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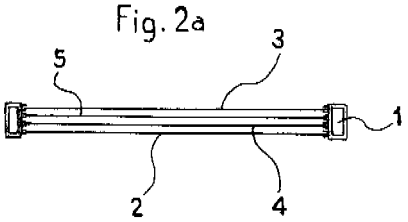
(54) Sound-absorbing transparent panel

(57) Sound absorbent panel of the type comprising a frame (1) to support at least a first front sheet (2) provided with a plurality of holes (12) and at least a second rear sheet (3) not perforated, substantially parallel with a said first sheet, and separated from the latter by a hollow air cavity, wherein said first sheet and said second sheet are realised in a material at least partially transparent The panel is characterised in that the holes of said first front sheet are micro-holes (6).

Fig. 2a



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Description

[0001] The present invention relates to a sound absorbent and acoustic insulation panel of the type comprising a framework, preferably of the cornice type, suitable to support a perforated front sheet associated in a parallel manner, with a rear non perforated sheet, and having a suitable air space sandwiched between the two sheets.

[0002] Hereafter the term "front sheet" will refer to that sheet facing the direction of the sound source (noise source), in other words, that sheet which is in initial contact with the sound wave generated by the noise source.

[0003] In prior technical art, as opposed to more common acoustically insulated panels composed of a support frame for a sheet coated, or composed of, a sound absorbent material (such as a polystyrene foam or an open cell polyurethane for example), sound absorbent panels have been produced, composed of a perforated front sheet separated at a certain distance from a non perforated sheet, by a hollow air cavity. These panels are able to dissipate the acoustic energy of particular frequencies thanks to the friction which is developed during the oscillation of the air inside said hollow cavity between the perforated and non perforated sheets, during the passage of the sound wave between said panels, according to an operation pattern that can be considered similar to that of the Helmholtz resonator.

[0004] In particular, in said panels, the dissipation of the acoustic energy of a certain frequency of the sound wave that strikes against the panel is at its maximum when the air oscillation reaches the frequency of system resonance. Since said resonance frequency is given by the geometry of the panel (including the hole diameter), for each panel geometry, and therefore for each hole diameter, the attenuation, through dissipation, only of a certain frequency of the sound wave to be attenuated.

[0005] In order to attenuate different frequencies of the sound wave that have an impact on the same panel, and therefore in order to reduce the noise, in prior technical art, panels have been produced such as the type described above, that include holes having different diameters on the same front sheet.

[0006] For example, patent EP-A-0 890 679 in the name of the Applicant DIESELBOX S.A., describes a sound absorbent panel of the aforesaid type, wherein the perforated sheet presents a plurality of holes of varying diameters, able to deaden different frequencies of the sound wave that hit the panel, by means of dissipation, according to the principle of the Helmholtz resonator. Furthermore, in said patent, the two parallel sheets that form the panel are composed of a transparent material, for use in installations out of doors, without creating barriers to light, which could be potentially harmful.

[0007] However, said panels resulted as being not particularly efficient, partly because they were able to absorb the frequencies for which they were configured only to a limited extent, because of the reduced number of holes of each diameter present on the sheet, and partially because, being based on the principle of the Helmholtz resonator which substantially provides for the absorption of the frequencies of the sound wave only for those oscillations able to induce a resonance frequency in the system composed of the small volume of air present between each hole and the non-perforated wall.

[0008] Furthermore, in this type of panel, the vibrations induced in the casing which supports the sheets generally transmit noise, in other words, sound at frequencies which it is intended to deaden with this type of panel.

[0009] Therefore an aim of the present invention is to produce a panel of the aforesaid type, wherein the drawbacks present in prior technical art, do not occur, or are at least reduced.

[0010] In particular, one aim of the present invention is to produce a sound absorbent and acoustic insulation panel of the type comprising a frame that supports at least two transparent sheets, parallel with each other, of which, one is perforated and the other is solid, and which demonstrate considerable efficiency in reducing the noise at the required frequencies during the project design stage, which is simple to construct, does not require complicated maintenance, and at the same time, does not form an undesirable barrier to light transmission.

[0011] Another aim of the present invention is to produce sound-proof barriers for use along roadways, composed of one or more of the aforesaid panels, which are efficient in reducing noise and which at the same time have a low impact on the environment.

[0012] These and other aims are achieved by the sound absorbent panel according to the first independent claim and the following subordinate claims.

[0013] The sound absorbent panel, according to the present invention, comprises a support frame for a first front sheet, being at least partially transparent, perforated with a plurality of holes, and a second rear sheet, also partially transparent, not perforated, substantially parallel to the said first perforated sheet, and separated from it by a hollow air cavity (i.e. a air space). Advantageously, the panel of the present invention envisages that the holes of said first front sheet are micro-holes.

[0014] It should be noted that the term "at least partially transparent sheet", refers to the fact that the relative sheet is transparent for at least a certain set of light wavelengths and that therefore, the sheet may be coloured, but not opaque.

[0015] It should also be noted that hereinafter, the term "micro-holes" refers to holes, similar to those generally cylindrical with a circular section, having a size (and in particular the diameter) comparable to the size of the acoustic boundary layer. In this case the noise absorption no longer occurs mainly due to energetic dissipation at the resonance frequency of the system (like the Helmholtz resonator.), but more because of damping caused by non adiabatic variations of the state of the air in proximity to the perforated walls, and by the force of the viscous friction between shear layers of the air flow.

[0016] Given the diameter and the density of the micro-holes (if we consider the preferable distance between adjacent micro-holes as ranging between 3mm and 12mm), sometimes the term "porosity" may be used to describe the perforations on the aforesaid micro-perforated sheet.

[0017] Naturally, the coupling of at least one micro-perforated sheet with a solid sheet, set in a parallel position thereto, according to the present invention, does not prevent an additional damping from occurring, caused by the resonance in the chamber defined between said sheets, according to the principle of the Helmholtz resonator. In other words the panel according to the present invention, would seem to combine both the aforesaid principles for noise reduction, in other words, the damping of the acoustic energy above all caused by the viscous friction in the micro-holes and, although only partially, the energetic dissipation of the resonance frequency of the system (Helmholtz).

[0018] The use of said micro-holes, generally having a diameter less than or equal to 2mm and preferably having a diameter less than 1mm in sheets with a thickness between 1.5mm and 7mm, implicates some physical behaviour by the panel of the present invention which differs from the behaviour based on the principle of the Helmholtz resonator of the non-micro-perforated sheets, common to technical state of the art; physical behaviour which, in the panel of the present invention, has resulted far more efficient in noise reduction than the behaviour of panels according to the prior art.

[0019] Furthermore, according to a preferred embodiment of the present invention, the sound absorbent panels comprise one or more further transparent micro-perforated sheets, sandwiched at fixed distances between and parallel with said first front micro-perforated sheet and with said second rear sheet. Each of the perforated sheets of said panel can also advantageously present a plurality of micro-holes having the same constant diameter, and wherein said constant diameter of the micro-holes of each sheet is different from the diameter of the micro-holes of every other sheet.

[0020] According to another embodiment of the present invention, the panel comprises parallel sheets, preferably made of polycarbonate, metacrylate, acrylic, or other synthetic material, with at least a partially curved surface, which have resulted as being not only efficient in noise reduction, but also adaptable for use with the particular geometries required in certain areas where the panels are to be installed.

[0021] Furthermore, according to a preferred embodiment of panel according to the present invention, the frame for the transparent sheets, preferably specifically shaped in cornice form, is produced in, or comprises traditional sound absorbent material, such as polyurethane or glass fibre or mineral fibre etc., in order to limit potential noise diffusion through said frame.

[0022] According to a particularly advantageous embodiment said frame metal for example, inside which traditional sound absorbent material is inserted.

[0023] According to another particularly advantageous embodiment of the present invention, the frame for the transparent sheets comprises at least one element with a surface having a plurality of holes, or micro-holes, coupled at a set distance with another solid surface to provide sound absorbent capacity according to the principle of the Helmholtz resonator (if holes with a large diameter are used, for example, larger than 2mm), and/or the same principle (damping through viscous friction and attenuation of resonance frequency) of the transparent micro-perforated sheets coupled with the non perforated sheets described in the following claims.

[0024] Below is a description, provided simply as a non limiting explanation, of several embodiments of the sound absorbent panel according to the present invention, with reference to the enclosed figures, wherein:

Figure 1 shows a front view of a sound absorbent panel according to a particular aspect of the present invention;

Figures 2a and 2b show a cross section and a profile view respectively of the panel shown in figure 1;

Figure 3 shows a side section view of part of a micro-perforated sheet of the panel shown in figure 1, illustrating a micro-hole;

Figure 4 shows a cross section view of part of the frame of a sound absorbent panel, according to another aspect of the present invention; and

Figures 5a and 5b show views in cross section and profile respectively of a sound absorbent panel according to a particular aspect of the present invention, with curved sheets;

Figure 6 shows a profile view of a sound absorbent panel according to a further aspect of the present invention, with sheets only partially curved;

Figure 7 shows a front view of a soundproof barrier for use on roadways comprising a plurality of sound absorbent panels, according to another specific aspect of the present invention.

[0025] With reference first of all to figures from 1 to 4, the sound absorbent panel, according to a particular aspect of the present invention, comprises a framework 1, preferably in the form of a cornice suitable to support at least one front sheet 2, with the entire surface perforated with micro-holes, that is, holes 12 having a diameter (d) comparable to the viscous boundary layer of the air in the same holes 12, and a rear, non perforated sheet 3, positioned parallel and at a certain distance from the aforesaid micro-perforated front sheet 2, thus forming a hollow cavity filled with air between said sheets 2, and 3. The sheets 2 and 3 are advantageously not opaque in order to permit the passage of light through the panel.

[0026] With regard to this aspect, the sheets 2 and 3 can be made from transparent or at least partially transparent materials (and therefore coloured) such as polycarbonate, metacrylate, acrylic, glass.

[0027] As stated previously, in order to ensure that the absorption of the sound waves on the front sheet 2 is mainly caused by damping of the oscillation due to the change in the state of the air, and above all due to the viscous type friction between the fluid layers in the holes 12, the diameter (d) of each micro-hole 6, in sheets 2 having a thickness (s) preferably ranging between 1,5mm and 7mm (and at most as far as 10mm), must substantially be equal to or less than 2mm and, preferably, be less than or equal to 1 mm.

[0028] However, it has been discovered that in the panel of the present invention described above, part of the noise reduction, in any case, would also seem to be linked to the principle of the Helmholtz resonator between the micro-perforated sheet 2 and the solid sheet 3. According to a preferred embodiment of the present invention, the diameter of the micro-holes ranges between 0.5mm and 2mm, the distance between the sheets 2 and 3 can be equal to 3.5cm, or more, and the (radial) distance between adjacent micro-holes on the sheet 2 can be equal to 4.2mm.

[0029] In the specific embodiment illustrated in the figures from 1 to 4, the sound absorbent panel comprises at least two additional sheets 4 and 5, also micro-perforated, parallel to the sheets 2 and 3, and positioned at a distance between the latter to provide the space for the relative hollow air cavities between one sheet and the next. The sheets 2 and 3 are also partially transparent to permit the light to pass through the panel, and can be produced in a material selected among polycarbonate, metacrylate, acrylic, glass.

[0030] Moreover, as can be seen in detail in figure 2a and figure 2b, the sheets 2, 3, 4, 5 which together with frame 1 form the sound absorbent panel described herein, are substantially plane/flat sheets.

[0031] According to another particularly advantageous aspect of the present invention, each micro-perforated sheet 2, 4, 5 comprises a plurality of micro-holes 12, positioned in a regular manner over the whole surface and having a constant diameter (d) said constant diameter (d) can vary from sheet to sheet, to permit easy deadening of a wide band of sound frequencies by the panel according to the present invention.

[0032] In particular, said diameter (d) of the micro-holes can be reduced from one sheet to the next, beginning from the front most external micro-perforated sheet (2) as far as the most internal micro-perforated sheet (5).

[0033] Moreover, according to another aspect of the present invention, the distance between the adjacent micro-holes of each micro-perforated sheet 2, 4, 5, can differ from sheet to sheet and in particular said distance can be increasing passing from the micro-perforated sheet 2 positioned furthest from the solid sheet 3 to the micro-perforated sheet 5 closest to the solid sheet 3. The (radial) distance between adjacent micro-holes in the micro-perforated sheets 2, 4, 5 for example, can be equal to 4.2mm, 6.5mm and 10.9mm respectively, beginning from the most external sheet 2 (in other words- that sheet closest to the sound source) as far as the most internal sheet 5.

[0034] The Applicant was able to establish that this specific conformation of the micro-holes in the sheets resulted as extremely important in order to increase the noise reduction efficiency, since it is able to increase the efficacy of the energetic attenuation of the sound wave caused by the principle of the Helmholtz resonator.

[0035] With special reference to Figure 4, the sheets 2, 3, 4 and 5 of the panel described up to this point, are held together by a frame 1, having a cornice configuration, composed of a plurality of structural elements suitable to support said sheets 2, 3, 4, 5, on the ground. The Applicant was able to establish that when said structural elements 1, are produced in or associated with a traditional acoustic insulation (or sound absorbent) material, this makes a considerable contribution towards reducing the impact of sound waves and therefore in reducing the noise.

[0036] In particular, said structural elements of frame 1 can be built using tubular bodies, produced in steel, aluminium, plastic wood, plain or reinforced concrete, inside which at least one acoustically absorbent (or insulating) material 11 can be inserted. This material can be glass or rock wool, polystyrene foam, open or closed cell polyurethane materials, fibre, polyester or bitumen materials, or other types of sound absorbent granular materials.

[0037] This solution which basically prevents the noise from being diffused through the frame 1 of the panel, makes the sound absorbent panels of the present invention particularly effective.

[0038] Alternatively, or used together with traditional acoustic insulation materials, one or more of the structural elements of frame 1 can include a first front surface, in other words, placed on the front micro-perforated sheet 2, equipped with holes or micro-holes, according to the meaning herein attributed to this term, and a second solid rear surface, positioned at a certain distance from the aforesaid first perforated or micro-perforated surface, in order to provide a hollow air cavity between the two surfaces.

[0039] Those skilled in the art will understand that this specific conformation of frame 1, or of some of its structural elements, employs the principle of the Helmholtz resonator, in the case of holes having a large diameter, over 2mm for example, or the principle of viscous dissipation of the acoustic energy through the use of micro-holes, to contribute towards reducing noise even further, basically preventing sound diffusion through the frame 1.

[0040] Furthermore, the structural elements of frame 1, can advantageously include non-permanent means of fixation for the sheets 2, 3, 4 and 5; such means, in the embodiment shown in figure 4, can include guide channels 7, 8, 9 and 10, inside which the respective sheets 2, 3, 4, 5 are inserted by sliding. In more detail, said channels 7, 8, 9, 10 can also be grooved into the two uprights of the frame 1, in a specular way, opposite one other.

The sheets 2, 3, 4, 5 can therefore be inserted between the uprights from at least one of the sides that forms the cross bar on frame 1. By removing one or other of the cross bars of the frame 1, at the top or the bottom, the sheets 2, 3, 4, 5, can be easily replaced or removed for maintenance. In fact, once one of the cross bars has been removed, said sheets 2, 3, 4, 5 can be simply slid out from the frame 1 along the guide channels 7,8,9 and 10.

[0041] According to another aspect of the present invention, not illustrated in the figures, the sound absorbent panel object of the present invention, can comprise means for washing said sheets 2, 3. 4, 5, preferably positioned inside the panel next to the sheets themselves, conceived not only to guarantee at least partial transparency of the sheets 2, 3, 4, 5, but also to ensure that the holes 12 do not become clogged with dust or dirt present in the air.

[0042] In the specific embodiment of the present invention illustrated herein, said washing means, can include piping for a washing fluid which passes inside the cavities of the tubular elements of frame 1, as well as nozzles, included in the same tubular elements positioned inside the air cavities between the successive sheets, and configured to permit the washing liquid to circulate as far as the sheets inside the panel.

[0043] In another embodiment of the sound absorbent panel according to the present invention shown schematically in the figures 5a and 5b, said panel can comprise a frame 101 with a substantially curved configuration, suitable to support the sheets 102, 103, 104 and 105, which also form a curved surface.

[0044] Alternatively, as shown in figure 6, the sound absorbent panel can comprise a frame 201, with relative sheets, only partially curved.

[0045] The use of sheets and frames at least partially curved, makes it easier to adapt the geometry of the sound absorbent panels according to the present invention for installation on sites having a complex geometry.

[0046] Lastly, figure 7 shows a sound absorbent panel according to another aspect of the present invention, in which a frame 301, preferably sound absorbent or coupled with traditional sound absorbent materials, is specifically shaped to support several front transparent micro-perforated panels 302a, 302b, 302c, overlaid on top of one another (or placed side by side).

[0047] The sound absorbent panels described above, and in particular the panels of the last embodiment shown in figure 7, result as being particularly efficient as soundproof barriers for roadways, partly for their capacity to absorb noise, partly for their transparent aspect, as well as for their simple installation and maintenance, and their very high mechanical resistance.

Claims

1. Sound absorbent panel of the type comprising a frame (1) to support at least a first front sheet (2) provided with a plurality of holes (12) and at least a second rear sheet (3) not perforated, substantially parallel with a said first sheet, and separated from the latter by a hollow air cavity, said first sheet, and said second sheet being realised in a material at least partially transparent, **characterised in that** the holes of said first front sheet are micro-holes (6).

2. Panel according to claim 1, **characterised in that** it comprises one or more additional sheets (4, 5) at least partially transparent, micro-perforated, parallel with said first and said second sheet, and sandwiched at a set distance between said first sheet and said second sheet.

3. Sound absorbent panel according to claim 1 or 2, wherein said micro-holes (6) have a diameter less than or equal to 2mm.

4. Panel according to any one of the previous claims, wherein each of said sheets has a thickness ranging between 1.5mm and 7mm.

5. Panel according to any one of the previous claims, **characterised in that** each of said micro-perforated sheets presents a plurality of micro-holes (12) having the same constant diameter (d) .

6. Panel according to claims 2 and 5, wherein said constant diameter of the micro-holes of each sheet differs from that of the micro-holes of at least one other micro-perforated sheet.

7. Panel according to any one of the previous claims in combination with claim 2, **characterised in that** the distance between adjacent micro-holes on one micro-perforated sheet differs from that of at least another micro-perforated sheet.

8. Panel according to claim 7, wherein said distance between adjacent micro-holes on said micro-perforated sheets increases as it passes from the most external sheet to the sheet closest to said non perforated sheet.

9. Panel according to any one of the previous claims, wherein each of said sheets has a plane surface.

10. Panel according to any one of the claims from 1 to 8, wherein each of said sheets has a surface that is at least partially curved

11. Panel according to any one of the previous claims, **characterised in that** said sheets are made from a material chosen among polycarbonate, metacrylate, glass, acrylic.

12. Panel according to any one of the previous claims, **characterised in that** said frame has a cornice configuration.

13. Panel according to any one of the previous claims, **characterised in that** said frame comprises at least one structural element to support said panels.

14. Panel according to claim 13, wherein said frame is produced in a material selected among steel, aluminium, plastic, wood, plain and reinforced concrete.

15. Panel according to any one of the previous claims, **characterised in that** said frame is at least in part sound absorbent.

16. Panel according to claim 15, **characterised in that** said frame comprises at least a sound absorbent (11) material.

17. Panel according to claim 15 or 16, **characterised in that** said frame comprises at least one tubular element, said tubular element being filled internally with said sound absorbent (11) material.

18. Panel according to claim 15, 16 or 17, wherein said sound absorbent material is chosen among glass or rock wool, polystyrene foam, open or closed cell polyurethane material, fibre, polyester, bitumen material or granular sound absorbent material.

19. Panel according to claim 15, wherein said frame comprises at least one element with a first surface having a plurality of holes and a second surface, set opposite said first surface and at a certain distance from the latter, which is not perforated with holes.

20. Panel according to claim 19, wherein said holes are micro-holes.

21. Panel according to any one of the previous claims, wherein said frame comprises means for the non permanent fixation of said sheets.

22. Panel according to claim 21, wherein said non permanent fixation means comprise at least a guide channel (7,89, 10) to retain at least one of said sheets.

23. Panel according to any one of the previous claims, **characterised in that** it comprises means for washing said sheets positioned between the said sheets to be washed.

24. Panel according to any one of the previous claims, wherein said frame (301) supports two or more front sheets (302a, 302b, 302c) perforated with a plurality of micro-holes, placed alongside and/or on top of one another, and two or more corresponding non perforated rear sheets, substantially parallel to said front sheets, and separated from each other by a relative hollow air cavity, said front and rear sheets being produced in a transparent material.

25. Sound-proof barrier of the type used for roadways comprising one or more panels, according to any one of the previous claims.

Fig.1

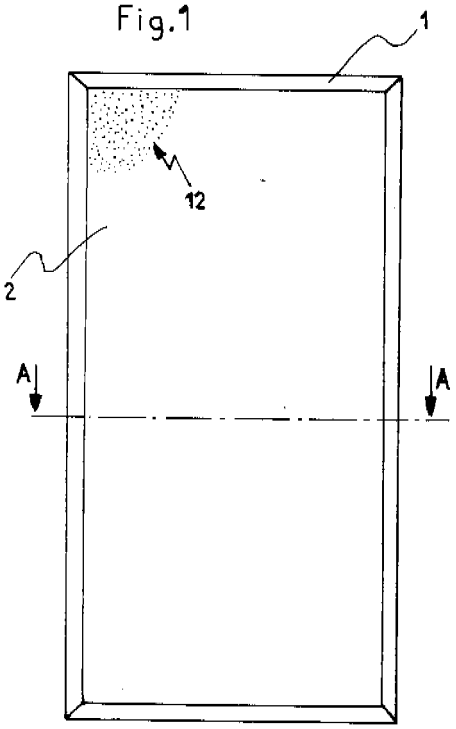


Fig. 2a

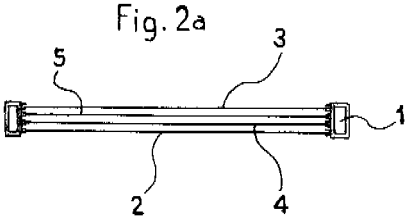


Fig. 2 b

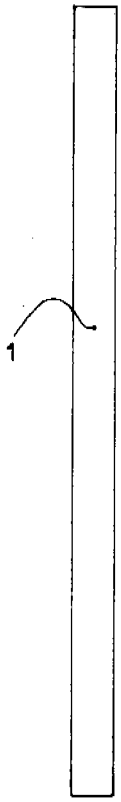


Fig. 3

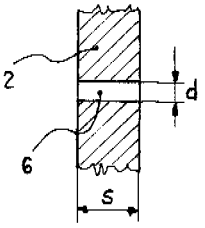


Fig. 4

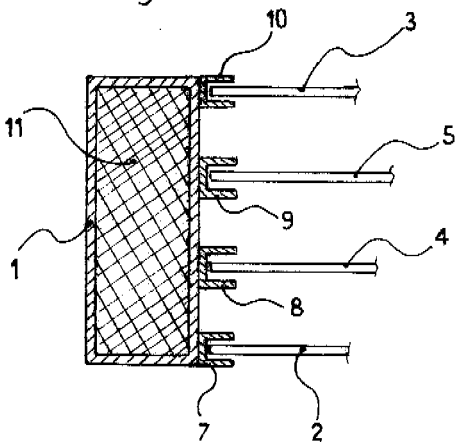


Fig. 5a

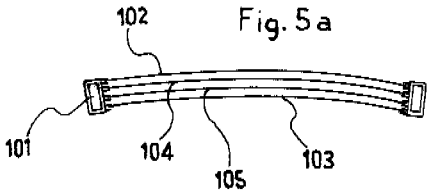


Fig. 5b

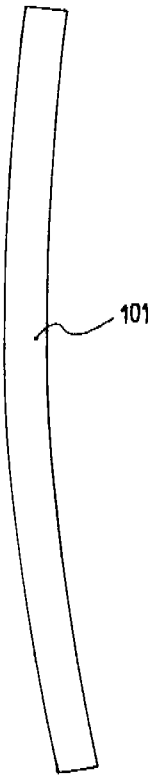


Fig. 6

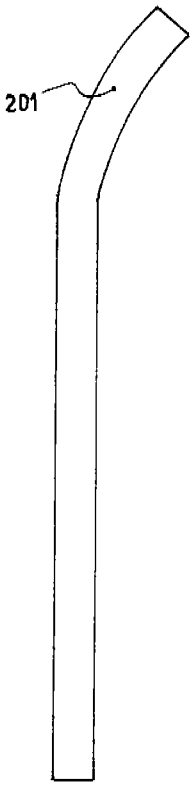
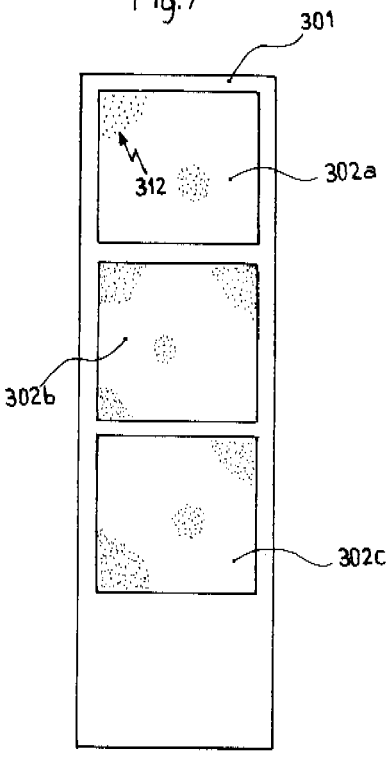


Fig.7



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EUROPEAN SEARCH REPORT

Application Number
EP 07 00 6825

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 197 17 266 C1 (FRAUNHOFER GES FORSCHUNG [DE]) 9 April 1998 (1998-04-09) * the whole document * -----	1,4,9, 11-13	INV. E04B1/86 ADD. E01F8/00
X	DE 43 15 759 C1 (FRAUNHOFER GES FORSCHUNG [DE]) 5 May 1994 (1994-05-05) * column 2, line 36 - column 3, line 11 * * column 3, lines 42-64; figures 2,5,6 * -----	1,3-5	
Y	DE 200 06 946 U1 (FAIST AUTOMOTIVE GMBH & CO KG [DE]) 16 August 2001 (2001-08-16) * page 3, line 1 - page 4, line 1 * * page 8, lines 10-27; figures 3-7 * -----	1-8,25	
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	-/--		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	19 July 2007	FLORES HOKKANEN, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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Application Number
EP 07 00 6825

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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X : particularly relevant if taken alone
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