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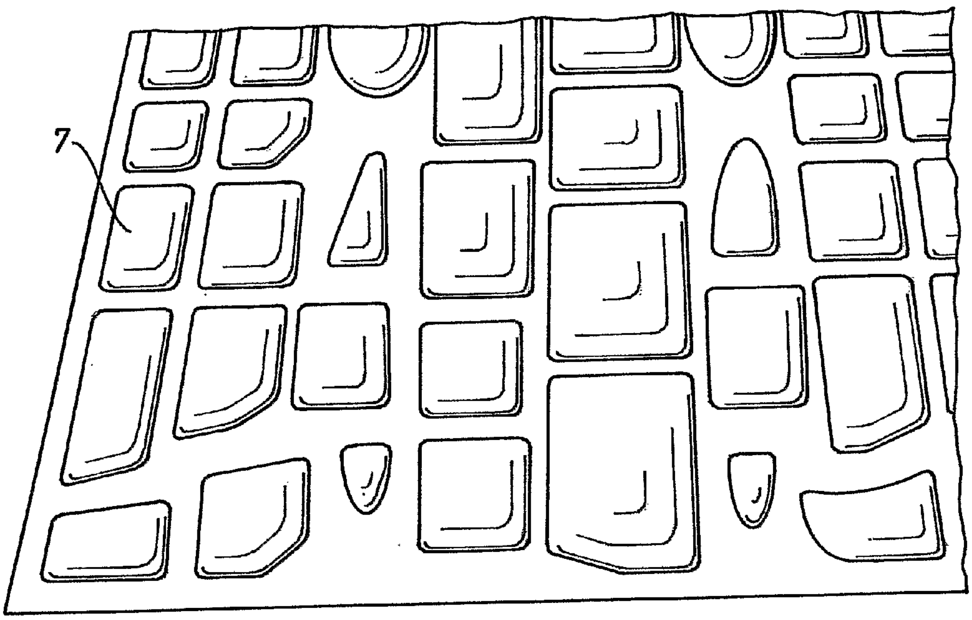
(54) **Title:** SEALED THIN MULTI-LAYER SOUND ABSORBER



(57) **Abstract:** The invention relates to a thin sound absorbing multi-layer assembly, which is intended, in particular, to reduce interior or exterior noise of a motor vehicle. The assembly according to the invention comprises at least three stacked layers consisting respectively of: a first layer (4) being impervious and having an area weight of between (20) to (100g/m2); a second layer (3) having an air flow resistance of between (250) to (2500Ns/m3) and an area weight of between (15) to (250g/m2); a third layer (2) being an open pored, acoustic spring type layer having a thickness of between (2) to (30mm) and an area weight of between (50) to (1000g/m2).

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Sealed thin multi-layer sound absorber

The present invention relates to a multi-layer sound absorber to be fixed on a carrier layer for reducing the exterior and interior noise caused by the engine of an automotive vehicle or its rolling wheels, in particular in the engine and under body regions of the automotive vehicle, according to the preamble of claim 1.

Modern car industry is increasingly seeking low-noise vehicles, i.e. vehicles preventing noise to be emitted to the interior or the exterior. For reducing the interior noise caused by the rolling wheels, the wheel housing outer liners and the aerodynamic under floor shields are provided with sound proofing materials. For reducing the exterior and the interior noise caused by the engine, the size and the number of the apertures of the engine compartment are minimized and the amount of absorbing material around the engine is maximized. Because of the presence of dirt, sand, water, snow, salt, ice and liquids like oils, coolant, battery fluid, brake fluid, fuels, washer liquid with anti-freeze and many other contaminating materials, the sound proofing materials located outside the passenger and trunk compartments need to be protected.

As disclosed in EP-0'229'977 it is known to use as a first measurement of protection a hydrophobic and oleo-phobic porous face fabric or a thin foil. This type of protection is sufficient for parts located near to the belt line of the vehicle, typically near to the engine top or the hood, like hood absorbers or water box absorbers, but generally it is not suitable for absorbers used near to the ground, like the under engine shield absorbers, as disclosed in FR-2'387'822, for which imperviousness and a certain ruggedness is required. It is evident for the man skilled in the art of acoustics that such qualities reduce the absorption properties of the absorber.

WO2005/007458 discloses an acoustically effective wheel housing which consists of at least three open pored layers having different air permeability. Unfortunately this kind of absorber sooner or later attracts external agents (dirt or salt in winter, humidity) which destroy the acoustic performance and increase the weight of the whole part.

It is also known to use wear resistant closed celled absorbers, as disclosed in WO02/066312, for manufacturing light-weight and noise reducing wheel housing elements, instead of open celled or fibrous absorbers sealed in a bag. Known closed celled polypropylene foam absorbers, in particular formed as a chamber absorber, as described in WO99/44816 or JP-58-177781, are lightweight and possibly low cost but their absorption properties are poor (absorption is rarely above $\alpha = 0.6$), especially if the size of the chambers (height, width or length) is below 20mm and the chamber walls are becoming too stiff, and little energy being dissipated inside the wall material itself.

Sealed absorbers generally are made of a non-woven felt die cut blank, generally cotton felt with phenolic resin, or alternatively of a slab of open cell PUR foam placed in a bag made of two foils welded together. The absorber is affixed to the under floor shield by fasteners, double sided tape or more generally by high frequency welding points. The acoustic absorption behaviour of a sealed single layer open celled absorber is generally spiky in the frequency domain (absorption peak has a narrow frequency bandwidth) and the maximum of the absorption value α is generally smaller than 0.8.

As known from PCT/CH2004/000572 it is acoustically advantageous to replace the known sealed single layer absorber by a two felt layer structure sealed in a bag. The sealed absorber described in above application comprises a top felt layer which exhibits an air flow resistance of between 300 to 1200Ns/m^3 (air flow resistance may be unambiguously determined using measuring methods as stated in ISO 9053 norm) and a bottom felt layer which has a thickness of between 1 to 20mm, typically 5 to 10mm. Both felt layers have an area weight of between 300 to 1200g/m^2. By using this layout a maximum absorption of $\alpha = 1$ could be reached, but more importantly this absorption shows a much wider peak frequency bandwidth. Unfortunately the area weight of the obtained laminate is typically around

1000g/m^2, which is rather heavy especially compared with the above mentioned chamber absorber.

In view of WO01/89883 a further critical parameter is the thickness of the absorber in a bag. A reduction of the thickness of the absorber shifts its maximum absorption frequency f_0 to a higher frequency region. If one tries to reduce the thickness of the absorber one takes the risk that the absorption spectrum of the absorber does not correspond anymore to the averaged noise spectrum of the engine or rolling noise, which the absorber was supposed to dissipate. For example a 10mm thick felt absorber with a 60g/m^2 foil has its maximum absorption peak in the region of about 2500Hz, while a rolling noise peak is generally generated at around 1000Hz.

Unfortunately all of the known products for reducing the exterior and the interior noise caused by the engine or the rolling wheels of an automotive vehicle show well recognized limitations and shortcomings. The known noise reducing wheel housing outer liners or under floor shields provide either a poor degree of sound absorption, tend to wear off and degrade over time, are heavy and space consuming, or absorb frequencies in a small bandwidth only. Most of them are difficult and expensive to manufacture.

Therefore it is the object of present invention to provide a sound absorber having excellent acoustic performance and broad frequency bandwidth, with significant weight and thickness savings and reduced production costs.

This is achieved according to the invention by a sealed thin multi layer laminate sound absorber having the features of claim1 and in particular by a sealed dual-layer sound absorber to be mounted on a carrier layer. The sound absorber according to the invention is to be mounted on a carrier layer and comprises at least three layers:

- a first layer, typically a foil having a thickness of 20 -100 μm and preferably 40 μm, being impervious to water and having an area weight of 20 to 100g/m^2, preferably less than 60g/m^2,
- a second layer being porous (preferably open pored) and having a thickness of 0.1 - 1.5mm, preferably of less than 1mm, in particular of 0.1 -

0.5mm, and a weight per unit area of from 15 - 250g/m^2, in particular of 25 - 150g/m^2, preferably 100g/m^2 and exhibiting an air flow resistance in the range of 250 < R_t < 2500 Ns/m^3, preferably 750 Ns/m^3,
- a third layer being an open pored non-woven fibre layer or an open cell foam layer and having a thickness of 2 - 30mm, preferably of 8mm, and an area weight of 50 to 1000g/m^2, preferably of 250g/m^2, whereby the first layer is protecting the other two layers against humidity or any other exterior contamination.
The preferred embodiment has an overall thickness of less than 10mm and an area weight of less than 500g/m^2, while providing an excellent sound absorption at the same time.

This sound absorber exhibits the surprising property that a conventional felt layer with a given air flow resistance of typically 300 to 1200Ns/m^3 and having a weight of typically 500g/m^2 and being about 4mm thick can be replaced by a much lighter (typically 25 - 100g/m^2) and much thinner (typically 0.1 - 0.5mm) layer, as long as the airflow resistance is maintained. This high airflow resistance can only be obtained by choosing very carefully the fineness of the fibres. Alternatively a micro-perforated foil with an appropriate hole diameter and open area ratio may be used for the same purpose.

In the preferred embodiments the first layer is, at least partially, made of polypropylene, polyester, polyamide or any thermoplastic polyolefin, or is made of a thermo set plastic, in particular polyurethane. The second layer comprises meltblown micro-fibres, the fibre fineness of which amounts 0.1 - 0.5 dtex. The second layer comprises polypropylene, polyester, copolyether-polyester, polyethylene, polyethylene terephthalate, polybutylene terephthalate or polyamide micro-fibres. The second layer may also be made of a micro-perforated layer, the perforations of which having a diameter or slit length of between 0.1 – 1.0 mm and generating an open area ratio of between 0.01 - 5%. The third layer is a non-woven layer of synthetic fibres, in particular polyester fibres or of natural fibres, in particular cotton fibres, or of a mixture of natural and synthetic fibres. The third layer comprises binders, in particular bi-component fibres, thermoplastic fibres, thermoplastic or thermoset resins, or rubber, or a combination thereof; or is anon-woven layer of fibres, which have been interlocked by means of a needling process or by means of water jet treatment. The third layer is a foam layer with a density of 10 to 50kg/m^3 and consists of an open cell foam, in particular polyurethane foam or melamine foam. The second layer has an area weight of 25 – 150 g/m^2. It appears to be advantageous for the absorber according to the invention, that the second and third layer, when measured together, have a combined air flow resistance in the range of $400 < R_t < 3000$ Ns/m^3, while the second layer has an air flow resistance in the range of $250 < R_t < 2500$ Ns/m^3, in particular $500 < R_t < 1000$ Ns/m^3. According to the present invention the multi-layer is sealed against liquids and dirt. This is achieved by the encapsulation of the second and the third layers between the first layer and a supportive carrier layer or preferably by a fourth impervious layer facing the third layer. Preferably the laminate is sealed against liquids and dirt on its edges by welding the first layer against the fourth layer on the edges of the laminate. In another preferred embodiment the multi-layer is sealed against liquids and dirt on its edges by welding all the layers together on the edges. The obtained absorbing multi-layer may be fixed to a supporting carrier by means of high frequency welding on points, double sided tape or by separate fasteners. The first, second and third layers may be welded together on the edges of the multi-layer against a supportive carrier layer in order to provide sealing against liquids and dirt without the expense of the fourth layer. The laminate may be encapsulated between the first layer and the supportive carrier layer by means of a continuous line of welding along the edges of the first layer. The three layers may be welded together on the edges of the laminate against a supportive carrier layer in order to provide sealing against liquids and dirt.

A further development of the present invention foresees to create individual pockets with the purpose to modify the absorption curve of the multi-layer and to avoid that, in case of a rupture or other damage of the first layer the whole multi-layer (or laminate) is contaminated and its acoustical performance is ruined. This structural design is only possible with sealable materials.

The technical advantages of the present invention are evident for the man skilled in the art and are to be seen in the significant reduction of thickness, reduction of weight, improvement of absorption performance and simple production.

In the following, preferred embodiments of the invention are described in more detail referring to the Figures, whereby:

Fig. 1 is a schematic view of a multi-layer absorber according to the invention;

Fig. 2 is a diagram disclosing the acoustic performance of the multi-layer absorber according to the invention;

Fig. 3 a, b are schematic views of different structural designs of the multi-layer absorber according to the invention;

Fig. 4 a, b, c are schematic views of different fixation constructions of a preferred embodiment of the multi-layer absorber according to the invention;

Fig. 5 is a three dimensional view of a further development of the multi-layer absorber according to the invention;

Fig. 6 is a diagram representing the frequency dependant absorption of the multi-layer absorber according to Fig. 5.

Figure 1 shows a schematic view of the structural design of the multi-layer absorber 1 according to the invention. This multi-layer absorber comprises a third layer or spacer 2 preferably consisting of a 100% PET felt with bi-component fibres. In a preferred embodiment this spacer 2 is 8 mm thick and has an area weight of about 250 g/m^2. It is within the scope of normal technical design to vary the thickness of this layer, i.e. in a range of between 4 and 12 mm, and to simultaneously vary the area weight or the density in order to achieve optimal acoustic properties. As well the fibres diameter and length may be optimized. The fibres of the preferred embodiment have a finesse of 5 dtex. It is understood that this acoustic spacer 2 may consist of an open celled foam material of thermoset plastics, in particular of polyurethane or melamine.

A thin and porous second layer 3 is arranged on top of this spacer 2. This second layer 3 consists preferably of a PP non-woven of approximately 50 g/m^2. It is essential for the invention that this porous (open pored) second layer 3 has a high air flow resistance value R_t. For the preferred embodiment an airflow resistance R_t of about 600 Nsm^{-3} is used. This so called AFR layer has in accordance with the invention a thickness of less than 1 mm. Preferably this non-woven comprises micro-fibres consisting of polypropylene, polyester, copolyether-polyester, polyethylene, polyethylene terephthalate, polybutylene terephthalate or polyamide.

On top of this AFR-layer 3 there is arranged a thin foil 4 preferably made of PP. This kind of foil has a conventional thickness of about 50 μm and an area weight of less than 50 g/m^2.

A further embodiment of the above described thin layer multi-layer absorber 1 further comprises a bottom foil (not shown) adjacent the spacer 2. This bottom foil has preferably an area weight of less than 50 g/m^2 and is either directly sealed with the top foil 4 or sealed together with all other layers of the multi-layer absorber 1 in order to protect the open pored layers 2,3 from any contamination.

Figure 2 shows the diagram comparing the acoustic performance (absorption) of the multi-layer absorber 1 (curve A) with a conventional sealed absorber (curve B) comprising a felt spacer encapsulated in a foil bag. As is clearly recognisable from this diagram the sound absorber according to the invention has an increased absorptive capability over the whole frequency range from 500 to 5000 Hz, although this sound absorber 1 is 50% thinner and 25% lighter than the conventional one.

Figures 3a and 3b show different embodiments of the present invention. According to Figure 3a the top layer 4 (first layer) exceeds the porous layers 3, 2 and is welded to a supportive carrier layer 5. The supportive carrier 5 is preferably but not exclusively an under engine shield, an aerodynamic under floor shield, a wheel housing outer liner shield or a top engine cover. Therewith the thin second layer 2 and the spacer 3 are protected against humidity or any other exterior contamination. Depending on the materials used for the open pored layers 2, 3 the complete thin layer multi-layer 1 may be welded to the supportive carrier layer 5, i.e. all individual layers are welded together, in order to achieve a water tight seal, as shown in Figure 3b.

Figures 4a – 4c show schematical views of different constructions for affixing a further embodiment of the multi-layer absorber 1 to the supportive carrier layer 5. This embodiment comprises a bottom foil 6 in order to encapsulate the porous layers 2, 3. The sealing of the absorber is achieved by welding the top foil 4 to the back foil 6 or advantageously by welding all the layers together in order to do without the pre-cutting stage of the layers 2 and 3. For both mentioned embodiments the thin layer multi-layer absorber may be mounted to the supportive carrier 5 by high frequency welding points 8, double sided tape 9 or separate fasteners 10 as illustrated in Figures 4a - 4c.

Figure 5 shows a three dimensional view of a further development of the multi-layer absorber 1 according to the invention. This development comprises a plurality of individual pockets 7 enclosing at least a porous acoustic spacer made of fibrous material (PET material) and a porous thin AFR-layer according to the invention and made of a micro-fibre felt (PP material). The individual pockets have a thickness of about 7 to 20 mm.

Figure 6 shows the acoustic effect of the pocket size of the sound absorber according to the invention. Curve C within the shown diagram represents the absorptive behaviour of an inventive sound absorber without any pockets. Curve D shows the absorptive properties of an inventive sound absorber with pockets having a width of 200 mm, while curve E represents the absorptive behaviour of an inventive sound absorber with pockets having a width of 75 mm. It becomes evident from this diagram that the size of the pockets shifts the absorption capability to higher or lower frequencies but does not influence the over-all performance.

The technical advantage of the present absorber comprising a sound absorbing thin multi-layer composition is obvious to the man skilled in the art and is to be seen in the significant reduction of thickness, the reduction of weight, improvement of the absorption performance, and reduction of production costs.

Claims:

1. A multi-layer sound absorber (1) to be mounted on a carrier layer or a frame (5) for reducing the exterior and interior noise caused by the engine of an automotive vehicle or by its rolling/rotating wheels, in particular in the engine region, or the under body regions, or the wet area of doors of automotive vehicles, comprising at least three layers:
   - a first layer (4) being impervious to contaminations and having an area weight of 20 - 100g/m^2,
   - a second layer (3) being open pored or open celled, and exhibiting an air flow resistance R_t in the range of $250 < R_t < 2500$ Ns/m^3,
   - a third layer (2) being porous and in particular consisting of an open pored non-woven fibre layer or an open celled foam layer and having a thickness of 2 - 30mm and an area weight of 50 to 1000g/m^2,

   whereby the first layer (4) is designed to seal the other two layers (3, 2) against any exterior contamination, characterised in that the second layer (3) has a thickness of 0.1 - 1.5mm, in particular of 0.1 - 0.5mm, and has a weight per unit area of 15 - 250g/m^2, in particular of 25 - 100g/m^2.

2. Sound absorber (1) according to claim 1, characterised in that the second layer (3) has an air flow resistance in the range of $400 < R_t < 1500$ Ns/m^3, in particular $500 < R_t < 1000$ Ns/m^3.

3. Sound absorber (1) according to one of the claims 1 or 2, characterised in that the second layer (3) comprises micro-fibres, the fibre fineness of which amounts to 0.1 - 0.5 dtex.

4. Sound absorber (1) according to claim 2, characterised in that the micro-fibres are made of polypropylene, polyester, copolyether-polyester, polyethylene, polyethylene terephthalate, polybutylene terephthalate or polyamide.

5. Sound absorber (1) according to one of claims 1 - 4, characterised in that the second layer (3) has an area weight of 50 - 100g/m^2.

6. Sound absorber (1) according to one of the claims 1 or 2, characterised in that the second layer (3) is a micro-perforated layer, the perforations of which having an opening size of 0.1 – 1 mm and generate an open area ratio of 0.01 - 5%.

7. Sound absorber (1) according to claim 1, characterised in that the third layer (2) is a non-woven layer comprising synthetic fibres, in particular polyester fibres, or natural fibres, in particular cotton fibres, or a mixture of natural and synthetic fibres.

8. Sound absorber (1) according to claim 7, characterised in that the third layer (2) comprises binders, in particular made of bi-component fibres, thermoplastic fibres, thermoplastic or thermoset resins, rubber or a combination thereof.

9. Sound absorber (1) according to claim 1, characterised in that the third layer (2) consists of a foam layer with a density of 10 to 50kg/m^3.

10. Sound absorber (1) according to claim 9, characterised in that the third layer (2) consists of an open celled foam, in particular made of polyurethane or melamine.

11. A sound absorber (1) according to one of claims 1 and 3 - 10, characterised in that the second (3) and third layer (2), when measured together, have a combined air flow resistance in the range of $400 < R_t < 3000$ Ns/m^3.

12. Sound absorber (1) according to claim 1, characterised in that the first layer (4) is made, at least partially, of polypropylene, polyester, polyamide, thermoplastic olefin, or any other thermoplastic material, or is made at least partially of a thermoset plastic, in particular polyurethane.

13. Sound absorber (1) according to any of claims 1 - 12, characterised in that the absorber (1) comprises a fourth layer (6) facing the third layer (2) and being impervious to contamination.

14. Sound absorber (1) according to claim 13, characterised in that the absorber (1) is sealed by welding the first layer (4) with the fourth layer (6) along their edges.

15. Sound absorber (1) according to claim 13, characterised in that the absorber (1) is sealed by welding all the layers together along their edges.

16. Sound absorber (1) according to one of claims 1 - 15, characterised in that the absorber (1) is affixed to a supporting carrier (5) by means of high frequency welding (8).

17. Sound absorber (1) according to one of claims 1 - 15, characterised in that the absorber (1) is affixed to a supporting carrier (5) by means of a double sided tape (9).

18. Sound absorber (1) according to one of claims 1 - 15, characterised in that the absorber (1) is affixed to a supporting carrier (5) by means of separate fasteners (10).

19. Sound absorber (1) according to one of claims 1 – 12, characterised in that the first layer (4) is welded to the supporting carrier layer (5) in order to provide fixation and sealing against any contamination of the second (3) and the third layer (2).

20. Sound absorber (1) according to one of claims 1 - 12, characterised in that at least the first (4), the second (3) and the third (2) layer are welded together to the supportive carrier layer (5) in order to provide a fixation and sealing against any contamination to the second (3) and the third (2) layer.

21. Sound absorber (1) according to one of claims 1 - 20, characterised in that the absorber (1) comprises a plurality of individually sealed pockets (7).

22. Sound absorber (1) according to claim 7, characterised in that the third layer (2) is made of a non-woven layer of fibres which are interlocked by means of a needling process or by means of a water jet treatment.

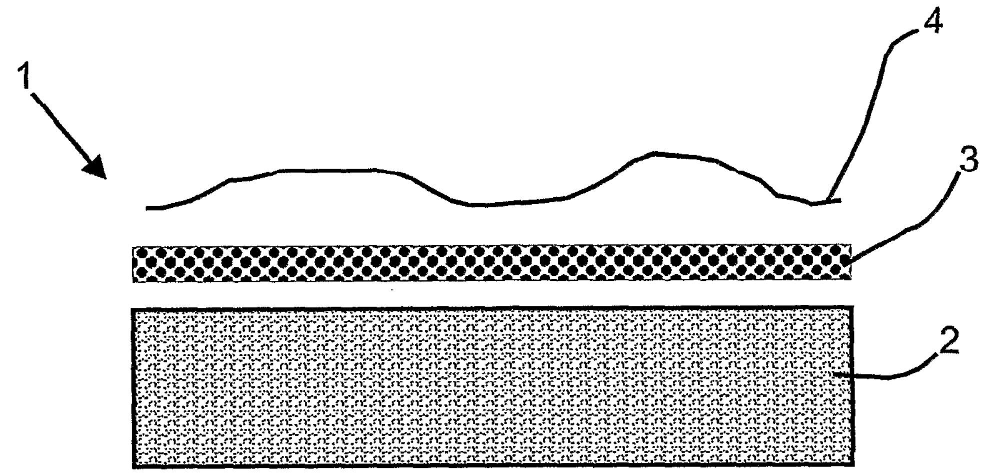

Fig. 1

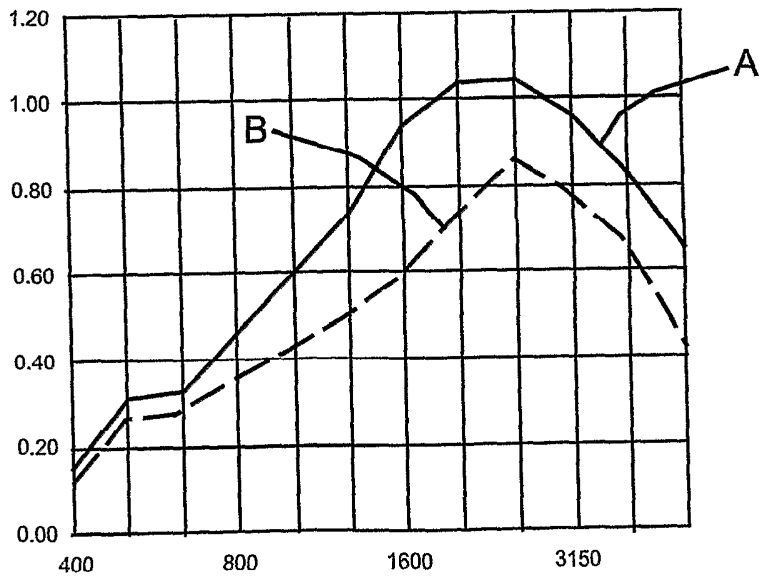

Fig. 2

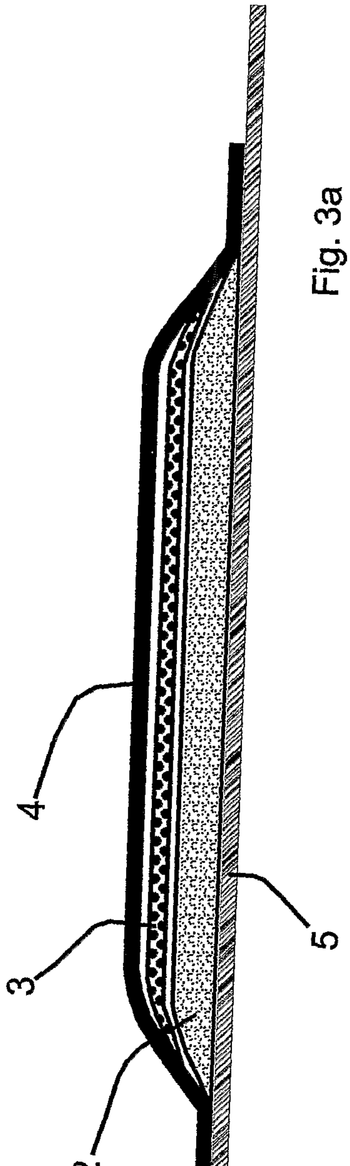

Fig. 3a

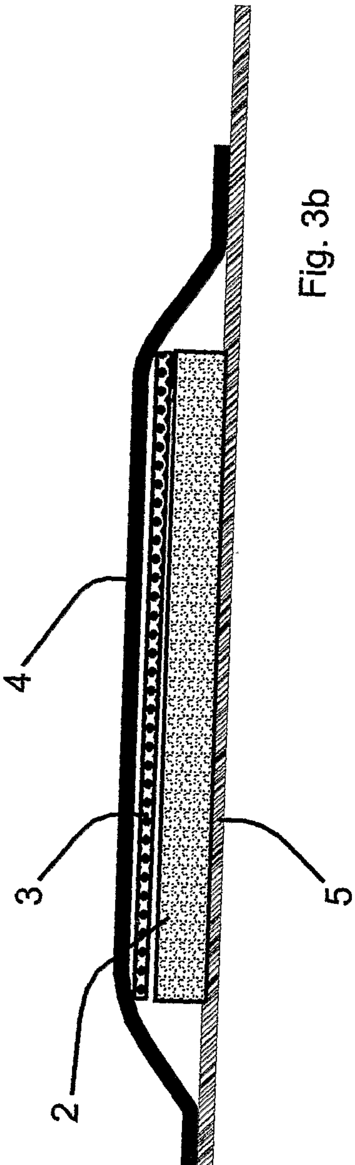

Fig. 3b

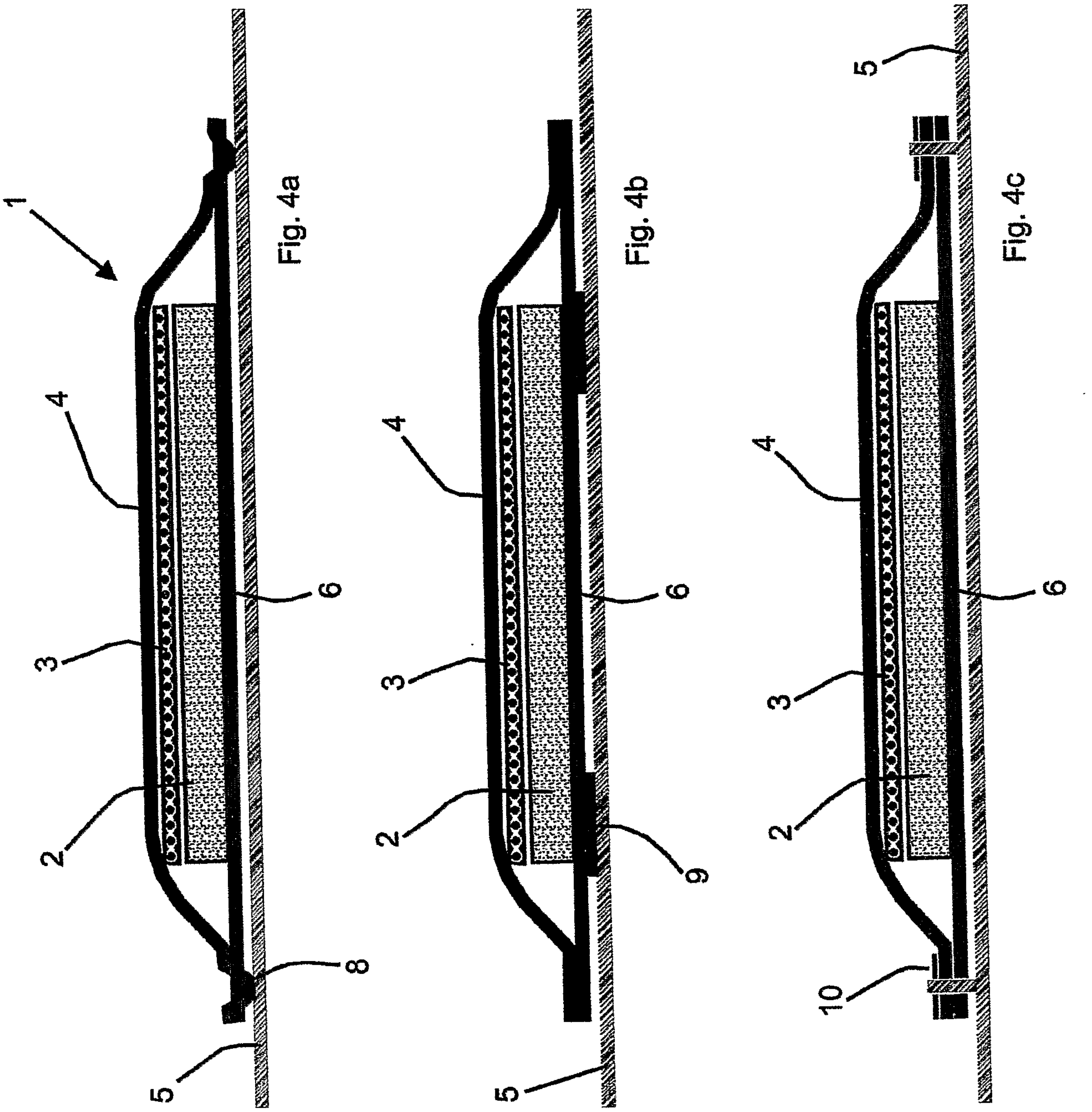

Fig. 4a

Fig. 4b

Fig. 4c

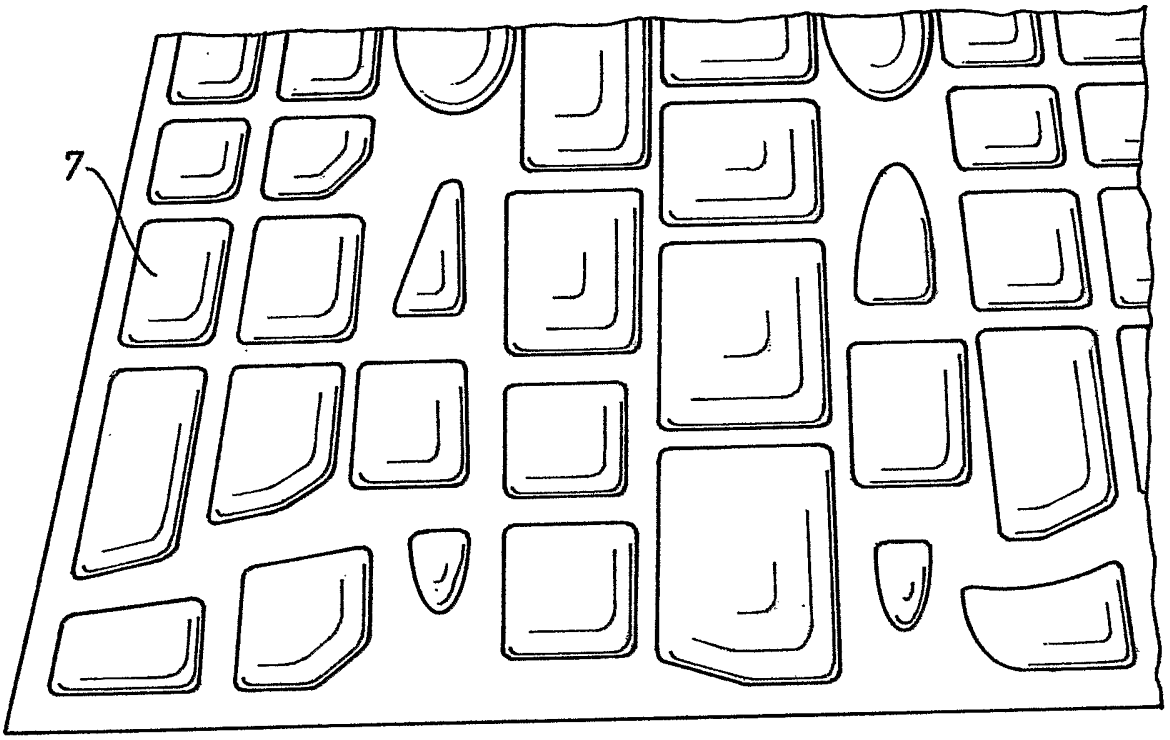

Fig. 5

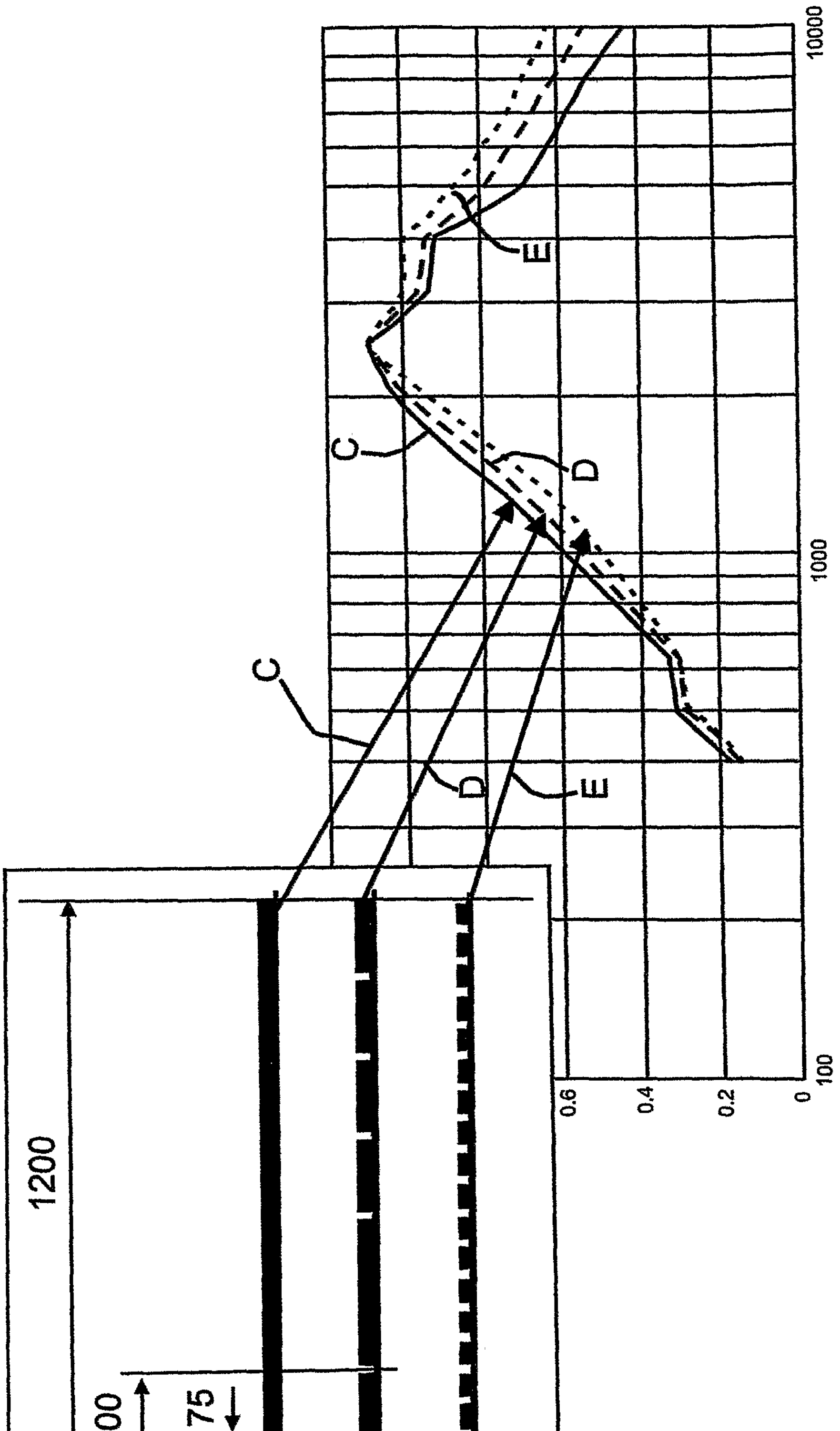

Fig. 6