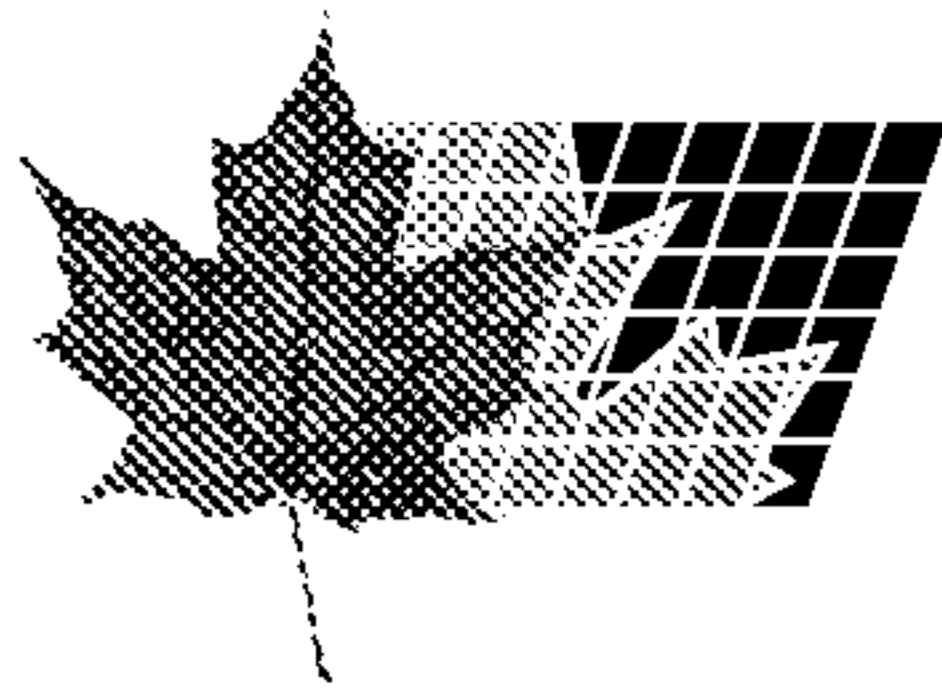
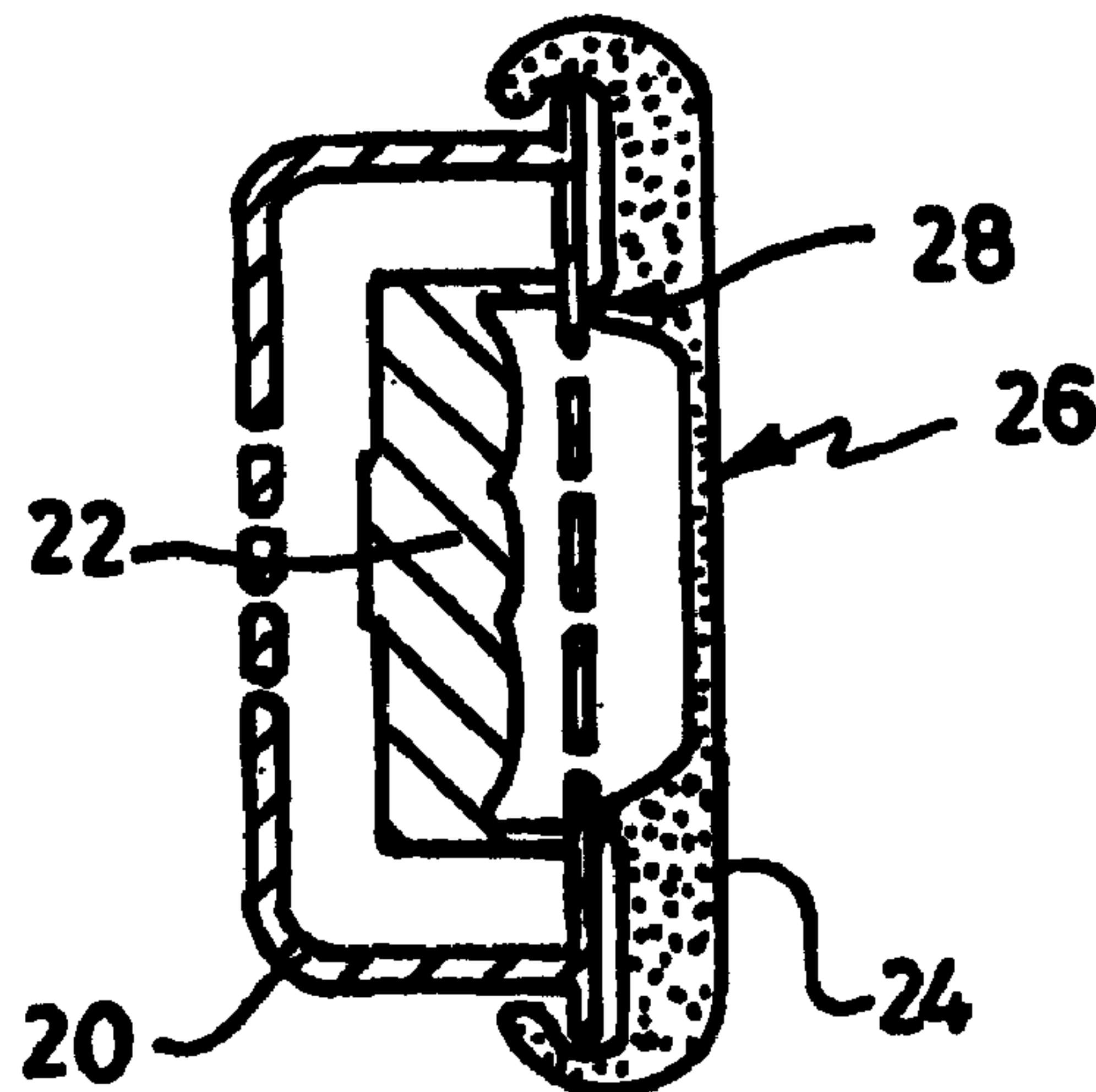




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(54) **ECOUTEURS A COUSSINET**
(54) **CUSHIONED EARPHONES**



(57) Ecouteur comprenant un excitateur (22) porté par une coque (20) d'écouteur et recouvert d'un coussinet (24) pour les oreilles en mousse auxétique.

(57) An earphone having a drive unit (22) carried by an earphone shell (20) and covered by an ear cushion (24) of auxetic foam.

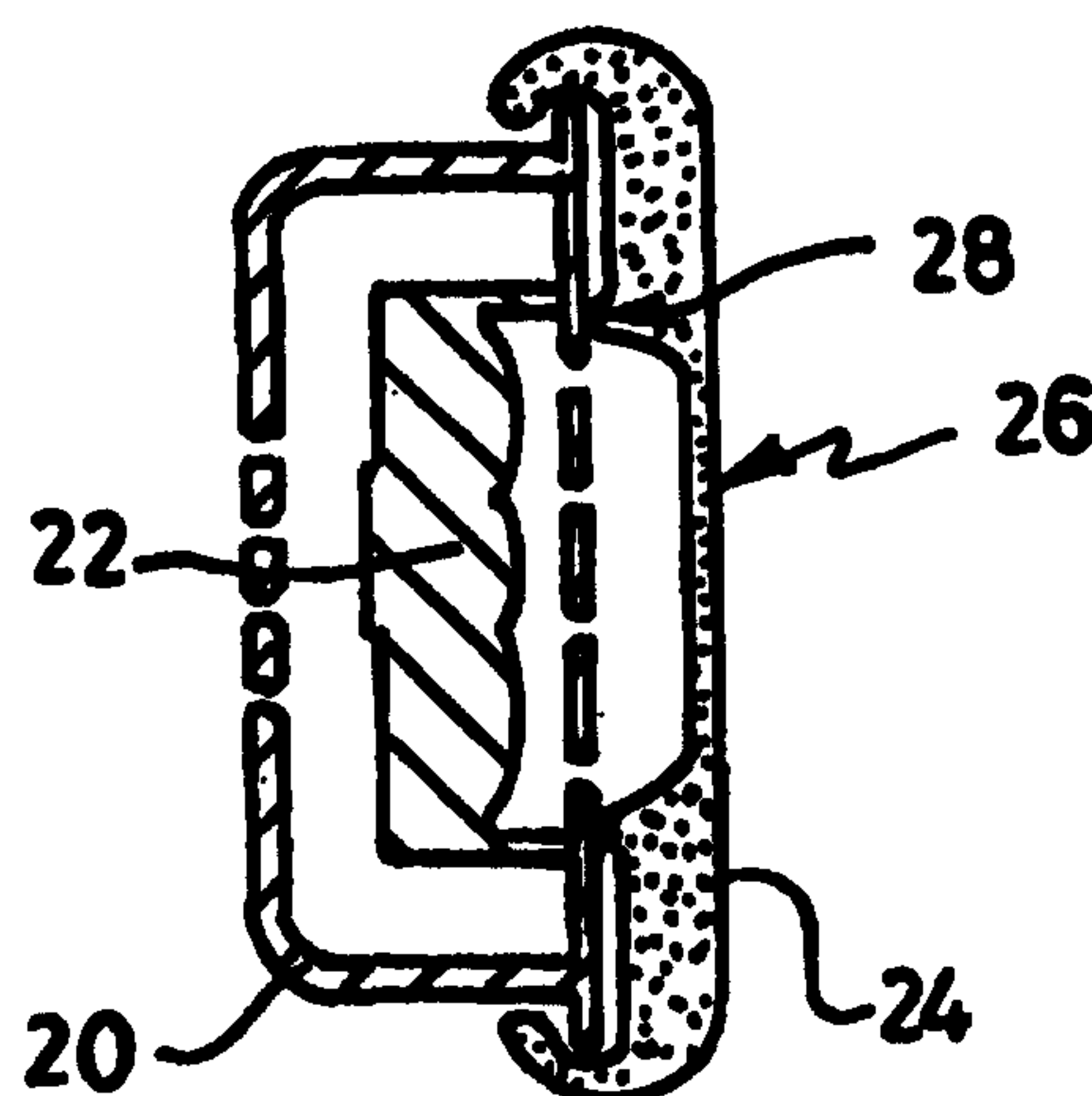
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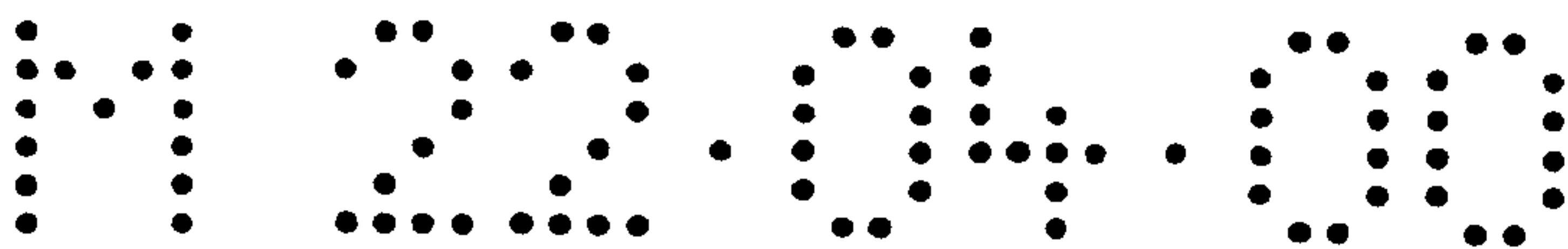
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(54) Title: CUSHIONED EARPHONES**(57) Abstract**

An earphone having a drive unit (22) carried by an earphone shell (20) and covered by an ear cushion (24) of auxetic foam.





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Cushioned Earphones

This invention relates to a cushioned earphone, and in particular to a cushioned active headset providing noise cancellation.

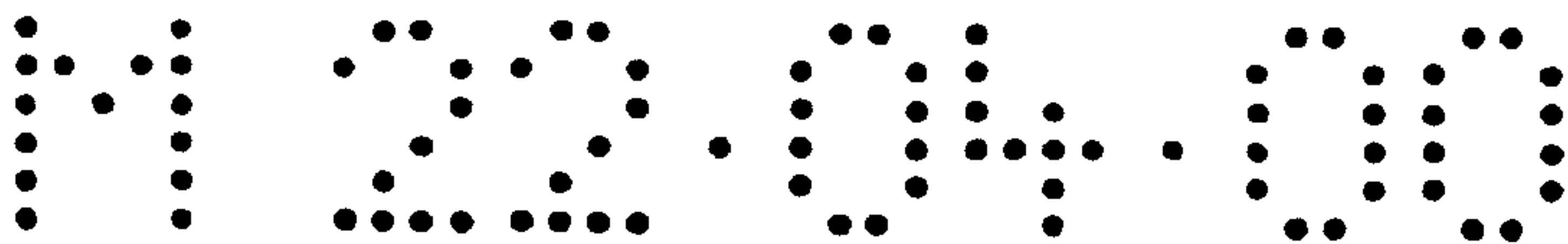
A conventional cushioned earphone, for example as known from US Patent No. 4809811, is shown in Figure 1 of the accompanying drawings. The drive unit 10 within the earphone shell 12 is separated from the ear by means of the foam cushion 14. The cushion 14 serves two purposes.

The first is one of comfort, whereby the foam is compliant enough to partially mould around the irregularities of the ear and thereby spread the pressure of the earphone more or less evenly over the entire contact area. This avoids 'hot spots' that can lead to soreness of the ear.

the second purpose of the foam is to allow the sound from the drive unit through to the ear more or less unimpeded whilst preventing it from leading out to the surrounding space thereby reducing the sensitivity of the headset. This leakage takes place through the body of the foam itself as well as through any gaps that occur between the foam and the ear due to imperfect sealing.

These requirements are unfortunately contradictory. The best comfort and least leakage due to poor contact is obtained if the foam is deep and of low density so that it's compliance is higher, but this allows more leakage through the foam and hence less sensitivity. Increasing the sensitivity by use of a denser foam not only reduces comfort but also forms more of a barrier between the drive unit and the ear.

There are ways to partially overcome these difficulties and one example is shown in Figure 2 of the accompanying drawings. This approach has a cushion that is moulded with a thinner central region 14A so that there is less impediment to the sound passing from the

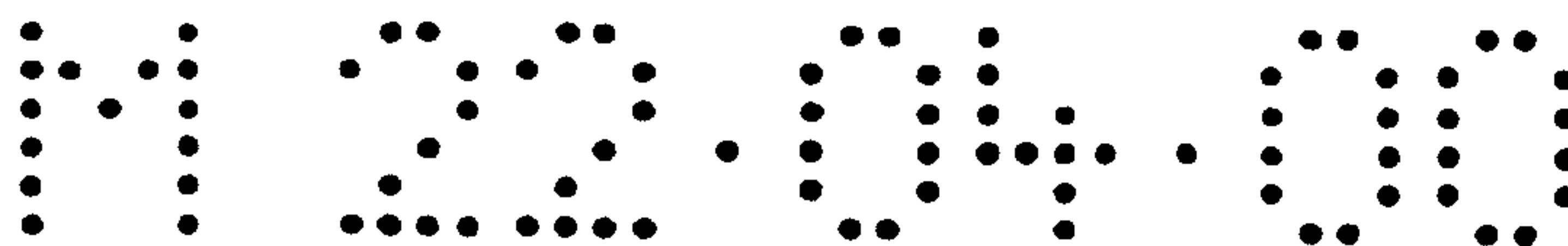


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drive unit 10 through to the eardrum, but there still remains the compromise between comfort and sensitivity in the choice of foam density.

his difficulty in the choice of foam density occurs because of the inherent characteristics of conventional foams. As the material is compressed in one direction its tendency is to expand in the perpendicular directions and vice versa, maintaining more or less constant volume. Thus if an object presses into a sheet of foam the thickness directly below the depression is reduced and therefore the region under the depression expands outwards. More importantly, however, the surface of the foam has been stretched in two dimensions over a fairly wide area in order to create the depression and the effect of this is for the thickness of the foam away from the immediate area of the depression to decrease, thus pulling the surface of the foam away from the object. In the case of a protrusion from a surface, as in the case of irregularities in the shape of an ear pressing into earphone foam, the result is to leave air gaps around the protrusion where sound can leak through. This effect is demonstrated in Figure 3 of the accompanying drawings, wherein a typical air gap is referenced 15.

Thus, with a conventional foam cushioned earphone, there is a problem with the acoustics of the headset when the earphone is pressed against the ear. Under these conditions the acoustics impedance of the foam increases, the leaks decrease and the volume between the drive unit and the ear canal also decreases. These factors cause the acoustic output of the earphone to increase. With a normal headset this merely causes frequency response variations (and a left/right imbalance if only one earphone is pressed against the ear), but with an active headset the results can be highly disadvantageous. With a virtual earth negative feedback type headset the rise in acoustic gain can lead to instability, whilst with a feedforward headset noise cancellation is severely degraded.



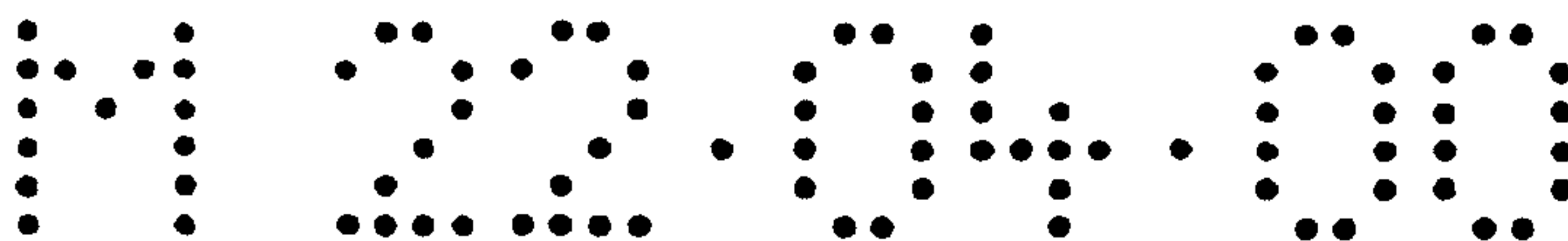
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According to the invention, there is provided an earphone having active noise cancellation including a sound drive unit and a deformable earpad, wherein at least part of the earpad which is compressible is made of auxetic foam.

An auxetic foam, as used in this specification and the appended claims, means a foam material which, in contrast with conventional foam materials, has the property of contracting in directions perpendicular to an applied compression, thus reducing their overall volume. Such auxetic foams are described in "A Stretch of the Imagination" in New Scientist No. 2875, pages 36 to 39. The aforesaid property stems from the unique structure of the foam whereby the cell walls bend inwards, as shown in Figures 4a and 4b of the accompanying drawings. Figure 4a shows an undeformed auxetic foam cell with concave side walls, and Figure 4b shows the effect of applying pressure in the direction indicated. When more pressure is applied, the cell walls buckle further inwards and reduce the cell volume. An auxetic foam material well known from US Patent No. 4668557.

Thus, in the earphone according to the invention, the tendency is for the auxetic foam more readily to mould around irregularities in the shape of the ear and so reduce air leaks. As the auxetic foam is compressed under a protrusion, the stretching of the surface causes the thickness of the foam away from the protrusion to increase and so push itself closer to the ear to reduce the size of any air leak. This cushion moulds itself more perfectly to the ear and increases comfort at the same time as reducing leakage.

Moreover, as Cutbert explained, pressing the earphone against the ear can lead to catastrophic results as far as active noise cancellation is concerned, when a conventional foam is used for the earphones.



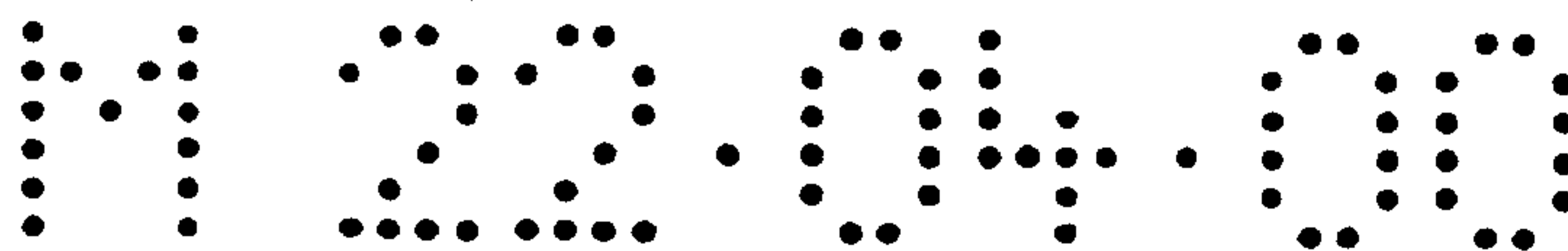
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However, when an open-cell auxetic foam is used for the earpad then these disadvantageous effects can be ameliorated. As explained earlier, the cell walls of the auxetic foam bend inwards when the foam is compressed and this causes the intersperses to increase in size. If the physical properties of the foam are correctly chosen then the acoustic impedance of the foam can be made to decrease as the foam is compressed, thus reducing the acoustic gain. The foam will also contract circumferentially and thus tend to reduce the front volume, but this can be somewhat counteracted by fixing the inner circumference of the foam so that the contraction is mainly confined to the outer circumference. In this way, the increase in acoustic gain will be lower than that for conventional foam and so improve stability margins and cancellation performance.

A preferred example of earphone for the headset is shown in Figure 5 of the accompanying drawings; Figures 6 to 10 show modifications.

In Figure 5, the earphone shell 20 supports a drive unit 22 which is covered by a cushion 24 of auxetic foam having a central portion 26 of reduced thickness of approximately the same area as the drive unit. The cushion 24 is fixed to the shell 20 at the perimeter of the drive unit, as indicated at 28, so as to minimise increase in acoustic gain and thus improve stability margins and noise cancellation performance, as previously stated.

Figure 6 shows a modification. Thus, the property of the auxetic foam 30 to decrease in acoustic impedance when compressed can also be used with advantage in combination with an ear-contact layer 32 conventional foam. With this combination of foam materials, the change in acoustic impedance with applied pressure can be reduced due to the properties of normal foam counteracting those of the auxetic foam. The performance of the earphone, and headset incorporating a coupled pair of such earphones, can therefore be arranged to have a more consistent response to changes in applied pressure.



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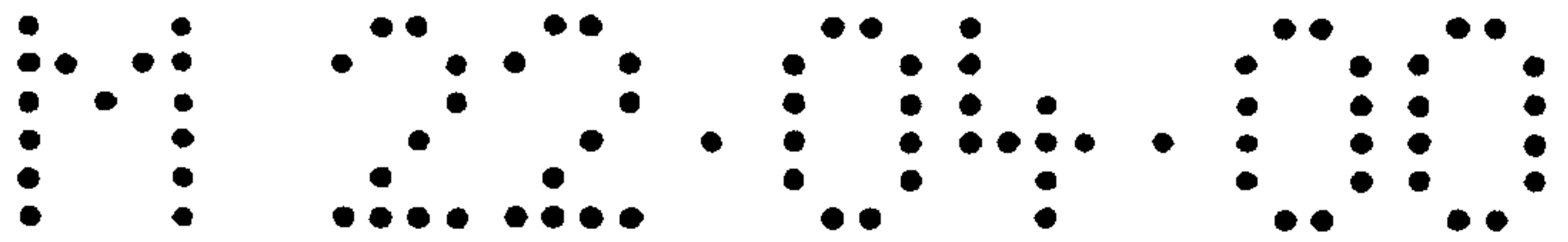
Figure 7 shows another modification in which the auxetic foam layer 30A is again combined with a layer 32A of conventional foam, but in this case the auxetic foam layer 30A is the ear contact layer, thus in use giving better moulding to the ear as well as improved acoustic performance.

In the embodiments of Figure 6 and 7, either the auxetic foam layer or the conventional foam layer or both may be impregnated with liquid, typically a light oil, also to improve acoustic performance. In such a case, the impregnated layer or layers require to be encased in an impervious skin or cover, for example of plastics sheet or leatherette.

Figure 8 shows a further modification wherein the auxetic foam layer is used in combination with a skin encased liquid layer, as an alternative way of improving acoustic properties. In Figure 8, the skin or cover encased liquid layer is referenced 34 and the auxetic foam layer is referenced 36. The complete cushion is encased in a cover 37. Less desirably, the liquid layer could be the ear contact layer.

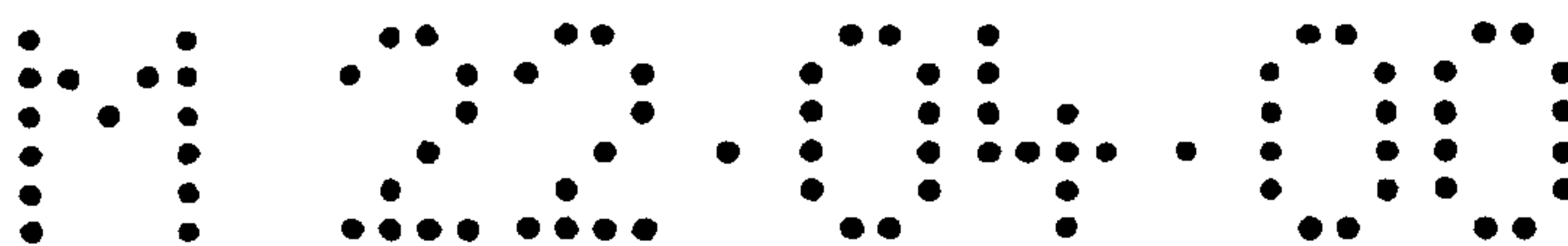
Figure 9 shows the application of the auxetic foam cushion to an earphone having means in the form of a baffle plate dome for limiting compression of the cushion when the earphone is pressed against the ear. The illustration shows an active headphone having a shell 38, baffle plate 40 with domed projection 42, drive unit 44, sensing microphone 46 and auxetic foam cushion 48. Any of the embodiments and modifications described with reference to Figures 5 to 8 could equally be applied to the earphone Figure 9.

Figure 10 shows the application of the auxetic foam cushion to an earbud type earphone, in which the cushion is designed to seal around the entrance to the ear canal. The illustration shows an active earbud having shell 49, front piece 50 with port 51, drive unit 52, sensing



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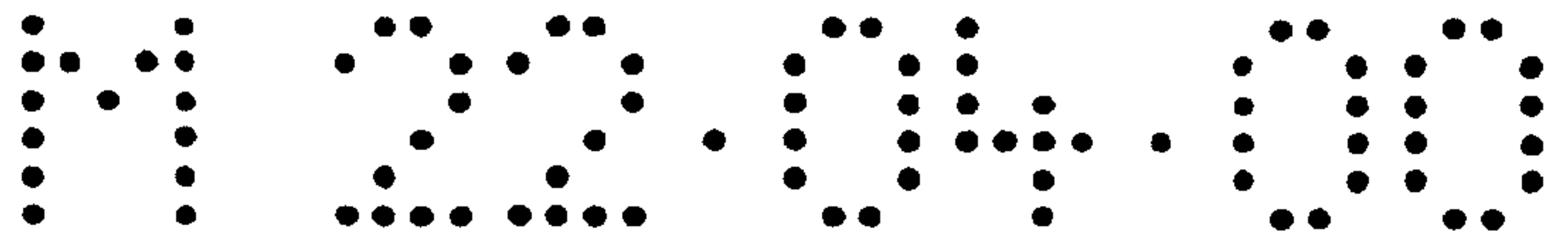
microphone 53 and auxetic foam cushion 54. Again, any of the embodiments and modifications described with reference to Figures 5 to 8 could equally be applied to the earphone of Figure 10



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Claims

1. An earphone having active noise cancellation, including a sound drive unit and deformable earpad, wherein at least part of the earpad which is compressible is made of auxetic foam, as hereinbefore defined.
2. An earphone according to claim 1, including an earphone shell carrying a baffle plate with an opening over the drive unit and between the drive unit and the earpad, the earpad being of reduced thickness in a central region having an area approximately corresponding to that of the baffle plate opening.
3. An earphone according to claim 1 or claim 2, wherein the earpad has multiple layers, including an auxetic foam layer and a supplementary layer of liquid, liquid/foam or conventional foam.
4. An earphone according to claim 3, wherein the auxetic foam layer is an inner layer and the supplementary layer is the ear-contact layer.
5. An earphone according to claim 3, wherein the conventional foam layer is an inner layer and the auxetic foam layer is the ear-contact layer.
6. An earphone according to claim 4 or claim 5, wherein the inner foam layer is an annular layer.
7. An earphone according to claim 5 or claim 6 when appendant to claim 2, wherein the inner annular layer surrounds the area defined by the central region of reduced thickness, which is formed in the outer layer.



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8. An earphone according to claim 2 or claim 7, wherein the central region of reduced thickness is spaced from the baffle plate so that the outer surface of the earpad remote from the baffle plate is approximately planar.
9. An earphone according to any of claims 2 to 8, wherein the earpad is fixed to the baffle plate around the said opening.
10. An earphone according to any of claims 1 to 9, wherein the earpad includes a skin covering.
11. An earphone according to claim 10,, wherein the auxetic foam is moulded with an integral skin.
12. An earphone according to claim 9 or claim 10, wherein the earpad is inserted into a separately formed skin cover.
13. An earphone according to any of claims 1 to 12, including means for limiting compression of the cushion when the earphone is pressed against the ear.
14. An earphone according to claim 13, in which the compression limiting means comprises a central projection on a baffle plate.
15. An earphone according to any of claims 1 to 14, in the form of a supra-aural earphone.
16. An earphone according to any of claims 1 to 14, in the form of an earbud-type earphone.

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17. A headset comprising two coupled earphones each comprising an earphone according to any of claims 1 to 16.

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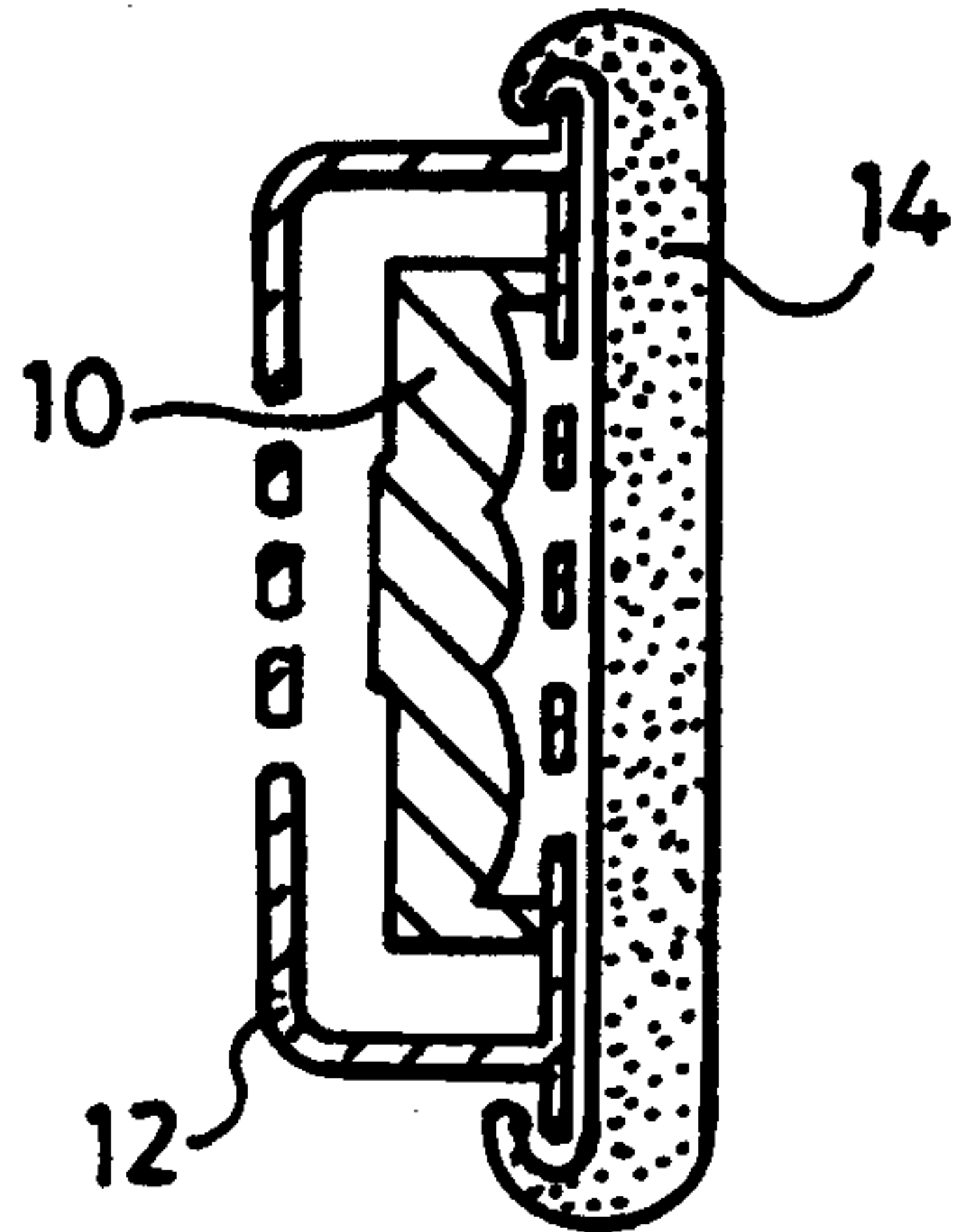


Fig. 1

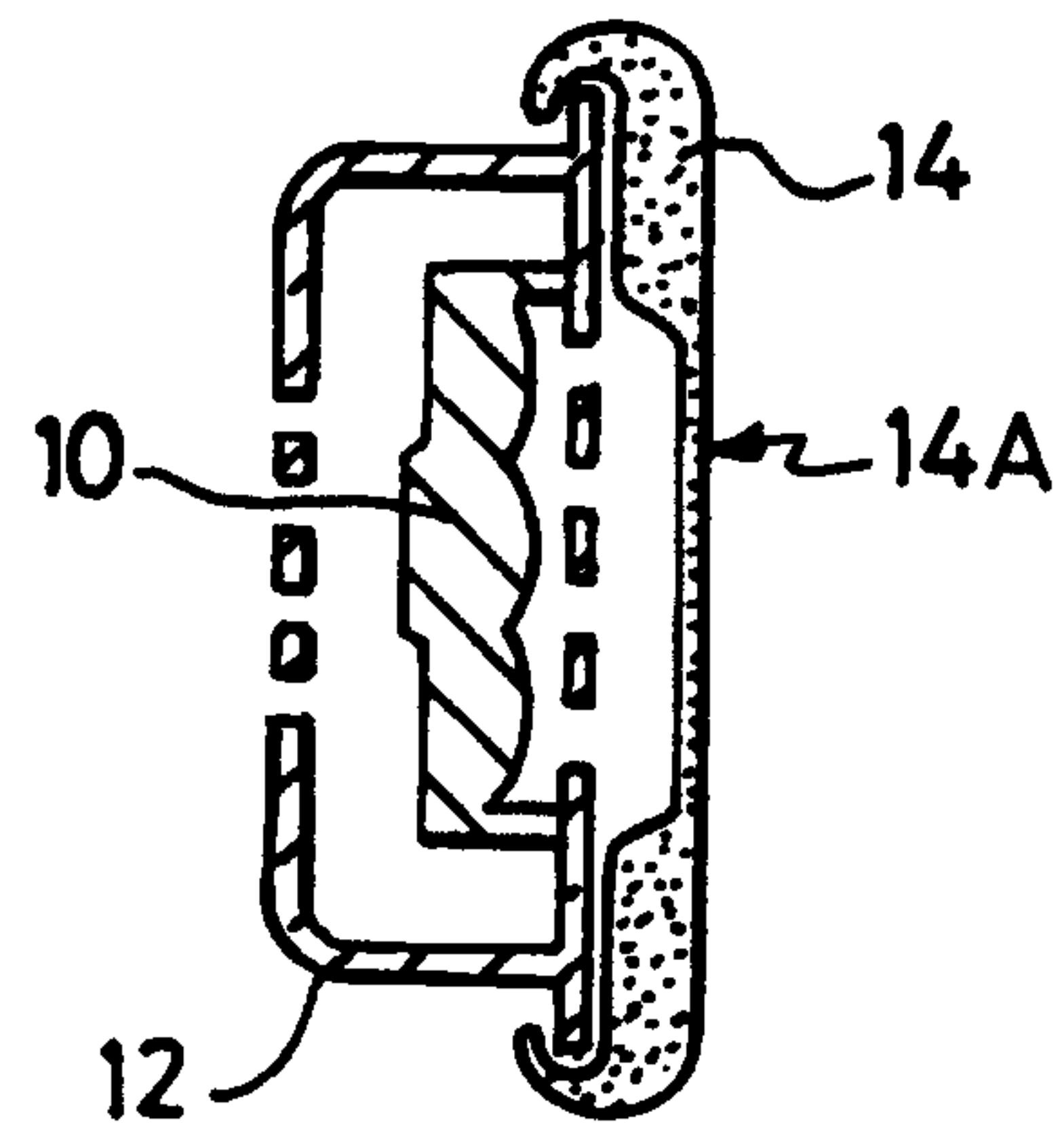


Fig. 2

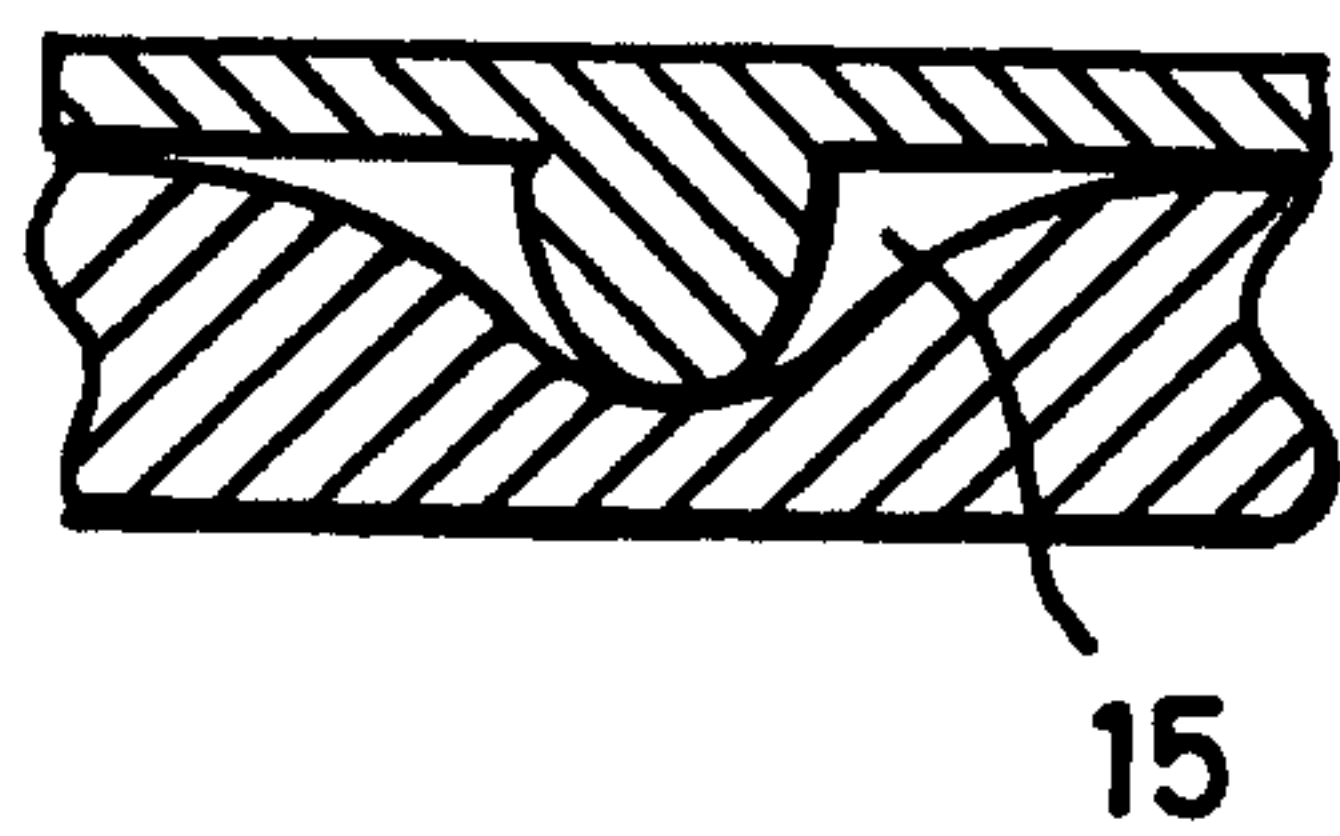
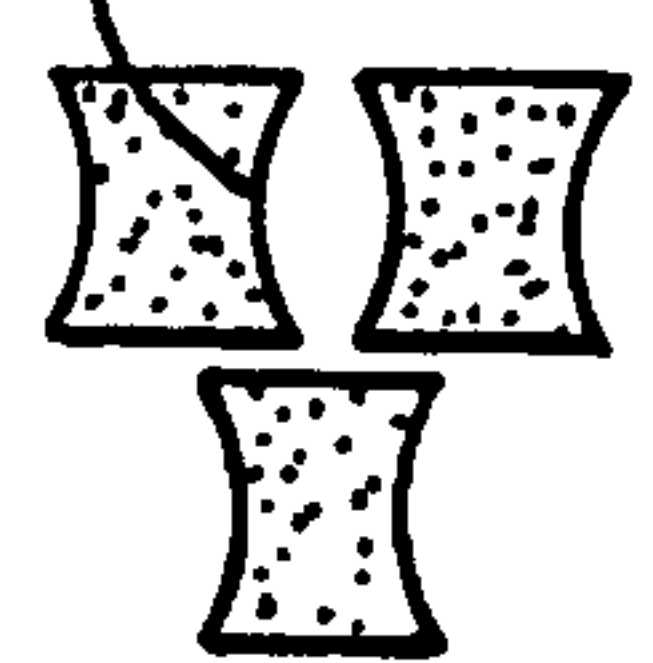


Fig. 3

CONCAVE
WALL

PRESSURE

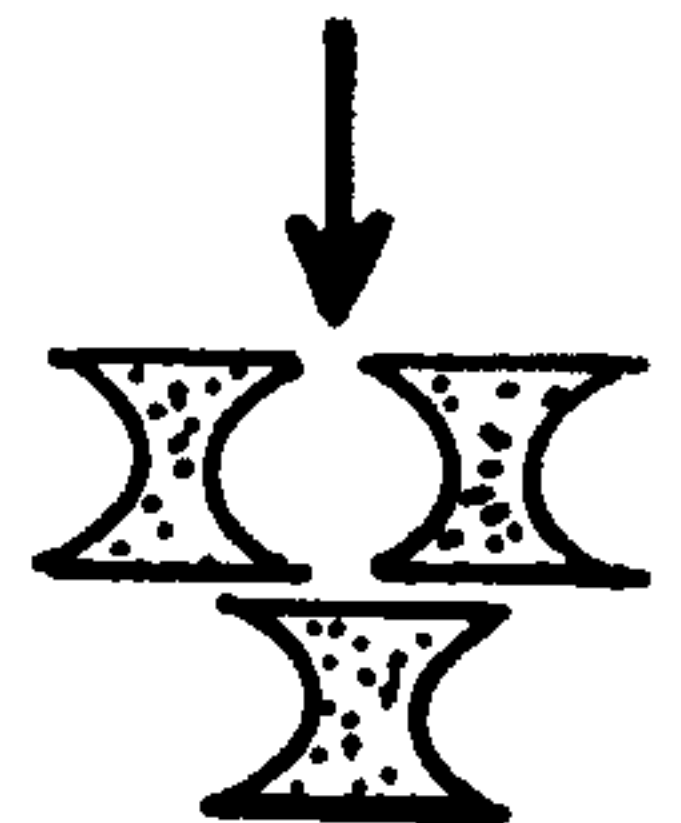


Fig. 4

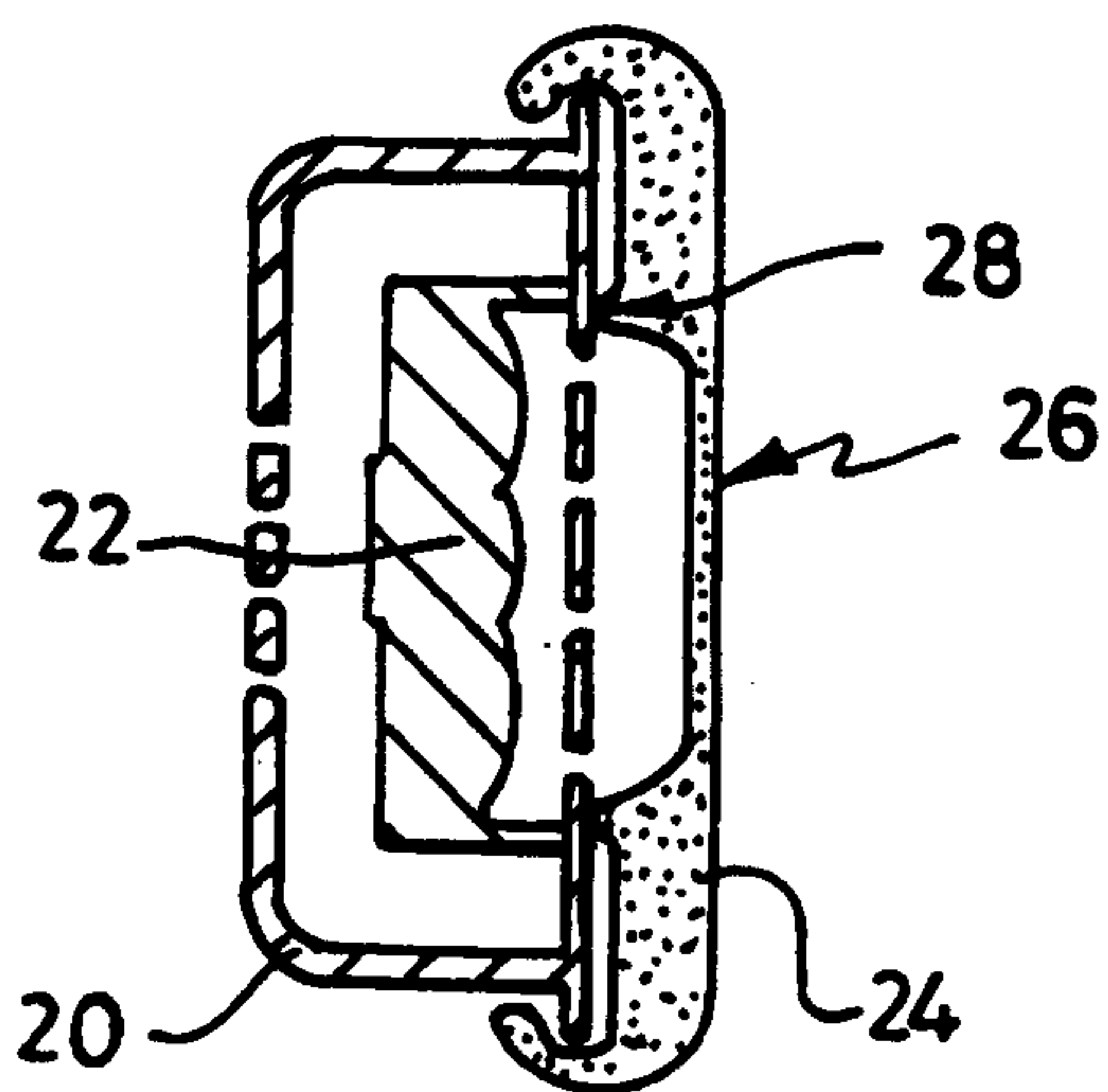


Fig. 5

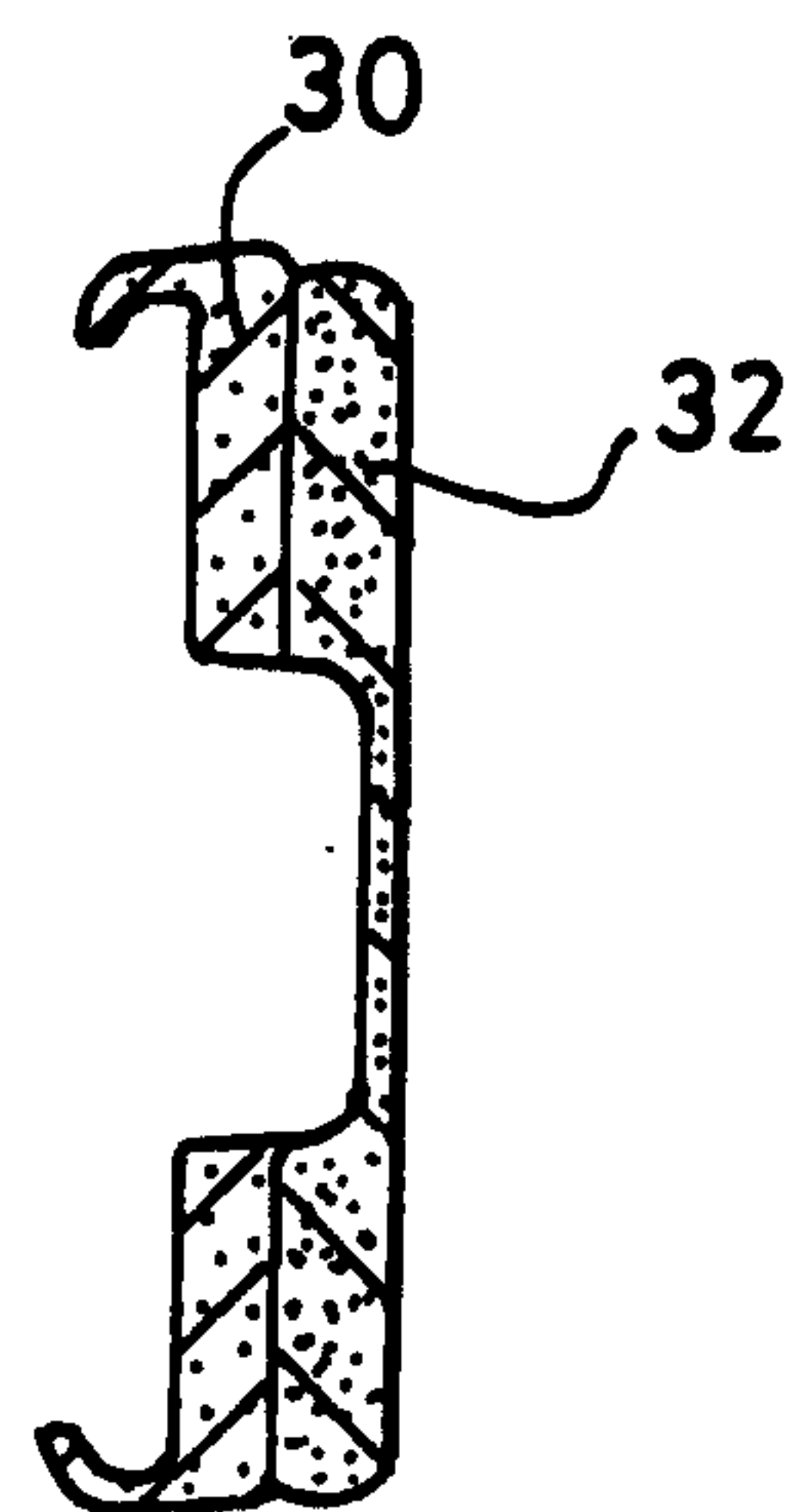


Fig. 6

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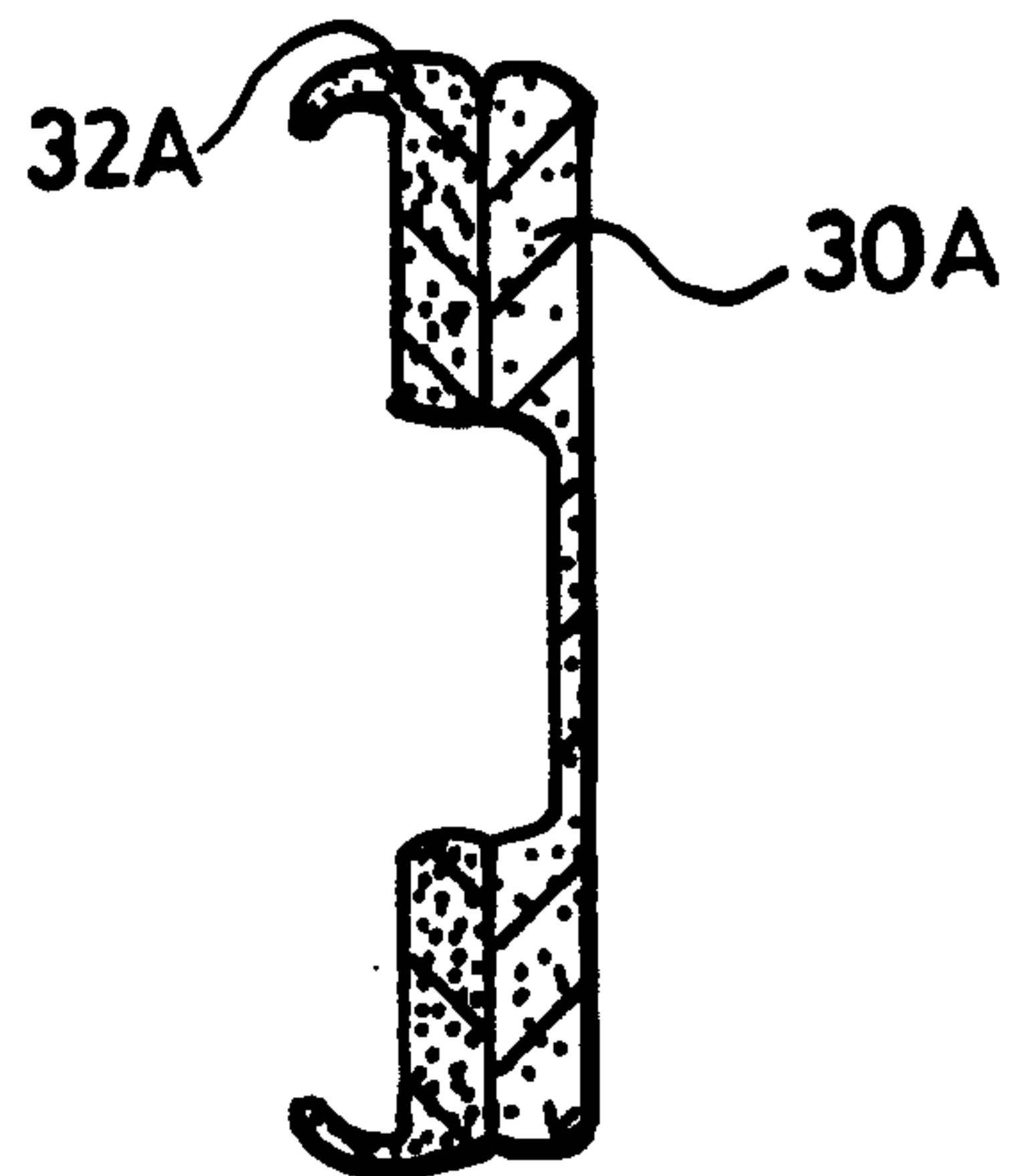


Fig. 7

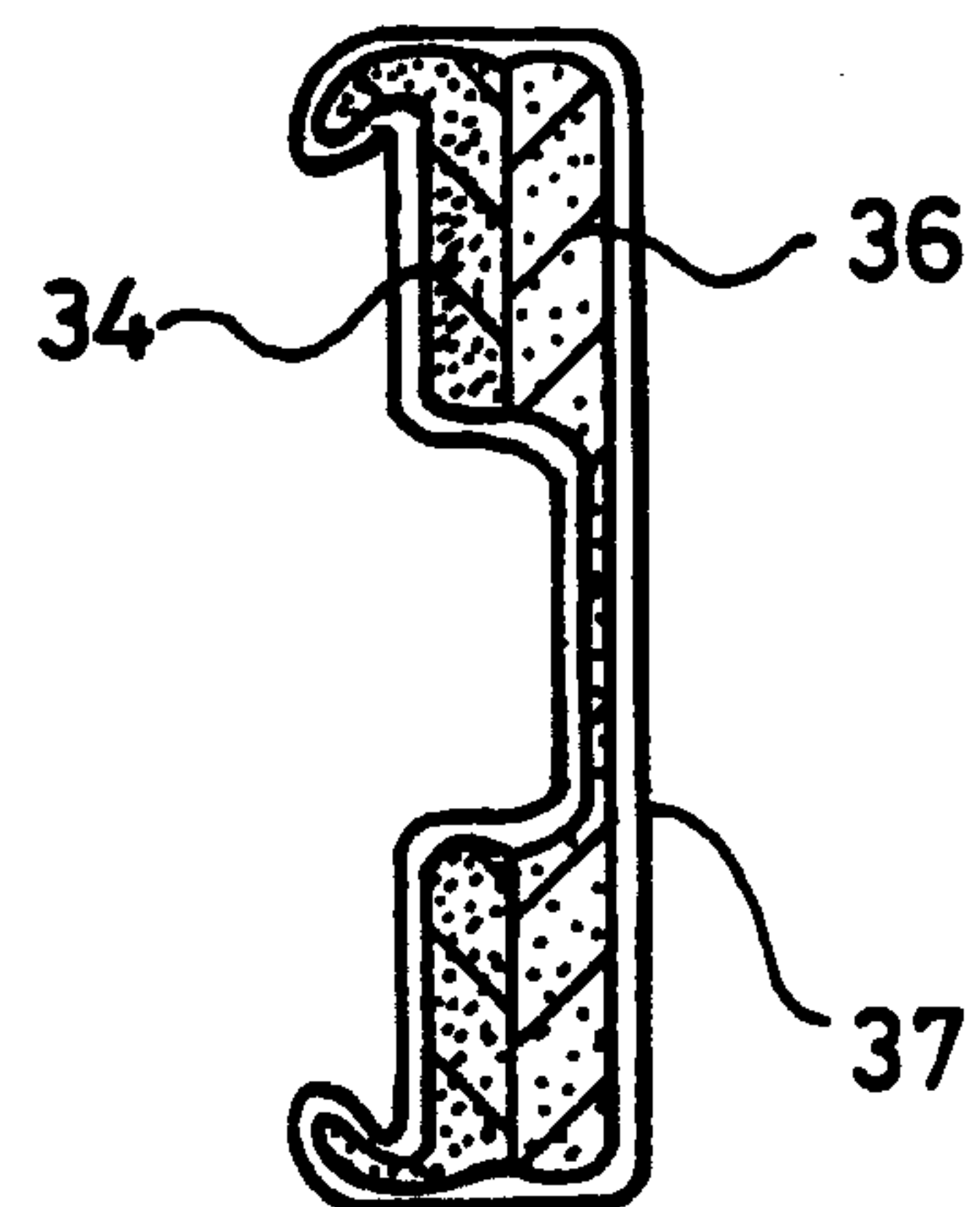


Fig. 8

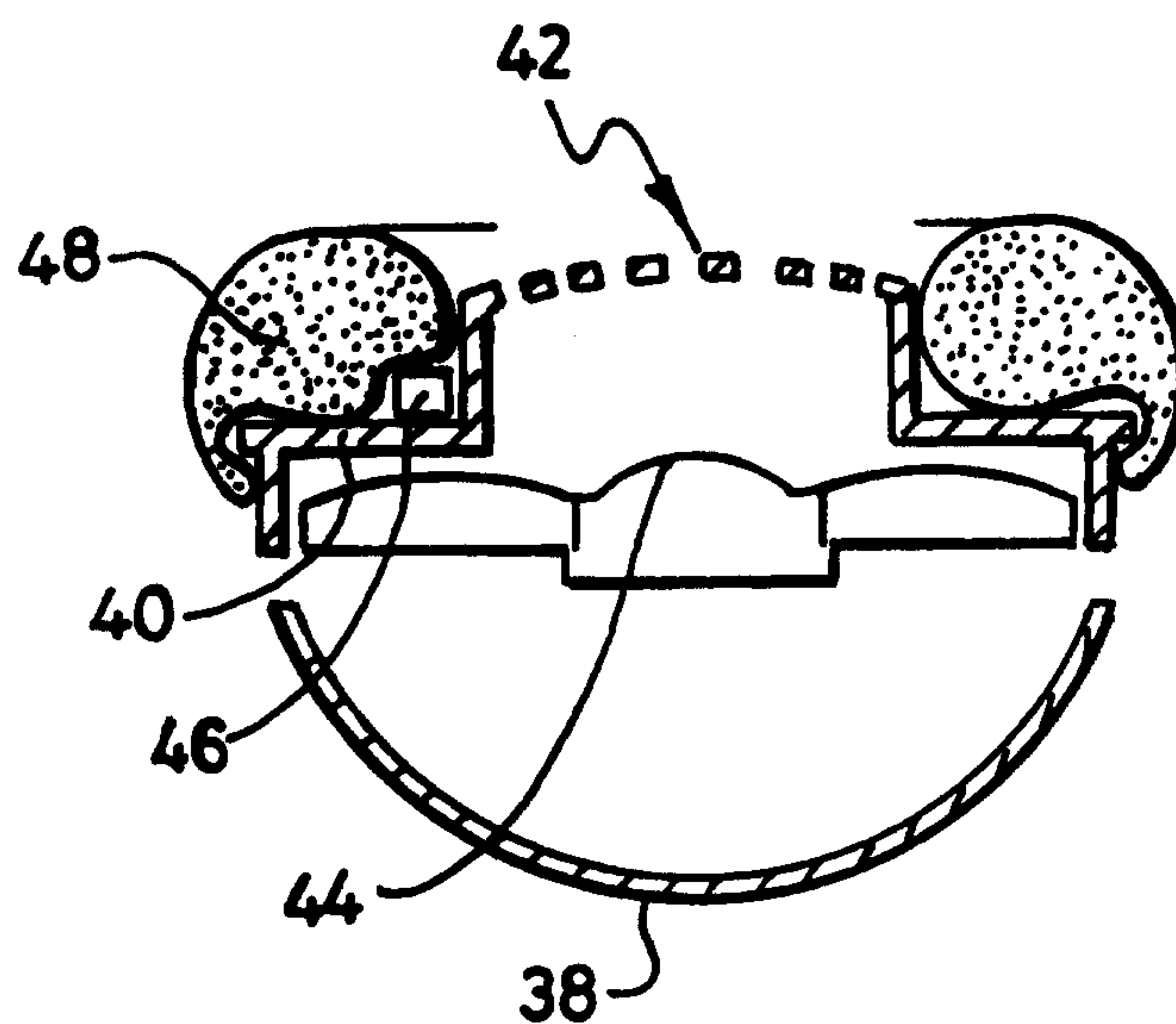


Fig. 9

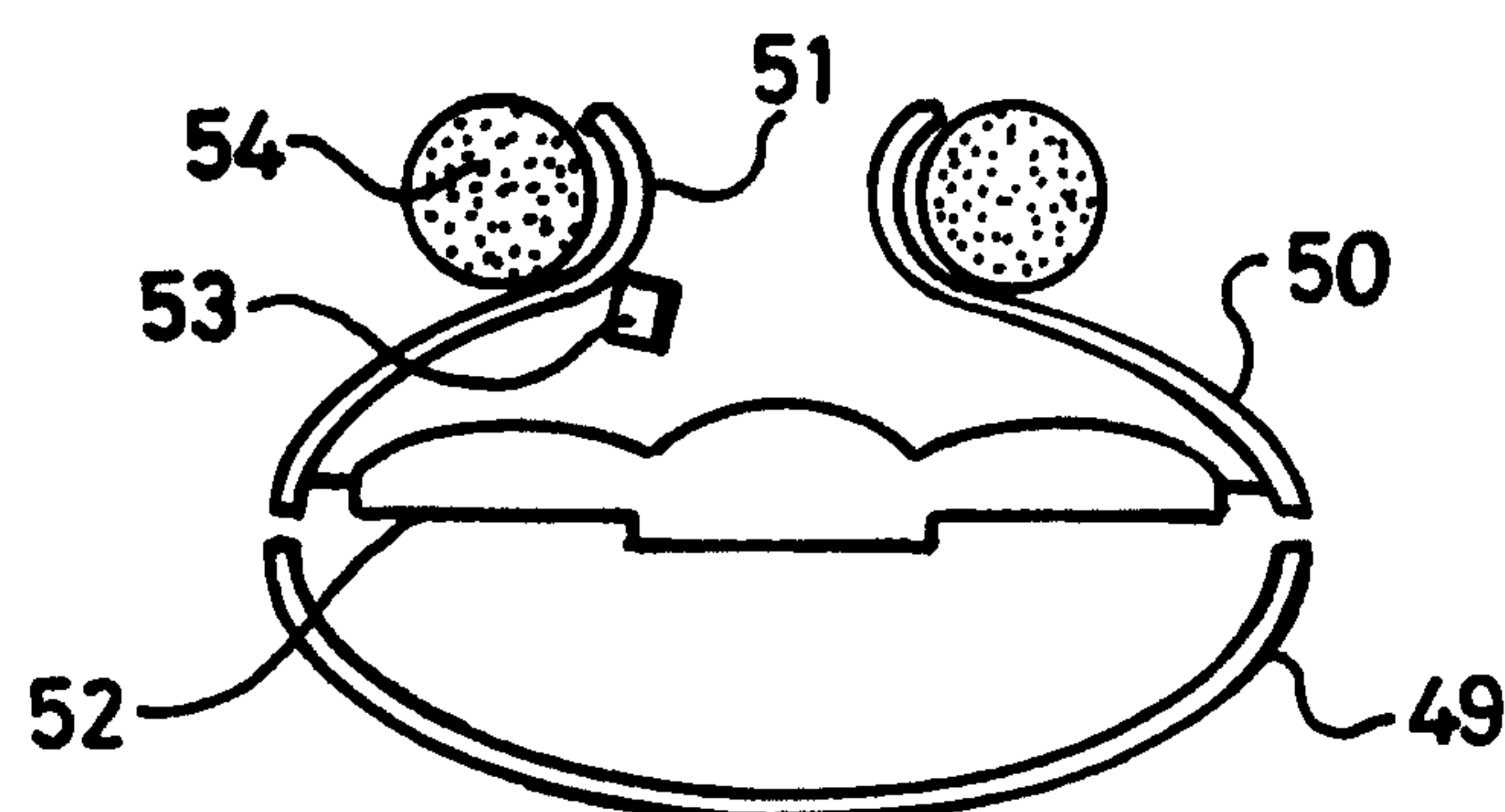


Fig. 10

