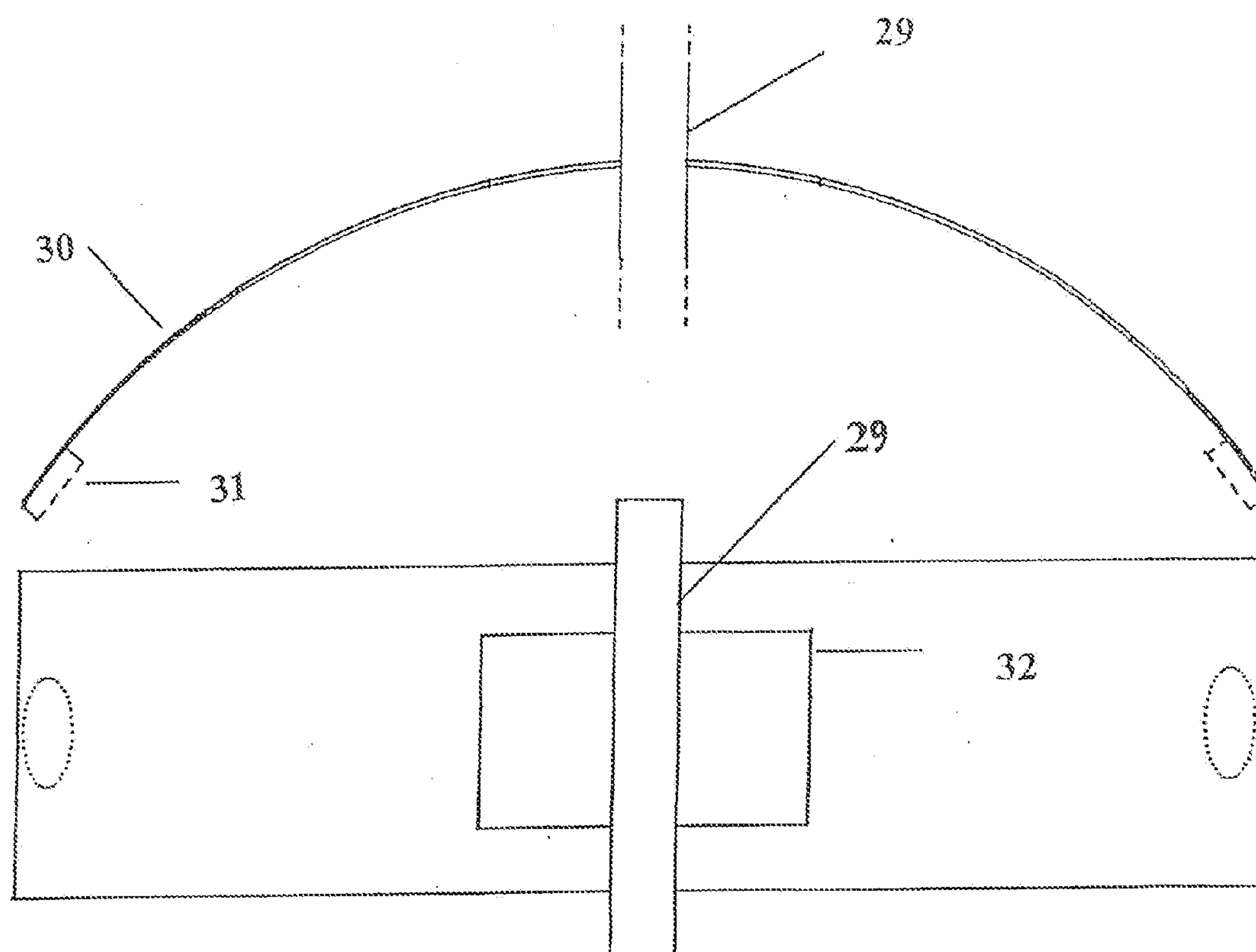


Figure 13

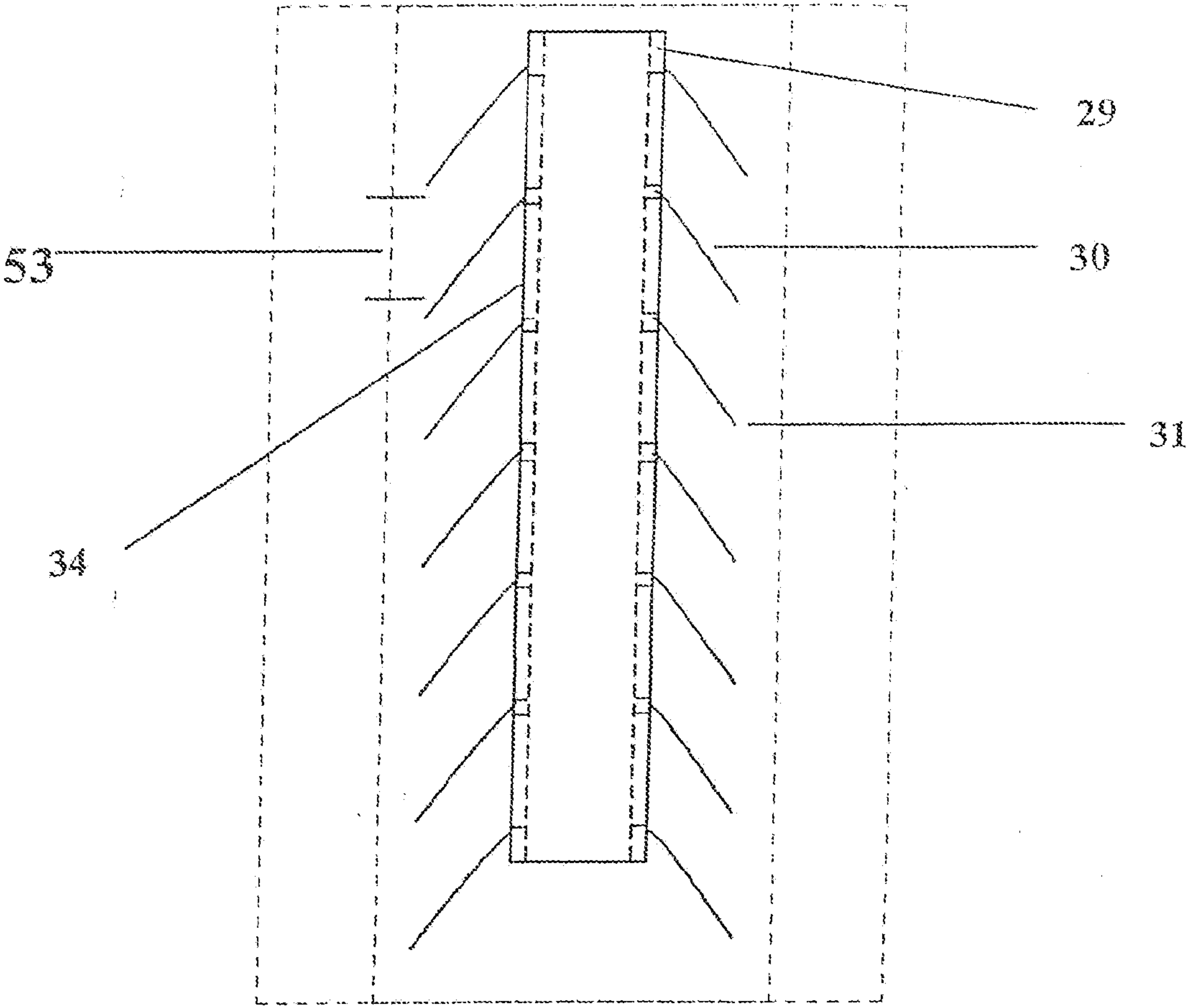


Figure 14

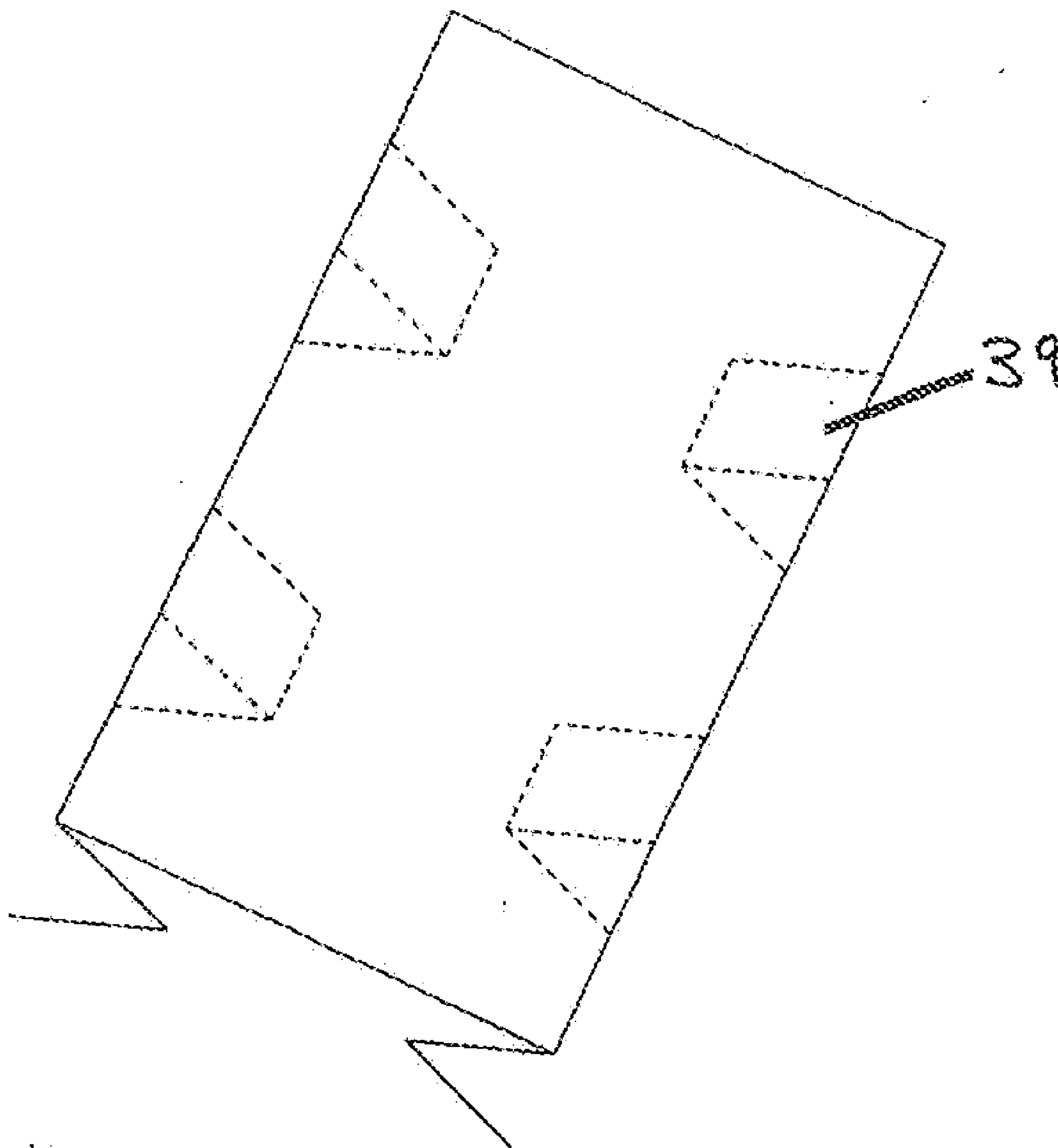


Figure 16

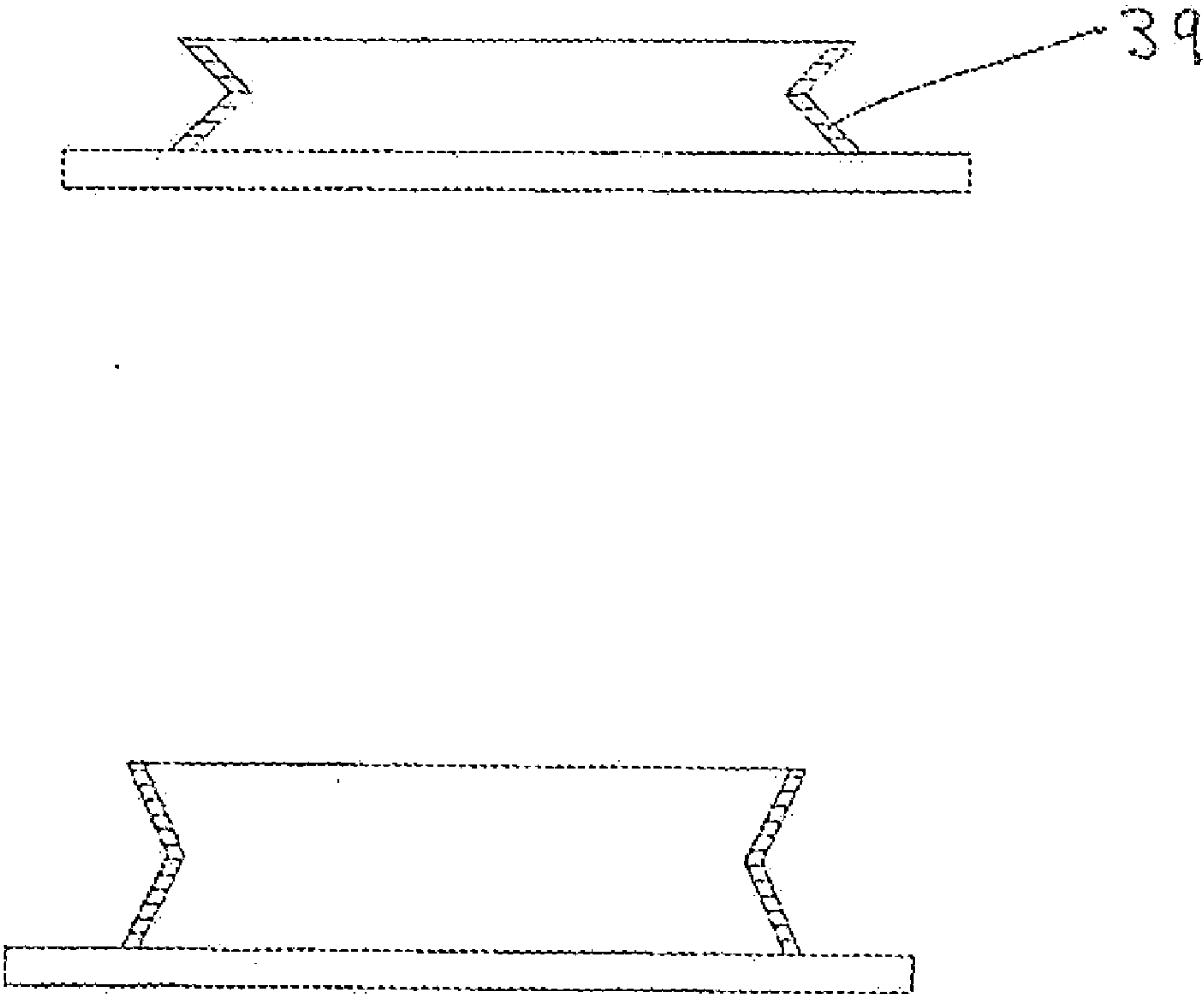


Figure 17

GARMENT VENTILATION STRUCTURE**CROSS-REFERENCE TO RELATED PATENT APPLICATIONS**

[0001] This patent application is a continuation of U.S. patent application Ser. No. 10/514,210 filed Apr. 26, 2005, which claims the benefit of PCT/GB2003/002019 filed May 12, 2003 designating the United States, and claims priority from United Kingdom Patent Application 0210733.2 filed May 10, 2002 and from United Kingdom Patent Application 0215729.5 filed Jul. 6, 2002. The teachings and disclosures of all those applications are hereby incorporated in their entireties by reference thereto.

FIELD OF THE INVENTION

[0002] This invention relates to garments including leisure apparel, and more particularly to sports shirts.

BACKGROUND OF THE INVENTION

[0003] In many activities, where sports and leisure apparel is worn, there is a demand for lightweight apparel, which is cool and comfortable, and has other desirable properties including moisture and perspiration transmission away from the wearer. In addition, fabrics and shirts with good wear characteristics and machine washability are desirable.

[0004] Manufacturers skilled in the art have developed a variety of synthetic fabrics that provide many properties advantageous to their use as sports-shirts fabric. COOL-MAX® for example, is a polyester fabric, which has many of the desirable properties, cited previously. Other fabrics based on acrylic, acetate, Lycra (registered trade name) and nylon are also available with similarly desirable properties. U.S. Pat. No. 5,297,296 Moretz et al describes a high performance moisture transport fabric.

[0005] The technology of sports shirts, including T-shirts, particularly in shape and geometry, follows traditional configuration in the main, with small and mainly aesthetic differences between manufacturers. Such configurations rely almost exclusively on the noted high performance fabrics providing the wearer with all the desired characteristics and comfort.

SUMMARY OF THE INVENTION

[0006] Unlike traditional sports shirts, the present invention is directed to improve wearer comfort by providing novel air channels for ventilation at selected points around the wearer's torso. Other structures may be provided in conjunction with the ventilation channels. Unlike a shirt that might provide ventilation by simple open holes or a large mesh, the channel openings in the present invention are concealed, thus protecting the wearer from sunlight and harmful U.V. radiation. It may also be desirable for aesthetic reasons to conceal the holes in the garment. Improved fabrication techniques, which exploit the thermoplastic nature of synthetic fabrics are also employed. It is well known that thermographic analysis of the human body shows that strenuous activity generates localised heat build-up around the chest and back as well as the upper arm. The thermal profile will naturally vary depending on many factors such as body size and the type of activity. Generally, the heart and main upper body muscles are the major areas of heat generation. Such heat generation induces perspiration in the body, causing the shirt wearer discomfort.

Perspiration and discomfort can occur anywhere on the body if covered by a heavy or insulating layer.

[0007] The present invention is intended to improve heat dissipation and reduce perspiration, at selected areas by improved ventilation. The provision of ventilation by near vertical air columns, guided by the channels, works with the natural direction of heat convection and serves to improve wearer comfort. For an effective channel depth D , the actual channel depth, for a channel width w must be $D+d$ where d can be calculated approximately from the formula $d=w^2/8r$, where r is the minimum localised body radius in a horizontal plane. In one embodiment, ventilation at the front and rear of the torso is provided by four vertical channels in total. In another embodiment, multiple channels in close proximity provide ventilation. Embodiments with non-vertical channels, are also described for application when, for instance, body shape or aesthetics impose design constraints. It is not necessary to improve ventilation at all points within the torso to afford improvement in wearer comfort and coolness. High performance synthetic fabric with known advantages is used as the main shirt material within the invention.

[0008] In another embodiment of the invention, the ventilation channels are provided with active ventilation structures within the channels. This embodiment is directed to further improve wearer comfort and is again provided at selected points on the wearer's body. Protective apparel in many cases encases the body in a heavy or insulating material, thus making better ventilation even more desirable. This embodiment continues to provide ventilation benefits even if covered with another layer, provided the channel openings are unobstructed. This is in contrast to a traditional shirt or garment, which, even if made from high performance moisture transport fabrics, results in poor cooling as the high performance fabric benefits are limited if covered by another garment layer.

[0009] This embodiment provides benefits in rigid material protective garments by increased ventilation performance since, unlike prior art, ventilation components are not restricted to being soft, non-intrusive materials. The active ventilation components are made from a variety of materials and thermoplastics fabrics including polypropylene, polyester, acetate, PVC, ABS, PTFE, Mylar, acrylic, nylon, metal foil or mixtures thereof. Ultra-sonic welding, stitching or adhesive bonding is used to join active components to the ventilation channel. Practical optimization of such techniques provides flexible active components, robust joints and trim. Wearer comfort is of primary consideration in overall design geometry, material choice and the forming process. In fabrication, choice of component material, composite layer structure, density, wall thickness and general characteristics is optimised to provide a functional ventilation structure. In rigid protective garments, the choice of material is extended to include metal foils and plastic-metal composites and laminates.

[0010] The present embodiment utilizes body motion, whether impulsive or repetitive movements, to generate resonant vibration in the proposed active ventilation structures. Fourier analysis of vibrations shows that any impulse or periodic function can be synthesized as the sum of sinusoids, each sinusoid being at a different frequency or harmonic. A repetitive square wave, of frequency 10 Hz, can be approximately synthesised by summing sinusoids of frequency 10 Hz, 30

Hz, 50 Hz, 70 Hz, 90 Hz etc. Each harmonic has a defined amplitude and phase. In this synthesis, the amplitude of the first harmonic dominates.

[0011] A movement impulse will also contain harmonics, when synthesized. Actual periodic body movements and impulses may be synthesized reasonably accurately with only a few harmonics, because any real impulse or movement transition edge will not be a sharp step-like function. In this case, the fundamental harmonic is even more dominant. Human repetitive action may be crudely estimated by considering a fast sports activity such as sprint race running where an athlete can travel 100 metres in ten seconds approximately. Taking the stride span as 2 metres, we can estimate a repeat period of 0.2 seconds, corresponding to a frequency of 10 Hz. If we take account of racket sports activities where fast arm movements occur, in 0.02 seconds approximately, an upper frequency limit can be estimated as being 50 Hz and certainly lower than 100 Hz. In activities where bulky protective clothing is worn, motions may be much slower. In summary, the frequency spectrum of body motion will contain various harmonics up to a limit of approximately 50 Hz.

[0012] It is also well known that structures such as plates and springs have a natural or resonant frequency of vibration. External periodic forces, even those of small amplitude, acting on a plate or spring can result in high amplitude resonant vibrations if their frequency matches the natural plate frequency. The natural frequency f of a free-ended cantilevered plate of length L is given by $f=0.56 K L^{-2}$ where K is the material stiffness constant, defined as $K=b (Y/12 \rho)^{1/2}$. Y is the elastic modulus, ρ is density and b is the plate thickness. The term cantilever implies that one end of the plate is fixed. Without frictional forces, a resonating plate would vibrate indefinitely at constant amplitude. In practice, air damping limits the number of vibration cycles, each cycle exponentially decaying in amplitude. Even with small amplitude vibration cycles, plate motion will stir the air will and assist ventilation. Even if only few vibration cycles occur, ventilation benefits still result; because further vibration stimulus will continually occur during wearer motion.

[0013] In the expression for the natural vibration frequency of a plate, the dimensional and material properties L , b , and Y , ρ respectively, can be selected to give any desired resonant frequency. On the other hand, in garments and apparel, dimensional choices are limited by other considerations such as the physical width limitations of a ventilation channel and the fact that any plate should be supported and robust in construction. In practice, useful resonant plate length will lie in the range 5 to 50 mm, approximately. Useful resonant plate thickness will lie in the range 0.05 to 1 mm, again approximately. These ranges will also be influenced by the intended use of the apparel, be it for sports or purely for protective clothing. In addition, because of the general desire for any ventilation component to be as unobtrusive and light as possible, smaller dimensions are favoured. Again referring to the expression for natural frequency, it can be seen that limiting the dimensional variables will restrict the choice of material properties to obtain a desired natural frequency. For natural frequencies below 50 Hz, with cm long plates, useful materials will have an elastic modulus within the range 500 to 2000 MegaPascals. Polypropylene is one such material along with nylon, PTFE, and PVC, acrylic, ABS, polyester, Mylar®, acetate, metal foil or mixtures thereof.

[0014] Further flexibility in the design choice can be made by optionally adding localized thickness or mass, at the free

end of the plate. This results in a reduction of the natural frequency. Noting again the practical constraints on component size and weight, any added weight should not greatly exceed the weight of the plate itself, and will ideally be less.

[0015] The theoretical expression for natural frequency does not involve the plate width. However, since plate area can affect the damping of vibrations by, for example, increased air friction, and needs to be considered, particularly for large area plates. Also implied in the expression is that the plate pivot point is fixed. The actual degree of freedom of this point, and its consequent modifications to the natural frequency, will depend on the stiffness properties of the material it is attached to and other practical factors. Since forcing perturbations from body motion will have a spectrum of stimulating frequencies, random and periodic, the absolute value of natural frequency is not of paramount importance, as long as it falls within the range of the forcing frequencies. Non-planar plate shapes will also affect the practical natural frequency away from the theoretical value, without significantly affecting the active ventilation benefits.

[0016] The discussions hitherto relating to plates are equally valid for springs where the equivalent natural frequency f_s , is given by $f_s=(1/2\pi) (K/m)^{1/2}$ where K is the spring stiffness constant and m is the load mass. For loads around 1 g and a stiffness constant of around 40 N/m, a spring will have natural frequency of around 35 Hz, ignoring damping effects. For springs used in series, the effective spring constant K_e is given by the well known expression $1/K_e=1/K_1+1/K_2$ so for an effective spring constant of 40 N/m two identical springs in series must have K values of 80 N/m. To maintain a desired natural frequency at greater loads, the stiffness constant must be increased proportionally.

[0017] In yet another embodiment, the ventilation channels possess different shapes and cross-sectional areas at different temperatures. In this way, comfort would be further improved by providing ventilation at elevated temperatures when it is most needed. A first shape would be an open channel as previously described. A second shape would be a collapsed form of the channel, which may be substantially planar with the shirt fabric. Further shapes would be within the range defined between the first and second shapes. In this embodiment, the ventilation channels are partially made out of at least one shape memory polymer. Optionally, shape memory polymer supports are attached to or integral with the ventilation channels. These may take the form of hinged buttresses, eyelets, a liner or some such combination. Optionally, shape memory polymers are used to control the channel opening geometry, as well as the channel cross section along the length of the channel.

[0018] Shape memory refers to the ability to return from a temporary shape to an original shape, i.e. to the “memorized” shape. Shape memory polymers, or thermally bi-stable polymers as they are also known, are polymers that possess this particular property. Shape memory polymers operate in two ways, irreversibly and reversibly. This embodiment mainly exploits the former phenomenon, whilst the latter is a volume change resulting from a phase change at a certain temperature. Irreversibility refers to the fact that the polymer shape change is in one direction, from a temporary shape to a permanent shape, in the case of a simple shape memory polymer. The shape memory polymer is chosen such that at least one and preferably two permanent shapes are memorized, a first shape dominating above a particular temperature and a second shape dominating below the particular tempera-

ture. This is possible through the inclusion of at least two different polymer segment species with different transition temperatures within the polymer. When taken through a heating-cooling cycle, the polymer will change from the first shape to the second shape before reverting to the first shape. It follows that above the particular temperature, the shape is temporary with respect to one segment, and below the particular temperature the shape is temporary with respect to the other segment.

[0019] The shape memory polymer will undergo a shape change above a particular temperature and in doing so will alter the geometry of the ventilation channels, so opening them. For example, as the wearer exerts himself, generated heat will cause the temperature of the shape memory polymer to increase above the particular temperature, so opening the channels. Ventilation ensues, lowering the wearer's body temperature. Subsequently, the ventilation channels will revert to the collapsed form, thus preventing ventilation. The garment is thus responsive and automatically adaptive. The shape memory polymers may optionally be actuated by electrical means or other stimuli, such as light or chemicals for example. The collapsed state is more compact and streamlined, thus reducing the overall garment volume. The garment's volume only increases when needed, so that at all other times, the reduced volume facilitates storage and renders the channels less obtrusive to the wearer, or observers. Other configurations of the shape memory polymer are possible, such as composites formed from at least one shape memory polymer.

[0020] For all embodiments, heat forming methods form the panel thermoplastic fabric into flexible air channels. Natural fabrics, including cotton, can readily be coated with a thin thermoplastic layer using vertical coating techniques and can thus be included as useable fabrics. The ends of each channel are terminated with a springy eyelet, formed by a similar process. Ultra-sonic welding is used to join the channel panel to the main fabric of the sports shirt. Practical optimization of such techniques provides flexible, self-supporting channels, robust joints and trim.

[0021] Wearer comfort is of primary consideration in overall design geometry, material choice and the forming process. A channel structure with non-intrusive contact against the skin is created by suitable material selection and channel construction. By non-intrusive we mean that the wearer is not at all discomforted by the channel structure during the activity and moreover that he or she is virtually unaware of the channel's presence. At the extreme end of the design mix, a very stiff, unbending and intrusive channel could be provided which would maintain a constant cross-section channel where airflow is totally unaffected by body movements. This would of course not be an acceptable solution because of its intrusiveness. At the other end of the design mix, a totally unsupported channel could be provided, but this would have no functional value. Practical embodiments that compromise between wearer comfort and channel construction are thus provided, taking account of the garment within which the channels are employed.

[0022] In fabrication, channel length and eyelet opening positions on the shirt will be dependent on factors such as the body size and shape, fabric material and the type of sport. Choice of fabric material, its density, gauge thickness and general characteristics will itself be influenced by similar factors; accordingly, modifications to the forming and joining method may be needed. Such minor modifications and

choices will be well understood by those skilled in the manufacturing art and will not be a departure from the substance of the invention. The ventilation function of the channels will ultimately also be affected by demands of aesthetics which are also part of the manufacturers art. Again, any such demands and modifications and will not be a departure from the substance of the invention.

[0023] An object of the present invention is to provide a leisure garment or protective apparel with improved ventilation and wearer comfort.

[0024] It is another object of the invention to provide a garment that provides beneficial ventilation even if covered with an additional layer or other garment.

[0025] Another object of the present invention is to provide a ventilated garment that is robust in construction, hardwearing and washable.

[0026] Still another object of the present invention is to provide a ventilated garment whose construction is amenable to economic production methods.

[0027] It is another object of the invention to provide a sports shirt that combines improved ventilation with the skin and the softness of high performance synthetic fabrics.

[0028] These and other objects of the present invention are achieved by providing self-supporting ventilation channels, non-intrusive to the body.

BRIEF DESCRIPTION OF THE DRAWING

[0029] Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

[0030] FIG. 1 shows the overall view of a sports shirt with ventilation channels and eyelets.

[0031] FIG. 2 shows a detailed embodiment of the channel cross-section.

[0032] FIG. 3 shows another channel cross-section geometry.

[0033] FIG. 4 shows details of a channel embodiment with integral liner strip.

[0034] FIG. 5 shows an embodiment of a springy eyelet opening and channel assembly.

[0035] FIG. 5a) shows in cut-away view a schematic of the channel and panel fabric arrangement of FIG. 5.

[0036] FIG. 5b) shows in exploded view a schematic of the channel, eyelet and panel fabric arrangement of FIG. 5.

[0037] FIG. 6 shows an embodiment of an integral eyelet opening and liner strip.

[0038] FIG. 7 shows multiple proximate channels.

[0039] FIG. 8 shows in isometric view an embodiment of a vertical channel with re-entrant multiple openings.

[0040] FIG. 9 shows in isometric view an embodiment of channels with re-entrant multiple openings, extended horizontally.

[0041] FIG. 10 shows in a cut-away perspective view another embodiment of a multi-apertured channel.

[0042] FIG. 11 shows part of an apertured garment ventilation channel.

[0043] FIG. 12 shows in front view an array of leaf vanes for active ventilation within a ventilation channel.

[0044] FIG. 13 shows the front and plan view of an individual leaf vane.

[0045] FIG. 14 shows the front view of a twin leaf vane array with a "U" shaped central spine.

[0046] FIG. 15 shows a perspective view of a single piece active ventilation vane array attached to springs.

[0047] FIG. 16 shows an isometric view of embodiment in which a ventilation channel is arranged with the shape memory polymer supports.

[0048] FIG. 17 shows a cross section of a schematic of a ventilation channel in use with shape memory polymer supports, in the collapsed and expanded states.

DETAILED DESCRIPTION OF THE INVENTION

[0049] Repeated use of reference numbers in the present specification and drawings is intended to represent the same or analogous features of the invention.

[0050] It is to be understood that to one skilled in the art that the following is a description of the exemplary embodiments only and is not intended as limiting the broader aspects of the present invention, which broader aspects are embodied in the exemplary fabrication. For illustrative and descriptive clarity only key items are included in the drawings. Details of trim and extraneous flanges for attachment to the apparel itself are shown only where necessary for clarity.

[0051] The present invention is directed to sports shirts fabricated with integral ventilation channels. Referring to FIG. 1, a sports shirt 1, is shown with integral ventilation channels 2, upper opening eyelet 3 and lower opening eyelet 4. For the purposes of descriptive clarity, only the front view of the sports shirt is shown and similar channels can be assumed for the rear of the shirt. In practice, the number of channels, their spacing and their eyelet opening starting points will depend on factors such as the shape of the wearer and the type of sports activity.

[0052] The dotted line 5 shows the channel fully extended to the waist band 6. However, the lower opening eyelets 4 are preferentially situated away from the waistband 6, to ensure unobstructed contours for the channels and openings. Dotted rectangles 7 represent the open areas in the main fabric of the shirt 8, not in contact with the skin. The upper and lower edges of the rectangles are set back within the channel, thus being discreet and out of view. The channel and opening eyelets are fabricated as a separate panel 9, and joined to the main fabric 8 by means of ultrasonic welding or stitching. The panel 9 is shown schematically but has a number of practical arrangements. For instance, the panel can end at the shoulder seam or it can extend to the rear of the shirt, so that front and rear ventilation channels are fabricated as one unit. The panel material and main body fabric are a synthetic thermoplastic fabric such as COOLMAX® polyester.

[0053] In FIG. 2, channel 2 has a preferred quasi-rectangular cross-section 10, surface modulated with corrugations 11. The corrugation geometry is shown as a series of arcs but could be any simple geometry such as triangular or rectangular, the important point being that they provide rigidity by being formed as a structure with wavy localised planes.

[0054] The channel profile is obtained by thermally forming the panel material 9. The channel envelope 12, shown dotted, has width of about 15 mm and height of about 5 mm, with corrugation dimensions around 2 mm in repeat pitch and 1 mm in depth.

[0055] Those skilled in the art will recognise that the practical channel profile and corrugation, shown in the embodiment, may be modified according to fabric characteristics, however, such modification being within the spirit and substance of the present invention. FIG. 3 is another channel embodiment, with corrugation applied to the channel wall 13. The corrugation structure becomes more necessary for producing a self-supporting channel as the size or span of the

profile increases. As the span and size of the profile is reduced, the need for corrugation structure is reduced; however, this being at the expense of reduced air volume per unit length of channel. Simple, geometric, cross-sectional profiles such as triangles, arcs, steps or composites thereof are appropriate for cross-sectional areas typically below 40 mm².

[0056] FIG. 4 shows an alternative channel construction useful when the fabric material used is of thin gauge. A thermoplastic liner strip 14 has thickness of about 0.2 mm and is heat formed integrally with the channel to support it. The liner strip 14, shown in cross-section, preferentially extends against the whole of the channel wall and its length. When additional non-intrusiveness is required the liner may be limited in extent or length, for instance only supporting the two side walls of the channel 10. Alternatively the liner 14 may be perforated throughout. Material for the liner strip 14 will have thermal forming properties that are similar to that of the channel fabric itself. Polyester, PVC, ABS, acetate, acrylic, nylon and composites thereof are a few suitable plastics. The liner strip 14 is an additional component, but adds flexibility to the channel profile arrangement and aesthetics and allows choice of thinner, lighter fabrics.

[0057] FIG. 5 illustrates the shape of a springy eyelet opening 3 and channel 2 in isometric view. For further descriptive clarity, FIG. 5a) shows an example of channel 2 and main fabric 8 arrangements. It is obvious that the areas shown as main fabric 8 could equally be fabricated as a panel 9 as in FIG. 1. Those skilled in the art will be aware of modifications to these fabrication arrangements, however, such modifications being within the substance of the invention. The eyelet 3 serves several purposes:

[0058] a) it protects the end of the fabric channel

[0059] b) it helps maintain the channel profile

[0060] c) it transforms the abrupt channel profile into a streamline shape, i.e. a lower, wider opening having a similar cross sectional area to the channel, in order to avoid snagging

[0061] d) it further masks the edge 7 of the channel.

[0062] The eyelet is injection moulded from thermoplastic including polyester, PVC, acetate, acrylic, nylon and composites thereof, its thermal characteristics matching closely those of the shirt and channel fabric. Mechanically, the eyelet is springy, durable and resistant to tearing. A slot 15 accepts the leading edge of the channel 2 and is used to anchor the channel 2 fabric from the underneath, forming a joint after ultra-sonic welding.

[0063] Typical welding points 16 are shown. The channel panel and its attached eyelet terminations 3 can be regarded as an assembly 18. A flange 17 is provided, which is used to join the panel assembly 18 to the main fabric 8, by ultra-sonic welding from the underneath.

[0064] A further example of an eyelet and channel assembly is illustrated in FIG. 6. The liner strip 19 has similar function to liner strip 14, as in FIG. 4, supporting the channel cross-sectional shape, but here it is integral with the springy eyelet 3. Both upper and lower springy eyelets 3 and liner 19 are thus a single piece moulding.

[0065] FIG. 7 shows the end view of multiple channels. Here multiple, closely spaced channels 20 are provided. The size of each opening is much reduced in comparison to channel profile 2, shown dotted. The number of channels and their length are variables of choice. The channel profile shown is sinusoidal in nature. Alternative shapes of triangular or rectangular corrugation are also useful practically. The reduced scale enables the channels to be incorporated as desired with-

out eyelet openings. It will be obvious to those skilled in the art of shirt fabrication that many traditional means of strengthening the end of the channels are available, such as reinforcement by stitching, for example.

[0066] FIG. 8 shows another embodiment of the invention where the channel 21 is formed as a saw-toothed surface, with an angled wall 22 and a re-entrant opening 23. Re-entrant opening 23 is preferentially open or alternatively capped with a large gauge mesh fabric. The uppermost opening has a springy eyelet 3, joined ultrasonically to the channel panel 9, to form an assembly. The construction thus provides a channel with concealed multiple air openings, thereby increasing the ventilation effects.

[0067] The length of the wall 22 may preferentially be about 9 mm and the re-entrant opening 23 about 4 mm with a channel width of about 15 mm. The angle between the wall 22 and re-entrant opening 23 is preferentially about 40 degrees. Those skilled in the art will recognise that the dimensions of the saw-tooth profile may be varied over a wide range whilst still providing ventilation benefits. The saw tooth 21 will be heat-formed similar to previous channel embodiments described and, as before, with thin gauge fabrics, the saw-tooth profile will be made self-supporting by means of a liner strip 24.

[0068] As before, the choice of liner thermoplastic, its extent and the material thickness needed for maintaining the channel profile need to be balanced against the requirement for a soft, non-intrusive channel. Preferentially, the material will be a thermoplastic matched to the shirt fabric material, such as polyester, PVC, acetate, acrylic, nylon and composites thereof, with average liner wall thickness about 0.2 mm. The liner strip 24 is shaped to duplicate the channel fabric profile. Where additional non-intrusiveness is required, however, the liner is produced with regular or discrete perforations, to increase the flexibility of the support. The channel saw-tooth profile shown is arranged as in the examples of FIG. 1 and FIG. 2 and their accompanying descriptions, where a number of elongated vertical channels are provided.

[0069] Another embodiment as indicated in FIG. 9, has channels 25, elongated horizontally. The length of the wall 22 may preferentially be about 9 mm and the re-entrant opening 23 about 4 mm. Depending on material gauge used, optional vertical struts 26 span all channels and support the saw-tooth profiles thus maintaining unobstructed openings. The openings can optionally be capped with a large gauge mesh fabric, the strut thickness and material being similar to that of the liner strip 24. Preferentially, the channel panel 9 extends around the whole body in a band of about 60 mm vertical height. Those skilled in the art will recognise that the dimensions of the channel profile may be usefully varied over a wide range around the preferred embodiment.

[0070] FIG. 10 shows a cut-away perspective view of another embodiment where the ventilation channel has multi-apertured side walls 10, as well as upper and lower openings terminated with eyelets. Multiple blades 27, are angled upwards to guide air flow, in sympathy with upwards air convection from the wearer's body. For clarity, the top wall of the channel is cut-away in the Figure. The blades 27 are inclined at 30 degrees to the channel long axis, preferentially with blade-to-aperture length being in the ratio of about 9:4. Channel width is about 20 mm and blade length is about 5 mm, giving a clear central channel of about 15 mm. Blade height is about 4 mm, which, for a channel height of 5 mm, ensures blade edges are not intrusive to the wearer. Preferen-

tially the channel, flanges and blades are fabricated as an integral injection moulding with average wall thickness about 0.2 mm. Preferentially, the material will be a thermoplastic similar to the shirt fabric material, such as polyester, PVC, acetate, acrylic, nylon and composites thereof. Because the blades 27 do not serve as supports, their thickness can optionally be made less than the rest of the moulding. This embodiment has an additional fabrication advantage in that it can be produced by a simple, single-action mould tool, since in plan view there are no re-entrant surfaces. Those skilled in the art will recognise that a variety of modifications to this embodiment and previous embodiments are possible, and are within the substance of the invention.

[0071] The embodiment shown in FIGS. 11-15 illustrates the active ventilation structures for use within the ventilation channels. Referring to FIG. 11, a vertical "U" shaped ventilation channel 50 has top and bottom openings 51 and 52 and side wall apertures 53. Static baffles 54 are angled upwards to guide air upwards and to conceal main fabric opening 55 from direct view. Only one static baffle pair 54 is shown for clarity. FIG. 12 shows, in front view, a preferred embodiment of an active ventilation vane array 28, comprising a vertical central spine 29 and leaf vanes 30, detailed in front and plan view in FIG. 13. The leaf vanes 30 have free-ends 31 and a central aperture 32. An optional load 33 at the free-end 31 is integral to the leaf plate 30, the whole plate being formed by injection moulding, vacuum forming or stamping. Optionally, the load 33 may be a small block of high-density material, which can be bonded to the leaf vane, or encapsulated within it during its forming process. The weight of this block may be in the range $W_p/10$ to $10W_p$, where W_p is the weight of the plate alone. Such a range allows for practical trimming of the plate natural vibration frequency, giving a greater choice of material and plate geometry.

[0072] Referring to FIG. 12, the vane array can be beneficially used within apparel ventilation channels, with the angled part of the leaf vanes 30, approximately in line with the channel aperture openings 53. The central spine 29 is attached to at least one of the ventilation channel walls. The formed shape of the leaf vane 30 is preferably a monotonic conic function, with the full plate areas beyond the aperture 32 having shallow curvature, and average surface tangent at around 30 degrees to the vertical. Other shapes are also possible. The central spine 29 has a relatively thick section to provide rigidity, so that vibrations about the plate width are minimal.

[0073] Another embodiment, shown in FIG. 14, has two leaf vane arrays supported by a "U" shaped central spine 29, with openings 34 between each leaf vane 30. This arrangement provides the advantages of extra support and ease of attachment. In this embodiment, the reduced leaf vane length increases the natural frequency. However, thickness or material choices can be varied to restore the desired natural frequency.

[0074] In FIG. 15, a single piece vane structure 35 is attached to the ventilation channel by leaf springs 36. The vane structure is constructed in one piece, providing ease of production. Angled vane sections 37 are approximately in line with ventilation channel aperture 53. Substantially transverse sections 38 have apertures 32, shown as elliptical holes. The longest span of the vane structure is between the two leaf springs 36, the span elsewhere being reduced so that vanes cannot interfere with the ventilation channel walls.

[0075] In practice, the sharp points in the drawing will be considerably rounded. Although only two leaf springs 36 are shown, those skilled in the art will recognize that a variety in the number of springs, their type and attachment is possible, whilst still being within the scope of the invention. The practical choice of effective spring constant enables the whole vane structure to have the desired natural vibration frequency to harness the impulse and periodic motion of the wearer. The whole arrangement in FIG. 15 can optionally be much reduced in scale and made substantially planar such that multiple vanes extend over the aperture 53. In this case the structure could be beneficially split in two halves with each planar vane structure close to the external apertures 53, left and right sides, but not in contact with them. Springs are attached to both the top and bottom of each planar vane structure.

[0076] Where the ventilation channel and surrounding material are rigid, such as in protective apparel, the active component design choices will enable use of rigid or semi-rigid materials, including metal foils within the construction. This is additionally beneficial because increased active ventilation benefits are possible where they are needed most, since such apparel will normally too be bulky or highly insulating. In other leisure and sport apparel, active ventilation benefits using flexible, non-intrusive components and materials are also provided. The use of all the embodiments described will be ideal for incorporation in rigid surrounding material such as might be used in protective clothing. In this situation, wall deformations will be minimal and any vane oscillations will be unhindered.

[0077] In other apparel, where elastic, soft or semi-rigid thermoplastic fabrics materials are employed, beneficial ventilation is still provided since it is not essential for the active ventilation to be continuous. It is no doubt obvious that in most activities, however active, that the wearer will be upright most of the time. Any momentary distortions of the vane structure or supporting wall, for example as the wearer bends, will soon be followed by restoration of the effective active vane structure and its beneficial effects as described.

[0078] Referring to FIG. 16, an isometric view of a schematic of a ventilation channel is shown, together with shape memory supports 39. The channel is shown in an intermediate state, between the collapsed and expanded states, examples of which are shown in FIG. 17. A range of intermediate states exists between the collapsed and expanded states, and act as transitional states. The collapsed and expanded states are usually the permanent states. Corresponding arrangements of the shape memory polymer supports may be programmed into the shape memory polymer's memories. In this way, below a particular temperature the polymer is in one state, and above a certain temperature the polymer is in another state. The particular and certain temperatures are usually the glass transition temperatures of the differing segments within the polymer and are not necessarily coincident. It will be obvious to the reader skilled in the art that the other mechanical properties of the segments may change with temperature, thus permitting the polymer supports to change shape.

[0079] Thus the expanded state can provide good ventilation, whilst the collapsed state provides limited or no ventilation, the ventilation channel being substantially closed. In another embodiment (not shown), there is a shape memory polymer which operates irreversibly, having only one permanent state. For example, the expanded state would be the permanent pre-programmed state. The channel would ini-

tially be configured in the collapsed state. On application of a suitable stimulus, such as heat, the polymer would expand and the channel would expand, pass through the intermediate states and assume the expanded state. The channel would then remain in this state until the temperature is lowered sufficiently that the wearer decides that ventilation is no longer required, and manually applies force to the channel such that it is reset into its collapsed state. Since the temperature is then below the glass transition temperature, the polymer would not revert to the expanded state.

1. A sports shirt comprising main areas of fabric, said main fabric areas providing a layer capable of contact with the wearer's skin when the shirt is worn by a person, said main fabric areas being separated from one another by apertures, each said aperture being partially enclosed by a second fabric layer that is held away from the wearer's skin when the shirt is worn by a person, said second fabric layer defining a pair of openings and concealing the aperture, said second fabric layer and said second layer openings defining a ventilation channel over the aperture, said ventilation channel defining a continuous air path along the entire length of the channel between said openings and over the wearer's skin.

2. A sports shirt as defined in claim 1, said channels being oriented so as to be substantially vertical when said sports shirt is worn by a standing person.

3. A sports shirt as defined in claim 1, wherein said channels are self-supporting and flexible.

4. A sports shirt as defined in claim 1, wherein said channels are formed from a thermoplastic fabric and have a corrugated profile along the channel length, said profile being defined by corrugations thermally formed in said thermoplastic fabric.

5. A sports shirt as defined in claim 4, wherein said channel thermoplastic fabric is a fabric material selected from the group consisting of polyester, acrylic, PVC, rayon, nylon, acetate and mixtures thereof.

6. A sports shirt as defined in claim 4, wherein said channel thermoplastic fabric is a natural fabric material, coated with a thermoplastic layer.

7. A sports shirt as defined claim 4, wherein said corrugations in said channel fabric have a depth of about 1 mm and repeat pitch of about 2 mm.

8. A sports shirt as defined in claim 1, wherein each of said channels is supported by means of enlarging said openings in response to temperature, said means comprising a shape memory polymer that is adapted to possess a first shape below a certain temperature and a second shape above the certain temperature.

9. A sports shirt as defined in claim 8, wherein said channels are approximately planar with said main areas of fabric below the certain temperature and are raised substantially above said main areas of fabric above the certain temperature.

10. A sports shirt as defined in claim 8, wherein the certain temperature is such that the shape memory polymer is actuated in response to heat generated by the wearer.

11. A sports shirt as defined claim 8, further including electronic means for actuating the shape memory polymer.

12. A sports shirt as defined in claim 1, wherein the a cross-sectional profile of each channel is about 15 mm wide by about 5 mm deep.

13. A sports shirt as defined in claim 1, in which said openings are formed by springy eyelets which terminate the channels, said eyelets serving to hold the channels open in a

desired cross-sectional shape and providing protection to edges of said main fabric areas at the apertures.

14. A sports shirt as defined in claim **10**, said eyelets being molded in a thermoplastic material selected from the group comprising polyester, acrylic, PVC, ABS, acetate, nylon, rayon and mixtures thereof.

15. A sports shirt as defined in claim **14**, said eyelets being attached to the main fabric layer and to the second fabric layer by at least one attachment method selected from the group comprising heat-forming, adhesive bonding, ultra-sonic welding and stitching.

16. A sports shirt as defined in claim **13**, said eyelets comprising a shape memory polymer that is adapted to possess a first shape below a certain temperature and a second shape above the certain temperature.

17. A sports shirt as defined in claim **1**, wherein said openings are capped with a large gauge mesh fabric.

18. A sports shirt made from a fabric that defines an interior of the shirt and an exterior of the shirt, said sports shirt comprising main areas of the fabric, said main areas being separated from one another by ventilation channels, said channels being self-supporting and flexible, said channels being oriented so as to be substantially vertical when said sports shirt is worn by a standing person, each of said channels defining an air path along a length of said channel from a lower end of said channel to an upper end of said channel,

said channel defining openings to said exterior of said shirt at said lower end and said upper end of said channel and said channel being open to the interior of said shirt along at least a major part of the length of said channel, wherein said channels are formed from a thermoplastic fabric and have a corrugated profile along the channel length, said profile being defined by corrugations thermally formed in said thermoplastic fabric.

19. A sports shirt made from a fabric that defines an interior of the shirt and an exterior of the shirt, said sports shirt comprising main areas of the fabric, said main areas being separated from one another by ventilation channels, said channels being self-supporting and flexible, said channels being oriented so as to be substantially vertical when said sports shirt is worn by a standing person, each of said channels defining an air path along a length of said channel from a lower end of said channel to an upper end of said channel, said channel defining openings to said exterior of said shirt at said lower end and said upper end of said channel and said channel being open to the interior of said shirt along at least a major part of the length of said channel, wherein each of said channels is supported by means of enlarging said openings when heat is generated by the person, said means being a shape memory polymer.

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