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S-541 91 Skövde(SE)**GÖTEBORGS PATENTBYRA AB Box 5005**
S-402 21 Göteborg(SE)(54) **A device for reduction of transmission noise.**

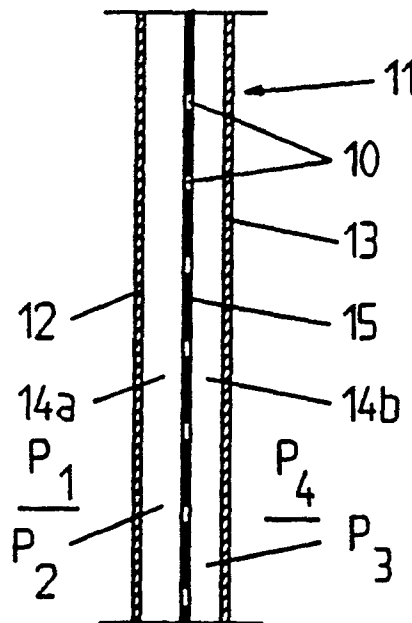
(57) A device for reduction of sound transmission through a structure unit (11), e.g. a wall, door, window or the like. The structure unit consists of at least two pane-shaped parts (12,13) spaced apart a small distance from each other, one of which parts is air-proof. The space (14) between the pane-shaped parts (12,13) is subdivided in several fluidum slots (14a,14b) by means of a longitudinally extending pane- or film-shaped element (15). In the element (15) and/or in limiting members (19) adjoining thereto are made through-openings (10), thus that the sound pressure (P) in the slots (14) is equalized. The rigidity (k) and the surface weight (m) of the element are chosen thus in relation to size and total area of the openings (10) that the oscillation velocity of the element, when this is oscillated, is offset in phase relative to the sound pressure, causing pressure differences in the slots (14), whereby the area of the openings (10) relative to the surface of the element (15) is

$$0,1 < w \cdot m \cdot s < 10$$

wherein: w = the dimensioning angular frequency ($2\pi f$) and

$$s = \frac{\text{area of openings}}{\text{surface of element.}}$$

FIG. 2



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A DEVICE FOR REDUCTION OF TRANSMISSION NOISE

The present invention refers to a device for reduction of sound transmission through a structure unit, e.g. a wall, door, window or the like, whereby the structure unit consists of at least two pane-shaped parts spaced apart a small distance from each other, one of which parts is air-proof, whereby the space between the pane-shaped parts is subdivided in several fluidum slots by means of a longitudinally extending pane- or film-shaped element.

Background of the invention

Sound transmission through structures occur in many connections, in buildings, in machine walls, in vehicles etcetera. The sound reduction is achieved in that the sound waves are urged to pass through tight structures, such as walls.

The reduction number is decided by the surface weight m of the wall, its rigidity k , and losses r . The reduction number is frequency dependent and for a pane, e.g. a single element wall, the complex relation between acoustic pressure p and the vibration speed v of the wall will be:

$$(p_1 - p_2)/v = i\omega m + k/i\omega + r$$

wherein p_1 and p_2 are the acoustic pressures on each side of the pane or the wall,

$p_2 = \rho c$ = the wave impedance,

ω = the angular frequency, c = speed of sound.

The relation between pressure and speed is named impedance. The quantity i is an imaginary number and expresses the phase difference and multiplication by i thus means that the pressure will lay 90° in front of v and division by i that it lays 90° behind.

The reduction number is defined as: common logarithm P/P_t , where P_i is the incident acoustic effect and P_t is transmitted acoustic effect. From the above defined impedance relation it can be seen that the reduction number for low frequencies is rigidity controlled, the reduction number is reduced with frequency, whereas it for high frequencies will become mass controlled and increase with frequency.

At a certain frequency, f_0 - the resonant frequency - the impedance is at minimum, i.e. $i\omega(m - k/\omega^2) = 0$.

The reduction number of the single wall is high for high frequencies. Within the architectural acoustics according to the standard specifications frequencies are only measured from 100 Hz and upwards. Normally this falls entirely within the mass controlled area.

A method for increasing the sound insulation is

to arrange two panes after each other - i.e. to provide a double wall according to Fig. 1. Common structures of this type are plaster stud walls, door leafs and windows. In walls the air slot is often filled with a damping material, e.g. mineral wool - Fig. 5 -, which increases the losses and thereby the sound reduction.

The two wall panes of a double structure according to Fig. 2 or 5 communicate with each other via the air slot. At low frequencies the air is so stiff that the wall layers will oscillate in phase, i.e. the double structure behaves as a single wall. At a certain frequency, the resonant frequency, determined by the surface weights of the wall layers (m_1 and m_2) and the resiliency of the trapped air volume, the wall layers will oscillate in opposition, the impedance is low, as the system will self-oscillate and the reduction number is low. Above the resonant frequency the reduction number will increase rapidly.

The reduction number of a double wall never will reach the sum of the reduction numbers of the two wall layers, as they are interconnected via the air spring. At low frequencies there is no wave propagation between the wall layers, the pressure is the same over the cross section. This means that the damping material (such as mineral wool in Fig. 5) has no bigger effect, as there is no pressure gradient. The air particles will move at the same speed as the fibres of the material, whereby there will be no big friction losses. There however are transversal pressure gradients, as the phase of the driving pressure over a wall surface is not the same at all positions and for that reason a filling of the air slot by e.g. mineral wool will have effect.

It is important to increase the sound insulation particularly at low frequencies for different types of partition structures. This can be effected by increasing surface weight or rigidity of the structures, but this is expensive. Inserting of a pane in the air slot according to Fig. 3 will give no big improvements, as the pane will only divide the air slot and create new resonancies. For double walls the sound insulation can be considerably increased if the two wall layers can be better disconnected from each other, i.e. if the pressure in the air slot can be equalized or a pressure gradient can be created over the slot. A method would be to let an over-pressure or a sub-pressure hiss through apertures in the outer panes, but the sound would also pass through these apertures.

By US 2.915.135 is known an acoustic panel for high air speeds within the panel. The problem at such panels is that common mineral wool will be blown away, whereby the intended sound damping

effect is deteriorated. The panel shall absorb sound from the inner side, but it should also prevent sound from being transmitted. The outer panel is constituted by a perforated pane for allowing sound transmission. Thereupon follows a perforated pane, which at both sides is provided with a material such as steel wool, which can stand wind loads. Thereupon comes a further perforated pane as protection for the mineral wool, which is closed by a tight pane.

As seen from the inner side, the second perforated pane, i.e. the one about which steel wool is wound, is resiliently supported on the steel wool and it is of limited size, whereby it may oscillate. Thus the rigidity of the pane is not utilized at low frequencies and it is neither created a difference against the mass impedance in the perforations. The panes furthermore shall be transparent to high frequencies, and this requires a high degree of perforation.

US 2.966.954 describes an acoustical correction element in form of a sound absorbing element with two or more layers with dense perforation (11%) and small space between the layers. This element is quite inexpedient for reduction of sound transmission, as the sound passes directly through the perforation.

SE patent 215.128 describes a sound insulating internal wall unit, which incorporates a layer, which is positioned between the the outer layers of a hollow wall and which layer consists of a carrier (e.g. paper), whereupon is sprayed a porous metallic fiber layer. The inner wall 4 acts as a sound trap and is non-perforated, which means that the sound pressure on both sides of the carrier can not be equalized.

SE-B-7811891-6 describes how the rigidity of a double wall may be improved without the base resonance thereby being essentially lowered. The inner flat element 5 is constituted by a perforated pane having a large number of evenly distributed perforations. The perforated pane is by means of spacing members 9 connected to a tight outer pane and at its opposite side to e.g. a mineral wool slab. From the description, page 4 it appears that the pane 5 shall be provided with a large number of preferably evenly distributed perforations and with the drawings as a starting point the overall hole area is far too big for achieving the effect aimed at according to the invention.

Purpose and most essential features of the invention

The purpose of the invention is by simple means to provide a reduction of the sound trans-

mission through a structural unit particularly at low frequencies and without requiring that the thickness, weight or cost of the structural unit are substantially increased. These tasks have been solved in that in the element and/or in limiting members adjoining thereto have been made through-openings, thus that the sound pressure (P) in the slots is equalized, whereby the rigidity (k) and the surface weight (m) of the element are chosen thus in relation to size and total area of the openings that the oscillation velocity of the element, when this is oscillated, is offset in phase relative to the sound pressure, causing pressure differences in the slots, whereby the area of the openings relative to the surface of the element is

$$0,1 < w \cdot m \cdot s < 10$$

wherein: w = the dimensioning angular frequency ($2 \pi f$) and

$$s = \frac{\text{area of openings}}{\text{surface of element}}$$

It thus is provided a phase difference between the pressure in the two or more air slots and the pressure can be equalized via openings in the or those partition element(s) or alternatively in limiting members surrounding them. Air flow through small openings give friction losses. Adaption of the size and number of openings in relation to the surface weight and rigidity of the element must be effected for achieving the intended pressure difference.

Panes with openings located in front of a wall is a structure which is known and common. Perforated sheet materials or plasterboards are for instance common as false ceilings, and these are then based on a resonance effect, when the mass of air in the holes rebounds against the elasticity of the volume of air situated therebehind and thereby give a high degree of sound absorption at and around the resonance frequency. This type of absorbing element is in fact an application of the Helmholtz-absorber, where the air mass in a hole or a tube rebounds against a separated volume of air provided therebehind. The perforated pane or the pane with slots with a common volume therebehind therefore are named coupled resonators.

The device according to the invention is not based on the principle of being a resonance absorber, even if that effect is of course part of the system, but on that pressure differences are created as the layer with the through-openings move with phase differences relative to the driving pressure and create pressure differences thus that air can be pumped through the holes or openings. This functions over the resonance frequency for the holes in the element considered as Helmholtz-ab-

sorber.

The function aimed at requires that the hole ratio s_1 is adapted to the mass or spring impedance. In relation to dimensioning frequency f , (angular frequency w) the hole percentage and the surface weight are chosen within the interval:

$$0,1 < w \cdot m \cdot s < 10$$

where the angular frequency $w = 2\pi f$.

A still better effect is obtained by positioning two elements with openings at some distance from each other in the air slot. By varying surface weight and rigidity for each element it is possible to control the phase differences between the three air slots thus formed.

It furthermore is so that as the pressure is urged to pass two elements the pressures p_2 and p_4 in the outer slots will lay ideally in opposition to each other and the gradient over the intermediate air slot p_3 will be at maximum. Other connections between the layers will of course occur, whereby the ideal situation will never be achieved, but the structure means that the pressure transmission via the elements and via openings are maladjusted relative to each other. If the openings lay close to each other the pressure transmission via those openings will dominate and no pressure gradients will occur. If, on the other hand, the openings lay far apart, the transmission via the wall layers will dominate, and the air slots will become stiff. For every chosen structure there will be an optimum. This optimum can be dimensioned to size and frequency by choosing material and size of the openings as well as their mutual space.

Due to the fact that a pressure gradient is created over the wall, also the damping material will have effect. A porous absorber with open pores absorbs sound by friction losses between the motion of the air molecules and of the pore walls (the fibres). An absorption material positioned between the two layers with openings thus will give big losses. The location of the holes in the two layers may be varied thus that the pressure differences absorbed over small or big distances due to the effect desired to obtain. As phase differences are also created over the outer air slots the absorption material will also have effect in these slots.

Description of the drawings

The invention hereinafter will be further described in some embodiments with reference to the accompanying drawings.

Fig. 1 shows a section through a part of a conventional wall, a so called double wall.

Fig. 2 shows a corresponding section through a double wall equipped with an element according to the invention.

Fig. 3 shows a section through a conventional tri-ply wall.

Fig. 4 shows a section through a four-ply wall equipped with double elements according to the invention.

Fig. 5 shows in a section analogous with Fig. 1 an insulated conventional wall.

Fig. 6 - 10 show sections through different alternative embodiments of structure units equipped with elements according to the invention.

Fig. 11 shows a section through a glass portion for a window.

Fig. 12 - 17 show diagrams of comparative curves referring to test results between conventional wall structures and structure units according to the invention.

Description of embodiments

In the drawings, 11 refers to a structure unit, e.g. a wall, door, window or the like consisting of two spaced apart outer, pane-formed parts 12 and 13, e.g. in form of hard panes, plaster boards or sheet metal and an air slot 14 situated between them. Fig. 1 shows a conventional wall structure, e.g. an interior wall. In the air slot 14 of Fig. 2 there is provided, in accordance with the invention, a longitudinal pane or sheet material element 15, which subdivides the space between the wall parts 12 and 13 in two air slots 14a and 14b. The element is provided with through-openings 10 preferably evenly distributed over its entire surface, whereby the two air slots communicate with each other. The openings can be in form of holes, slots or the like. If the structure member 11 is a wall, this is limited at its end edges in known manner, e.g. by ceiling and floor and adjoining walls, whereby the air slots are enclosed.

Fig. 3 shows a conventional tri-ply wall consisting of three panes 12, 13 and 16.

Fig. 4 shows a four-ply wall, where in the space between the outer panes 12 and 13 are provided two elements 15a and 15b according to the invention.

In Fig. 5 is illustrated the same type of wall as in Fig. 1, but provided with an absorber 17, e.g. mineral wool, between the outer panes 12 and 13.

In Fig. 6 - 8 are shown different alternative disposals of the element according to the invention in form of different types of walls with insulating material 17 positioned in the air slots 14 between the element 15 and the panes 12 and 13. It is important that the insulating material 17 is a porous absorber with open pores or fibres, thus that the air inside the insulating material can pass through the cavities in the material and via the openings 10 to an adjacent air slot 14. The material in the element

15 can be a hard pane or a board, e.g. of wood fibre, plaster or sheet metal, but it may also consist of a foil, e.g. an aluminum foil.

In the diagrams shown in Fig. 12 - 17 are given some examples of test results at comparison between known wall structures and a structural unit according to the invention.

In the diagram according to Fig. 12 the curve a, shown in continuous lines, refers to a single wall of 0.9 mm sheet metal and the dash-lined curve b, a double wall in accordance with Fig. 1 and the dash-and-dot curve c a wall in accordance with Fig. 1, i.e. a tri-ply wall consisting of three hard panes of 0.9 mm sheet metal.

The diagram according to Fig. 13 shows a comparison between the tri-ply wall according to Fig. 3 and the wall structure according to Fig. 2, which is equipped with an element 15 according to the invention consisting of 0.9 mm sheet metal, in which is made 8 mm holes with a centre space of 35 cm. The continuous curve a refers to the conventional tri-ply wall and the dashed line b the wall according to Fig. 2.

In the diagram according to Fig. 14 the wall according to Fig. 1 is compared a four-ply wall according to Fig. 4, whereby the continuous curve a refers to the wall according to Fig. 1 and the dashed curve b to the wall according to Fig. 4.

The diagram according to Fig. 15 shows a comparison between the wall according to Fig. 5 and the wall according to Fig. 6, whereby the difference compared to the previous wall structures is that in the slots between the panes are provided sound absorbers 17. The continuous line a refers to the wall according to Fig. 5 and the dashed line b to the wall according to Fig. 6.

In the diagram according to Fig. 16 the double wall according to Fig. 1 is compared to the wall according to Fig. 7, i.e. in this case one of the elements 17 according to the invention is facing outwards as a sound absorber. In the diagram the continuous curve a is again the wall according to Fig. 1 and the dashed curve b refers to the wall according to Fig. 7.

The diagram according to Fig. 17 finally shows a comparison between the wall according to Fig. 5 and the tri-ply wall according to Fig. 8, which last-mentioned in the diagram is shown in dashed lines b whereas the double wall according to Fig. 5 is shown in continuous line a.

The test results shown represent the sound level difference between the sound pressure level in a room 1 m in front of the test wall inserted in a door frame, with a surface of 2 m², and the acceleration level on the wall layer on the recipient side. The tests are relative as only changes between different structures were measured. It is very difficult to meter reduction numbers down to 20 Hz,

but the differences may be metered in this manner. The wall layers were of 0.9 mm sheet metal and the openings in the intermediary panes were round holes, having a diameter of 8 mm and a centre space of 30 - 40 cm.

The measurements shown give examples only of how the structure may be utilized. The wall layers may be everything from foil to concrete layers. The holes may be holes between 1 - 20 mm in diameter or corresponding slots. The holes may be positioned at different distances from each other, and a centre spacing between 1 mm and 1 m can be possible, depending on the frequency range to be improved. The structure may have or not have a porous absorbing layer 17 between the elements 15 in the slots 14.

The structure can be used between two panes in a wall. In floor structures or door leaves the function will be the same. The panes between which the elements are positioned thus may be anything between 20 cm concrete and 1 mm veneer, or even thin foils.

In windows a non-covering structure may be positioned between the glass panes 18, but the dimensions of the window means that it for low frequencies is enough with slots outside at the frames between the inner glass pane/panes and the frame such as shown in Fig. 11. Such a slot is readily combined with a frame absorber 19 for increasing the damping effect. An alternative is also to make holes in the inner glass pane/panes just in front of the glazing bars in a window having glazing bars, or in the very glazing bars.

The double element 15 with the openings 10 may also be used for improving the sound insulation for a single wall according to Fig. 9, in that the elements are positioned on one or both sides of the single wall. The structure then is located at a distance from the wall 20, thus that the air is allowed to move to the holes. The slot or slots 14 may of course be filled with mineral wool 17 for increasing the damping.

In these cases with positioning externally against a pane the structure will also act as a sound absorber. Structures having perforated surface layers as sound absorbant are already known, but it is here intended a structure with two elements with through-holes, thus that the vibrations of the elements cause the air transport through the holes. This also means a structure thus that the sound absorption can be effectful down to very low frequencies.

A common problem is to improve the sound insulation for an existing structure, e.g. a wall 20 in Fig. 10 if a tight layer is desired against the room.

Hitherto only applications in air have been discussed, but structures of panes with holes can also be used for reducing or absorbing vibrations and

pressure waves in fluids although the fluids are considerably less compressible than gases, and the structure is particularly useful as a sound absorber in fluids, wherein the energy losses are big at flow through holes. Combinations between fluid and air are also possible.

the frames or in window glazing bars and/or in the frames.

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Claims

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1. A device for reduction of sound transmission through a structure unit (11), e.g. a wall, door, window or the like, whereby the structure unit consists of at least two pane-shaped parts (12,13) spaced apart a small distance from each other, one of which parts is air-proof, whereby the space (14) between the pane-shaped parts (12,13) is subdivided in several fluidum slots (14a,14b) by means of a longitudinally extending pane- or film-shaped element (15),

15

characterized therein,

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that in the element (15) and/or in limiting members (19) adjoining thereto have been made through-openings (10), thus that the sound pressure (P) in the slots (14) is equalized, whereby the rigidity (k) and the surface weight (m) of the element are chosen thus in relation to size and total area of the openings (10) that the oscillation velocity of the element, when this is oscillated, is offset in phase relative to the sound pressure, causing pressure differences in the slots (14), whereby the area of the openings (10) relative to the surface of the element (15) is

25

$0,1 < w \cdot m \cdot s < 10$

30

wherein: w = the dimensioning angular frequency ($2 \pi f$) and

35

$$s = \frac{\text{area of openings}}{\text{surface of element}}$$

40

2. A device as claimed in claim 1,

characterized therein,

that several elements (15) are provided at distances from each other, and that the openings (10) in one of the elements are displaced in relation to the openings of the adjacent element.

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3. A device as claimed in claim 1,

characterized therein,

that the space in the slots (14) is at least partly filled by a porous, air-permeable, absorbing material, e.g. mineral wool.

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4. A device as claimed in claim 1,

characterized therein,

that in windows or doors having glass openings, the element (15) is a glass pane (18) and the openings (10) are provided in the glass adjacent

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FIG. 1

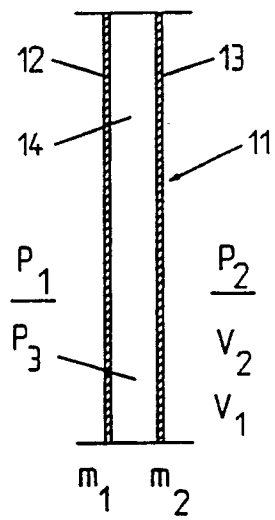


FIG. 2

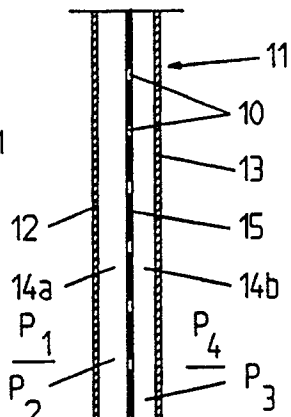


FIG. 3

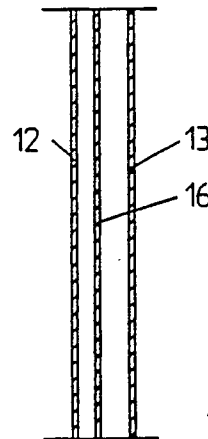


FIG. 4

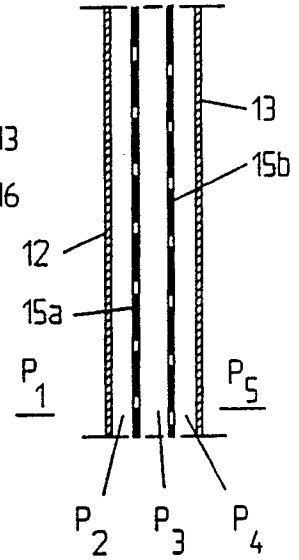


FIG. 5

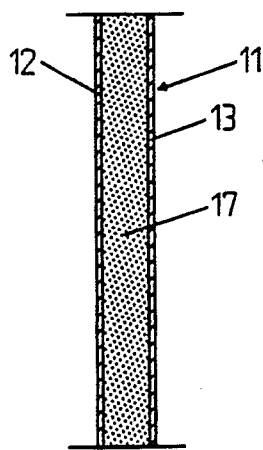


FIG. 6

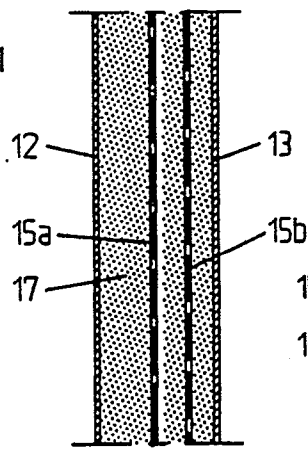


FIG. 7

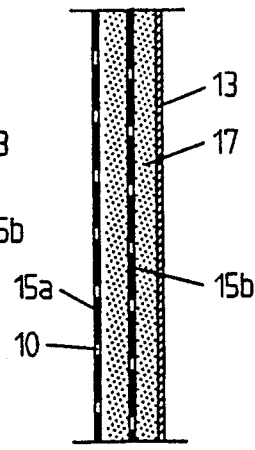


FIG. 8

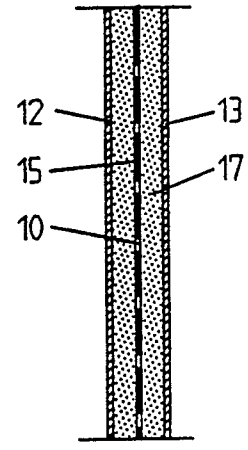


FIG. 9

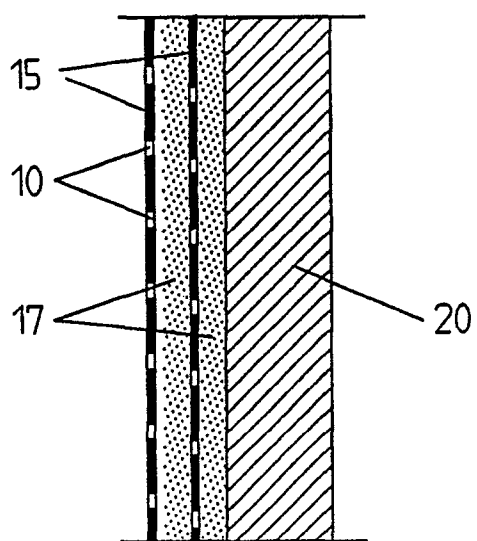


FIG. 10

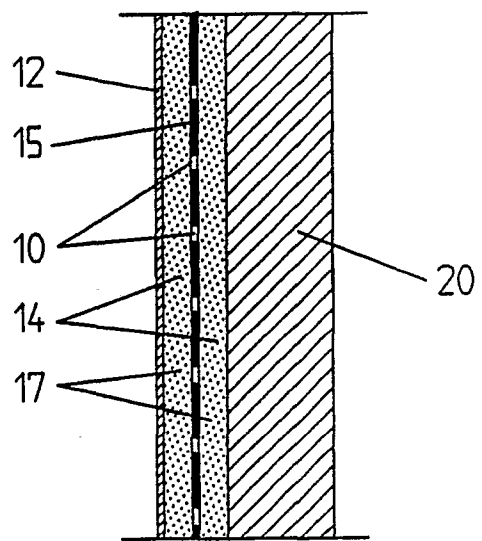
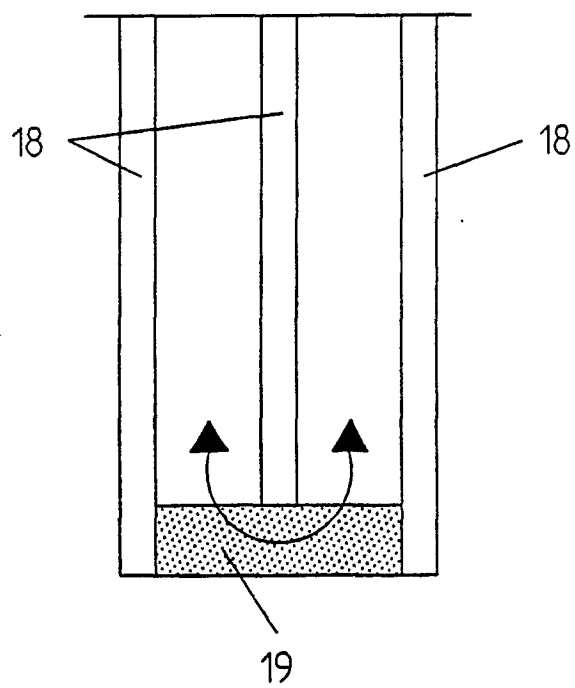
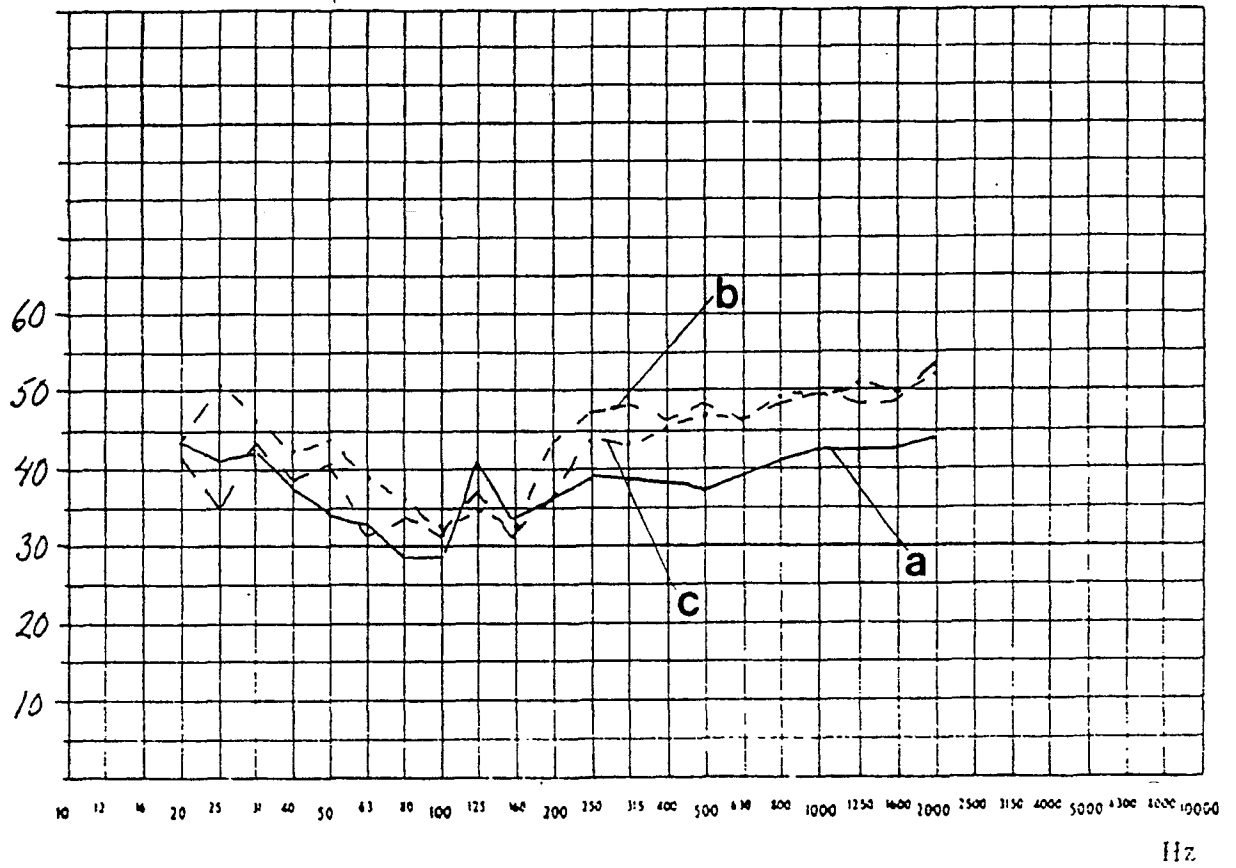


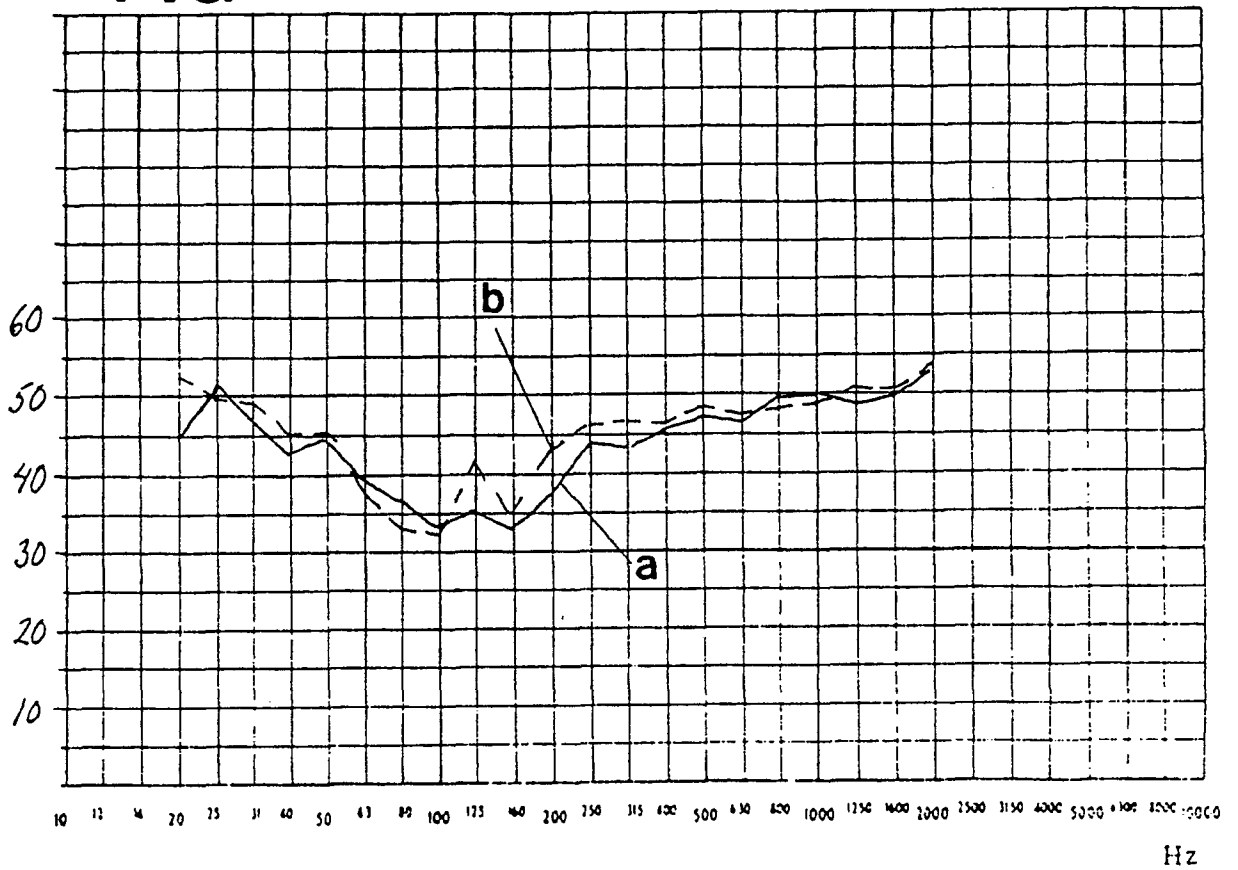
FIG. 11



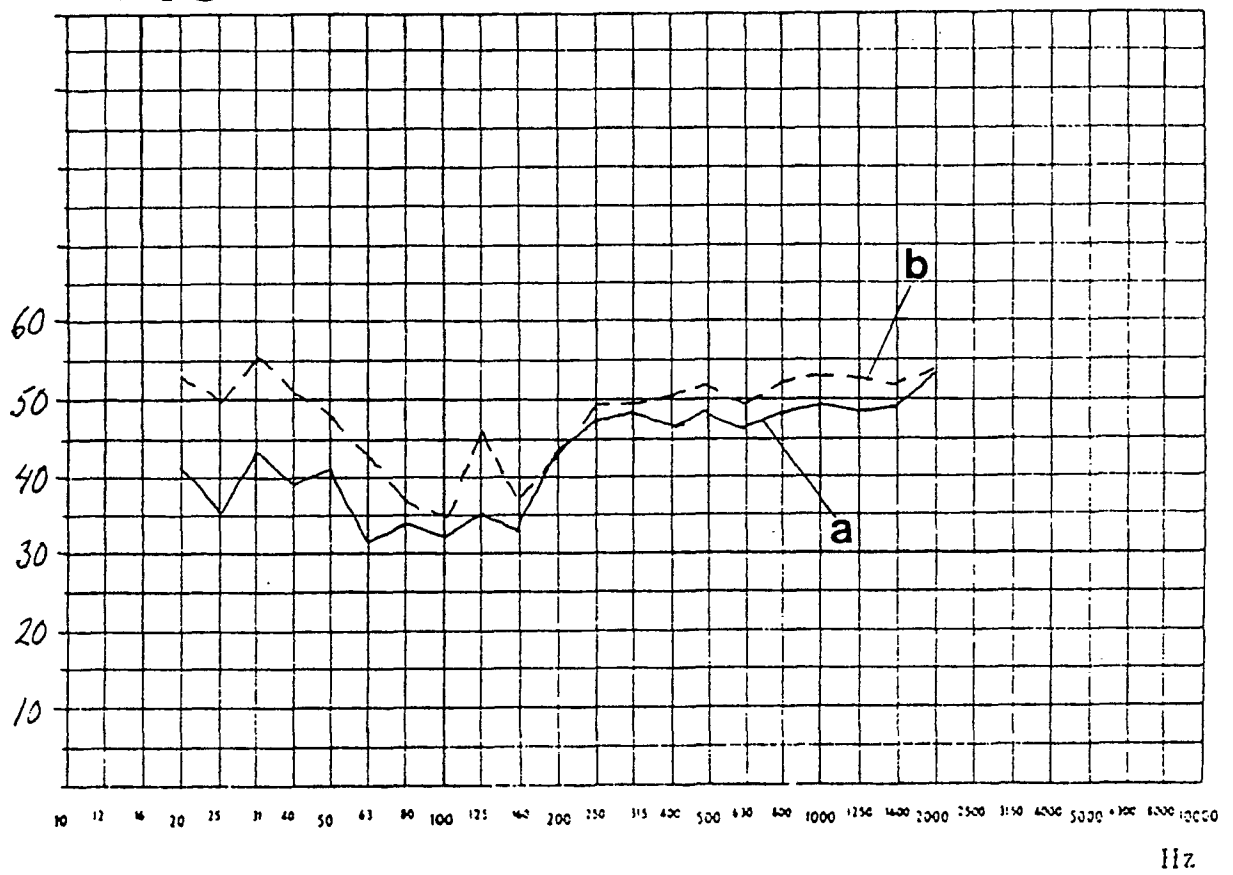
Δ FIG 12



Δ FIG 13



ΔL FIG 14



ΔL FIG 15

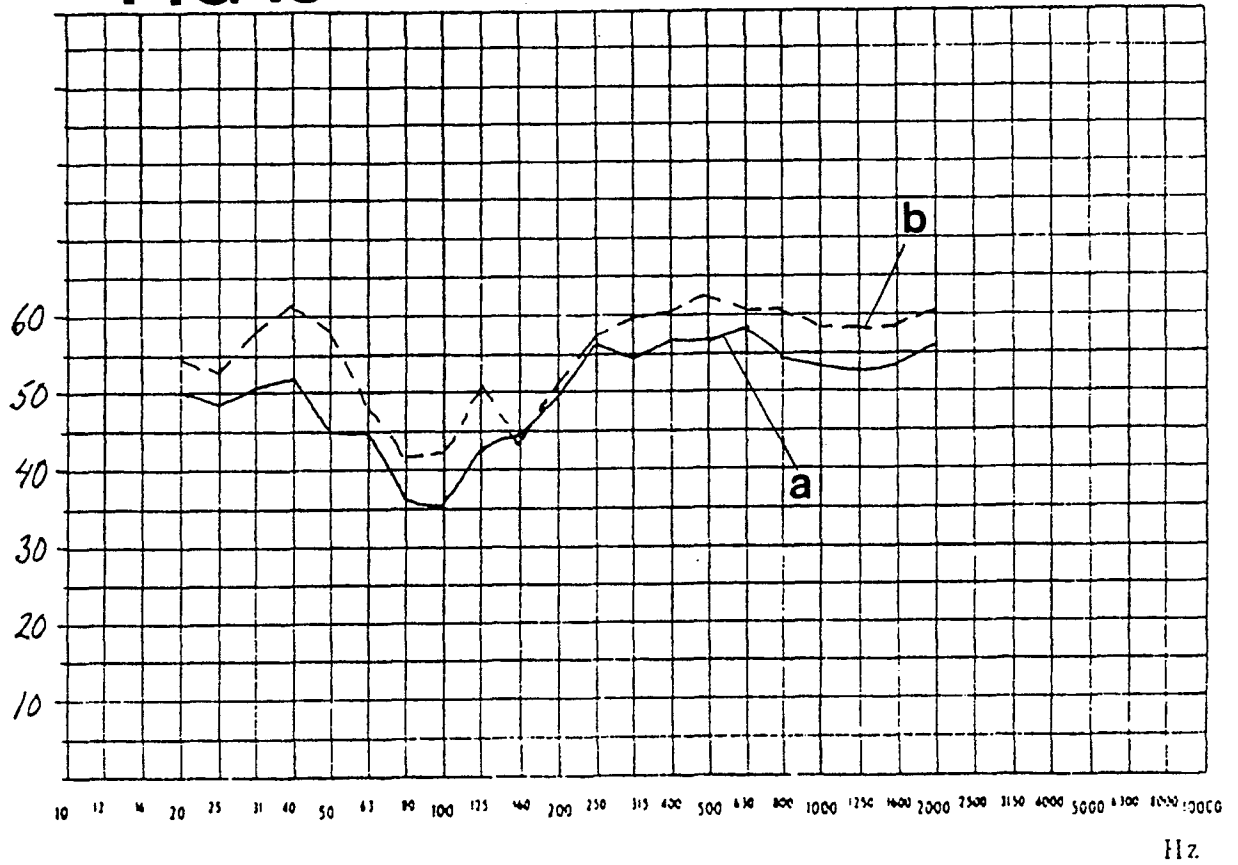


FIG 16

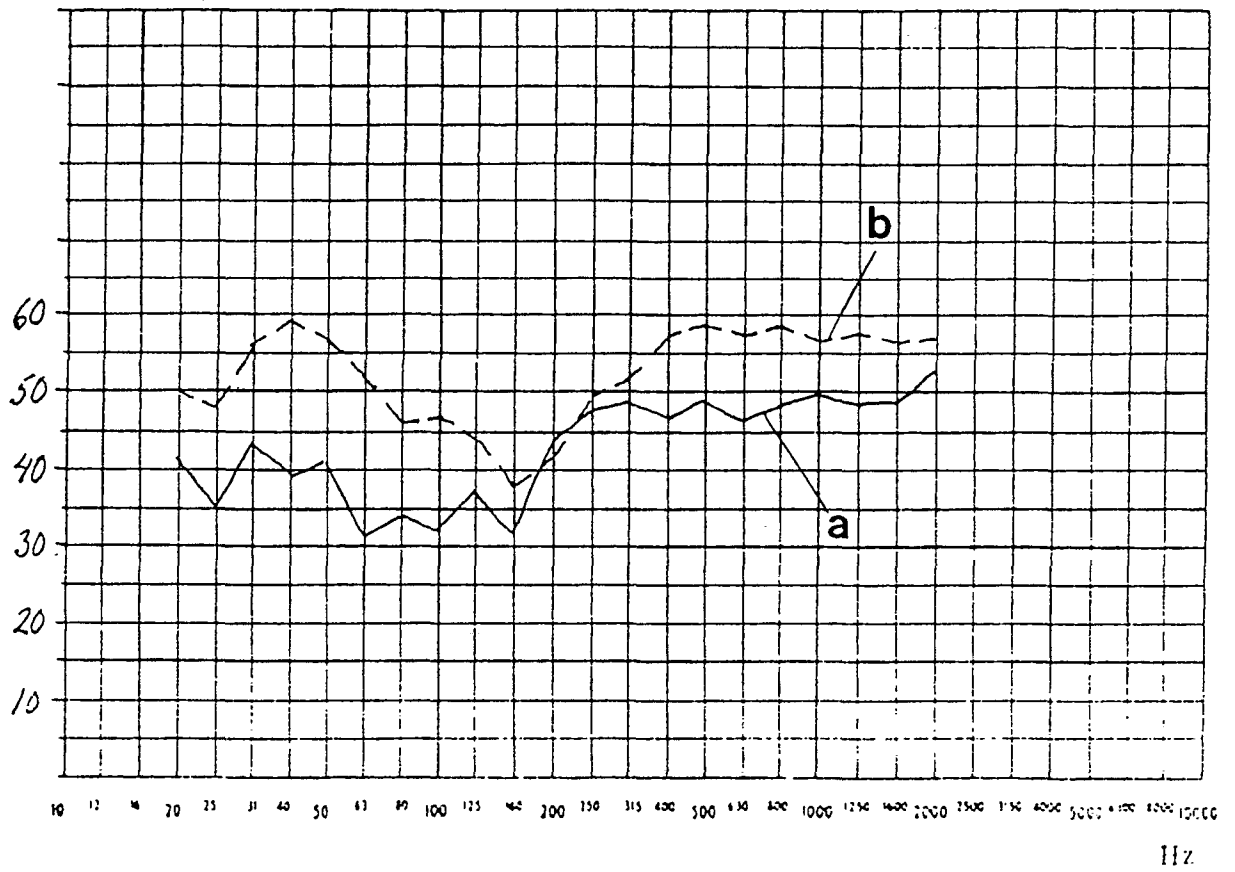
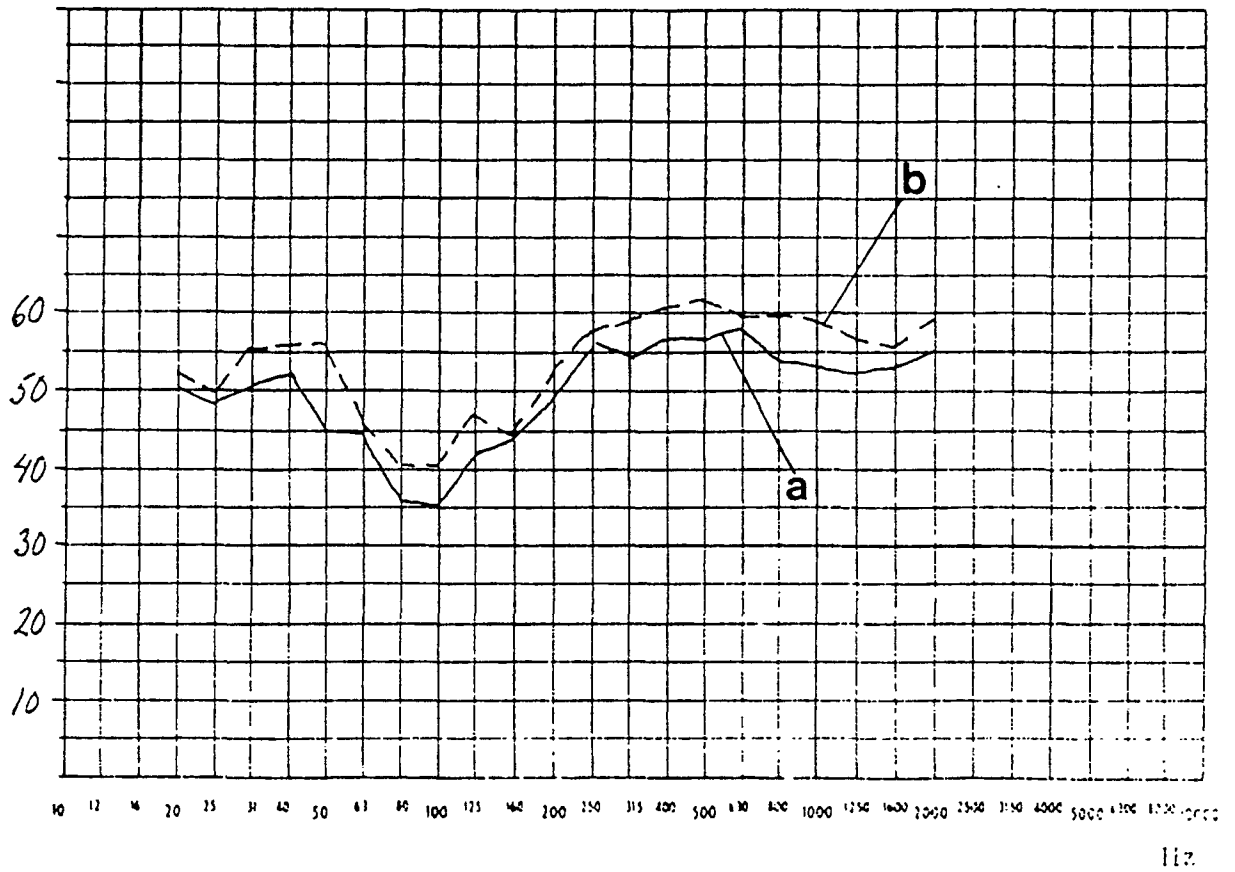


FIG 17





DOCUMENTS CONSIDERED TO BE RELEVANT															
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)												
A	DE-A-2 105 403 (KAISERAUER) * Page 3, lines 18-25; page 4, lines 1-29; page 5, lines 1-11; figures 1,2 * ---	1	G 10 K 11/16 E 04 B 1/86												
A	US-A-4 421 201 (NELSEN) * Column 3, lines 1-68; figures 3,4 * ---	1,2													
A	GB-A- 694 000 (LEMMERMAN) * Page 2, lines 85-130; page 3, lines 1-37; figures 1-5 * ---	1,3													
D,A	US-A-2 915 135 (LEMMERMAN) ---														
D,A	SE-A- 215 128 (PONCET) & DE-A-1 484 019 ---														
D,A	US-A-2 966 954 (SABINE) -----														
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)												
			G 10 K E 04 B												
The present search report has been drawn up for all claims															
Place of search THE HAGUE		Date of completion of the search 21-02-1990	Examiner SCHOLS W.L.H.												
<table border="0"><tr><td>CATEGORY OF CITED DOCUMENTS</td><td>T : theory or principle underlying the invention</td></tr><tr><td>X : particularly relevant if taken alone</td><td>E : earlier patent document, but published on, or after the filing date</td></tr><tr><td>Y : particularly relevant if combined with another document of the same category</td><td>D : document cited in the application</td></tr><tr><td>A : technological background</td><td>L : document cited for other reasons</td></tr><tr><td>O : non-written disclosure</td><td>& : member of the same patent family, corresponding document</td></tr><tr><td>P : intermediate document</td><td></td></tr></table>				CATEGORY OF CITED DOCUMENTS	T : theory or principle underlying the invention	X : particularly relevant if taken alone	E : earlier patent document, but published on, or after the filing date	Y : particularly relevant if combined with another document of the same category	D : document cited in the application	A : technological background	L : document cited for other reasons	O : non-written disclosure	& : member of the same patent family, corresponding document	P : intermediate document	
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Y : particularly relevant if combined with another document of the same category	D : document cited in the application														
A : technological background	L : document cited for other reasons														
O : non-written disclosure	& : member of the same patent family, corresponding document														
P : intermediate document															