(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 871 345 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
14.10.1998 Bulletin 1998/42

(51) Int. Cl.[6]: H04R 17/00, H04R 1/22

(21) Application number: 98200716.3

(22) Date of filing: 06.03.1998

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 03.04.1997 BE 9700309

(71) Applicant:
Sonitron, naamloze Vennootschap
9100 Sint-Niklaas (BE)

(72) Inventor: Michiels, Hugo
9180 Moerbeke-Waas (BE)

(74) Representative: Donné, Eddy
Bureau M.F.J. Bockstael nv
Arenbergstraat 13
2000 Antwerpen (BE)

(54) Element for reproducing and/or recording sound

(57) Element for reproducing and/or recording sound, consisting of a membrane (3) which is equipped with a piezo-electric element (5), electric connecting means (6) working in conjunction with the piezo-electric element (5) and a housing (2) for the membrane (3), characterized in that the element (1) contains a wall part (17) situated at a short distance (D1) from the membrane (3), such that the sound vibrations which are generated by the membrane (3) are damped.

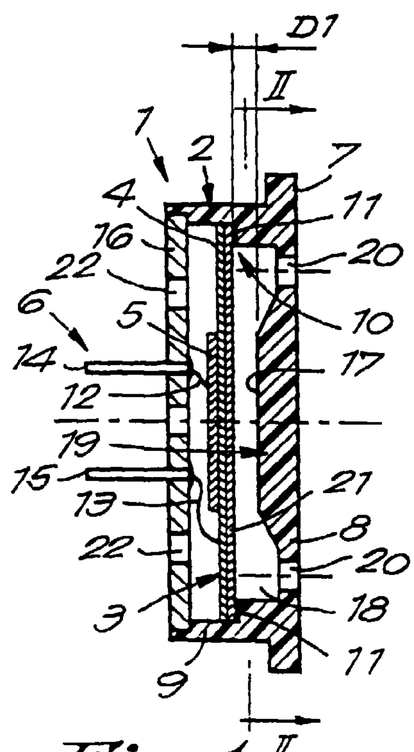


Fig.1

EP 0 871 345 A1

Description

The present invention concerns an element for reproducing and/or recording sound, in particular a loudspeaker and/or a microphone.

In particular, the invention concerns an element for reproducing and/or recording sound which uses a piezo-electric element.

It is known that an electric signal can be converted in an audible sound vibration by means of various sorts of reproducers, and that, vice versa, sound vibrations can be converted in electric signals.

A first type of known sound reproducers consists of the electrodynamic loudspeakers.

Such loudspeakers which usually make use of a paper cone have as main disadvantages that they:

- occupy a relatively large volume;
- require much power;
- have a large power consumption, so that thick connecting wires are required;
- have quite a large depth, because of the height of the magnet;
- offer a bad reproduction of the high tones;
- are sensitive to the temperature and air humidity;
- have a low output;
- require large dimensions for a "Full range" reproduction;
- produce an electromagnetic field (EMC);
- are relatively little reliable, since the coil is heated under a constant load and will break down;
- require special protection for the paper cone, which is very fragile;
- have a complex design.

Another type of known sound reproducers consists of the electrostatic reproducers.

However, these reproducers also represent a considerable number of disadvantages, namely in that they:

- are very expensive;
- require large dimensions for a "Full range" reproduction;
- require high tensions;
- have a critical and complex design;
- are very sensitive to humidity;
- are sensitive to interferences;
- their output is but reasonable;
- require an adapted space.

A third type of known sound reproducers consists of the piezo-electric reproducers.

This latter type of reproducers uses a vibration membrane which consists of a support, usually a thin metal disc, and a piezo-ceramic disc fixed to this support.

This membrane is suspended, either by means of a nodal suspension whereby the membrane is fixed to a housing on the nodes by means of flexible adhesive, or by means of a suspension over the entire perimeter by means of a hard or flexible adhesive.

By supplying a variable tension to this membrane and the piezo disc, the material of the piezo-ceramic disc will expand or shrink such that, since the metal support cannot expand or shrink itself, the whole will bend as a function of the varying tensions, so that an audio signal is generated which is in proportion to the frequency and the amplitude of the supplied varying potential.

It is also known that the piezo-electric effect is mutual, in other words that when the membrane and the piezo disc are moved, for example by means of sound vibrations, an electric tension will be generated which is in proportion to the movements carried out by the membrane and the pressure changes generated in the piezo-ceramic disc as a result thereof, such that the whole, consisting of the support and the piezo element, forms an element which functions as a microphone.

The general advantages of such piezo-electric reproducers are that they:

- have a very thin, respectively flat design;
- have a simple but robust design;
- are shock-resistant, water-resistant and temperature-resistant;
- can be used as a microphone;
- do not produce an electric field (EMC);
- have a small weight;
- require little energy;
- do not require much current in the wires to the loudspeaker;
- have a very large acoustic output, even for very small loudspeakers.

However, a disadvantage of the embodiments of such a piezo-electric reproducer known until now consists in that they are merely suitable for reproducing relatively high tones and cannot be used for the fully audible frequency range of 15 Hz to 20 kHz.

In particular, no or only a very bad reproduction of sounds beneath 1,000 Hz is possible. Thus, a large part of the spoken word and of the musical spectrum cannot be reproduced up to now by means of a piezo-electric membrane. Also, such piezo-electric reproducers have only been used until now for buzzers, transducers and tweeters or for microphones and loudspeakers in applications where the reproduction does not need to have a good quality.

The invention concerns an element for reproducing and/or recording sound whereby use is made of the piezo-electric principle, but whereby the above-mentioned disadvantages of the known embodiments are excluded or minimized.

In particular, the invention concerns a piezo-electric loudspeaker providing for an optimal sound reproduction in the full range of 15 Hz to 20 kHz.

The invention hereby aims an element which is both suitable for small and large embodiments, in particular designs having a diameter which is smaller than 10 mm up to designs having a diameter of 1 metre.

To this end, the invention concerns an element for reproducing and/or recording sound, consisting of a membrane which is equipped with a piezo-electric element, electric connecting means working in conjunction with the piezo-electric element and a housing for the membrane, characterized in that the element contains a wall part situated at a short distance from the membrane, such that the sound vibrations which are generated by the membrane are damped.

In particular, the above-mentioned wall part is situated at such a short distance from the membrane that the air which is moved during the generation of the sound vibrations is reflected against the above-mentioned wall part, such that the reflected vibrations produce a damping on the membrane.

Preferably, the distance between the membrane and the above-mentioned wall part is situated between 0.5 mm and 10 mm, and better still between 0.5 mm and 5 mm.

In this manner, a very good sound reproduction is obtained in the full range.

This is explained among others in that the quality factor of the higher harmonics is reduced as a result of the above-mentioned damping and in that the resonance frequency is lowered.

In the above-mentioned wall part and/or in the perimeter thereof are preferably provided holes which allow for an outflow of air, so that the sound can easily come out without the damping effect of the above-mentioned wall part being lost, however.

According to a particular embodiment of the invention, the above-mentioned wall part consists of a thickening, which offers among others the advantage that parasitic vibrations on this wall part are excluded or are at least minimized.

According to another embodiment, which is particularly useful for designs with larger diameters, the above-mentioned wall part is provided with a body having a relatively large weight, so that the above-mentioned damping effect is enlarged and among others parasitic vibrations are prevented.

One or several composing parts of the element according to the invention can be provided with a damping layer, preferably a damping elastic material such as silicone which can absorb among others vibration energy in case of fragmentation and which makes sure that sharp resonance peaks at high frequencies are damped. As a result, a reproduction of better quality is obtained.

In order to better explain the characteristics of the invention, the following preferred embodiments are described as an example only without being limitative in any way, with reference to the accompanying drawings, in which:

figure 1 shows a section of an element according to the invention;

figure 2 shows a section according to line II-II in figure 2;

figures 3, 4 and 5 show sections which are similar to that in figure 1, but for variants;

figure 6 shows a view to a larger scale of the part which is indicated by F6 in figure 4;

figures 7 to 22 represent a number of schematic representations.

The element 1 according to the invention for reproducing and/or recording sound consists of a housing 2; a membrane 3 which is at least composed of a support 4 and a piezo-electric element 5 fixed to it; and electric connecting means 6.

The housing 2 in this case contains a housing part 7 with a front wall 8 and a cylindrical side wall 9. This housing part 7 is preferably made of synthetic material.

The membrane 3 is fixed with its edges on a collar 10 provided in the housing part 7, preferably by means of an elastic or flexible adhesive 11.

The support 4 of the membrane 3 consists of a metal disc, for example made of brass, of a very small thickness.

The piezo-electric element 5 consists of a piezoceramic disc, for example having a thickness in the order of 30 micrometre, which is fixed against the support 4, for example with an adhesive.

The electric connecting means 6 consist of conductors 12-13 which are connected to the membrane 3 in such a manner that an electric potential can be generated over the piezo-electric element 5.

These conductors 12-13 are for example connected to terminal pins 14-15 which are fixed in a cover plate 16 forming the back side of the housing 2.

The invention is special in that the element 1 is provided with a wall part 17 extending along the membrane 3, at a distance D1 thereof, which produces a damping effect.

The distance D1 is in proportion very short and preferably smaller than or equal to 10 mm. Usually, this distance D1 is situated between 0.5 mm and 5 mm, depending on the size of the loudspeaker.

On the contour, between the membrane 3 and around the wall part 17, is formed a chamber 18 which is deeper than the distance D1.

The difference between the distance D1 and the depth of the chamber 18 is obtained as the front wall 8 has a thickening 19.

It should be noted that according to a variant which is not represented here, the front wall 8 at the height of the wall part 17 can be bent inward, so that the front wall must not necessarily be thickened. The use of a thickening and/or reinforcement 19 makes sure, however, that the production of parasitic vibrations due to the vibration of the front wall 8 is prevented, as will be described hereafter.

According to another variant which is not represented here, the inside of the front wall 8 is entirely flat and is situated over its entire surface at a short distance D1 from the membrane 3.

In the housing 2 are provided holes 20 which make it possible for the sound to propagate outward, whereby these holes 20 open in the chamber 18 and whereby these holes are sufficiently large to guarantee the outflow of air and to exclude, minimize respectively, a possible filtering effect.

According to figure 1, the membrane 3 is provided with a damping layer 21 on the front side, preferably made of a flexible material such as silicone, silicone rubber or an elastomer, whereby this damping layer 21 is meant to absorb vibration energy created during the fragmentation of the membrane, and also makes sure that sharp resonance peaks at high frequencies are damped.

The above-mentioned cover plate 16 may consist of a printed circuit board onto which electronic components may possibly be provided, whereby holes 22 are also provided in this cover plate 16 which make sure that no extra strain is exerted on the membrane 3 by the enclosed air.

The above-mentioned housing part 7 and the wall part 17 are preferably made of synthetic material.

The housing 2 further, has a flange in which fixing holes 23 are provided.

The working of an element 1 is based on the principle that, when an electric signal is given to the terminal pins 14-15, the membrane 3 will start to vibrate as a function of this signal. This causes an air displacement, so that sound is generated. Due to the short distance D1, as well as due to the fact that the front wall 8 is provided with a thickening 19, the above-mentioned damping effect is created.

Figures 3, 4 and 5 show three variants whereby the above-mentioned wall part 17 is provided with a weighting body or mass 24 in order to enlarge the damping effect, whereby this body 24 consists of a disc made of a material with a large density, for example a metal such as copper or lead, and whereby this disc is provided in the housing 2.

While a damping layer 21 is already provided on the support 4 of the membrane 3, a damping layer 25 can also be provided in other places, namely on the wall part 17 or on the side of the body 24 which is directed towards the membrane 3, as is represented in figure 3.

In the variant according to figure 4, the body 24 is situated on the outer side of the front wall 8, and the damping layer 25 is enclosed between the housing 2 and the body 24.

Figure 5 shows a variant whereby the body 24 and the damping layer 25 provided on it are provided such that the chamber 18 is significantly enlarged as it continues behind the body 24, whereby the latter is fixed on a central support 26.

It should be noted that the support 4, the piezoelectric element 5 and the layer 21 in the figures 1, 3, 4 and 5 are schematically represented as if they were all more or less equally thick, but that, in reality, the layer 21 is significantly thicker than the membrane 3, as is represented in a more realistic manner in figure 6, for example ten times thicker and thus in the order of 1 mm. Also the layer 25 will preferably have a thickness in the order of 1 mm.

In order to further illustrate the invention, the following theoretical approach of both a number of general principles and of specific characteristics of the invention is given hereafter.

Figures 7 and 8 schematically represent the difference between a nodal suspension (figure 7) on the one hand and of a suspension on the edge of the membrane 3 (figure 8) on the other hand.

Such membranes represent resonance frequencies. On these resonance frequencies are created unwanted effects which have a negative influence on the quality of the sound.

According to the invention, we try among other things to lower these resonance frequencies to the lower limit of the audible spectrum, in other words to produce a sort of damping so as to generate a frequency reproduction which can drift almost flat as of 30 Hz up to 20 kHz and thus cover the full range without any resonance frequencies being produced.

The resonance frequency F_{rn} of a circular, nodally supported plate can be expressed according to the following formula:

$$F_{rn} = \frac{t}{S} \times \frac{y}{d \times (1-r^2)}$$

Whereby:

t = the total thickness of the membrane 3;
S = the surface of the membrane;
y = Young's modulus (N/m^2);
d = the density of the support 4, which is at least 2.5 kg/dm^3;
r = the ratio of Poisson.

This clearly indicates that the resonance frequency strongly depends on the thickness and the surface, in other words the diameter of the membrane 3. The thinner the membrane 3 is, the lower the resonance frequency.

In order to minimize the resonance frequency, one may try to reduce the thickness of the membrane 3 by reducing the thickness of the support 4 and/or of the element 5 to a minimum.

For physical reasons, the thickness of the support 4 cannot be less than 20 micrometre, however. Moreover, in order to obtain that the generated vibrations are as concentric as possible, it is desirable that the support 4 and the element 5 have the same thickness. As a result, the resonance frequency can only be minimized to a limited extent due to the selection of the thickness of the support 4 and the element 5.

It should also be noted that, with a suspension on the edge, the ratio between the diameter D2 of the element 5 and the diameter D3 of the support 4 must be situated between 0.85 and 0.5. It is clear that a larger support 4, and consequently a larger surface S and a smaller resonance frequency, require a larger element 5, so that the cost price rises significantly.

The resonance of a piezo-electric membrane 3 which consists of a ceramic disc which is glued on a metal support 4, forming what is called a "unimorph", depends on the manner in which the membrane 3 is suspended. With a suspension on the edge, one has to reckon with a mounting factor K, which is usually 0.7, in order to calculate the resonance frequency.

For a suspension on the edge, this implies:

$$F_{rr} = K \times F_{rn} = K \times \frac{t}{S} \times \frac{y}{d \times (1-r^2)}$$

Starting from a theoretical approach with a metal strip which, as is represented in figure 9, is made heavier on its free end with a weight G, this strip will initially have no potential energy and no kinetic energy in its rest position.

When the weight is brought from the position P1 into the position P2 by a force F, the weight G will have a maximal potential energy and a minimal kinetic energy.

When the force F is removed in the position P2, the weight will go back to its rest position P1 and build up speed and kinetic energy during this movement. This kinetic energy has a maximum value on the moment the weight G goes through the position P1, whereas the potential energy is equal to zero on that moment.

The maximal kinetic energy makes sure that the weight G goes back into the position P3, where the kinetic energy again reaches its minimum value and the potential energy is again maximal. An oscillatory vibration is created which would continue endlessly if no energy was lost.

This oscillatory frequency is determined by the length L of the strip, the mass of the weight G and the elastic modulus of the strip. In principle, the ratio between these quantities in relation to the oscillatory frequency is as follows:

$$F_{osc} = Y / (L \times G)$$

whereby

y = Young's modulus
L = length of the strip
G = weight at the end of the strip

Thus, we can say that the oscillatory frequency diminishes when the mass of the weight G increases, which is represented in figures 10 and 11 respectively, where the oscillation is represented without a weight and with a weight.

Taking into account that the frequency is inversely proportionate to the weight in the above formula of the resonance frequency, this gives the following result:

$$F_{rr} = K \times \frac{t}{S} \times \frac{y}{d \times (1-r^2)} \times \frac{1}{G}$$

In order to obtain this with a flat, circular membrane 3, it can be glued in on the edge with a flexible adhesive 11, such as for example silicone rubber, so that the housing 2 will function as a weight and the pitch over is situated exactly in the flexible zone where the membrane 3 is glued in on its edge.

This is schematically represented in figure 12, whereby the bent-out form of the membrane 3 is exaggerated.

The bending is characterized by the following dimensions:

A = deflection of the membrane in the centre, which is for example 1 mm for 100 Hz, 0.3 mm for 300 Hz and 0.01 mm for 10 kHz;
B = radius of the free part of the vibrating membrane 3;
a = deflection of the glued-in part on the edge;
b = width of the supporting edge, in other words of the above-mentioned collar 10.

We could roughly say that the ratio a/b is equal to the ratio A/B and that, consequently:

$$a = (A \times b)/B$$

With a radius B of 12.5 mm and a supporting edge with a width b of 2 mm, we find that:

a = 0.16 mm at 100 Hz
a = 0.04 mm at 300 Hz
a = 0.0008 mm at 10 kHz

Thus, the end of the vibrating plate moves maximally

0.16 mm at 100 Hz
0.04 mm at 300 Hz
0.0008 mm at 10 kHz

When a flexible silicone adhesive is used with a viscosity of for example 35,000 mPa-s, the movement of the end of the membrane 3 will not be restrained, but, in combination with the weight of the surrounding housing 2, it will lower the resonance and dampen it according to the above-described principle. This resonance is damped in such a design and is less sharp than in other designs.

This is schematically represented in figure 13 by means of the curves F_{rn}, F_{ri} and F_{rr} which represent the resonance frequencies with a nodal support, a support whereby the membrane 3 is glued or clamped on the edge, and a support whereby the membrane 3 is glued on the edge by means of a flexible adhesive 11 respectively.

The above-mentioned factor K can be expressed as follows:

$$K = (b/D4) \times v$$

whereby:

b = width of the collar 10;
D4 = diameter of the membrane measured between the collar 10;
v = viscosity of the adhesive 11.

The formula of the resonance frequency is then:

$$F_{rr} = \frac{b \times v}{D4} \times \frac{t}{S} \times \frac{y}{d \times (1-r^2)} \times \frac{1}{G}$$

As the density d (the weight per volume) of the plate has an influence on the resonance frequency and forms the opposing force, the inertia of the creation of the vibration by the density will have an influence on the resonance. The higher the density, the lower the resonance frequency.

The reaction inertia also has an influence on the damping of the higher resonances. When the membrane 3 produces sound vibrations and these are reflected from a short distance, the membrane 3 will receive more resistance over its entire surface and thus it will start to move more slowly. As a result, the quality factor of the higher harmonics will be reduced and the membrane 3 will be apparently heavier, so that the resonance frequency decreases.

Moreover, the higher and sharper harmonics will be attenuated.

From the above we may conclude that when the membrane 3 is mounted close to the inner side of the front wall 8, i.e. at a short distance D1, the density d will apparently rise, so that the resonance phenomenon is damped and moreover smoothed.
From the above we may derive that the density d apparently increases as the above-mentioned distance D1 becomes smaller, and also as the surface S1 of the wall part 17, by which is meant the part which is situated at the distance D1 from the membrane 3, becomes bigger. Taking into account this influence in the formula of the resonance frequency $F_{rr'}$, it will look as follows:

$$F_{rr} = \frac{b \times v}{D4} \times \frac{t}{S} \times \frac{y}{d \times (S1/D1) \times (1-r^2)} \times \frac{1}{G}$$

whereby:

S1 = surface of the wall part 17 situated at a short distance D1 from the membrane 3;
D1 = distance between the membrane 3 and the wall part 17.

It is clear that the resonance frequency can be lowered by selecting the distance D1 as small as possible.

The difference is illustrated in the accompanying figure 14, in which the drift of the resonance frequency at a distance D1 of 10 mm is represented by means of the curve C1, whereas the drift at a distance D1 of 2 mm is represented by means of the curve C2.

Further, it should be noted that piezo-electric membranes can react very fast and actually have no restrictions whatsoever as far as band width and reaction rate are concerned. In a complex signal, such as speech or music, an infinite number of harmonics are briefly present. The membrane 3 is obliged in this case to vibrate and to react to these frequencies. Thus, there are situations in which certain frequency contents would resonate on certain places of the membrane 3 and thus fragmentate at higher frequencies. Consequently, sharp peaks in the higher frequencies are noticed in a frequency analysis, which should be avoided as they produce a specific interference with a certain frequency content. These sharp peaks are schematically represented in the curve of figure 15.

By covering the membrane 3, as mentioned above, with a layer 21 of flexible material, such as silicone, this is prevented according to the invention. This layer 21 absorbs the vibration energy in case of fragmentation, and the sharp resonance peaks at high frequencies are damped, as is schematically represented by the curve in figure 16.

Figure 17 schematically represents how the vibrations T which are created during local fragmentation are absorbed by the layer 21. In applications where the higher frequencies are required for alarm functions or where a lot of sound pressure is required for specific higher frequencies, this damping layer may not be provided at all or may be provided only partially.

It is clear that the above-mentioned front wall 8, at least when no measures are taken, starts to vibrate due to the sound vibrations which are emitted on the inner side of the front wall 8 by the membrane 3. Thus is created a parasitic vibration on the front wall 8 which is out of phase in relation to the required vibration produced by the membrane 3, and which is emitted through the holes 20, so that an audible distortion of the sound signal may be created.

Also, for this reason, measures are taken according to the invention which dampen the front wall 8 so as to prevent and/or to minimize parasitic vibrations.

As mentioned above, these measures consist in that the front wall 8, in particular the wall part 17, is stiffened and/or reinforced by means of a thickening 19 and/or by using a body 24 respectively.

The effect of the damping layer 25 will become clear from the following exposition.

The kinetic energy of the moving front wall 8 can be expressed as follows:

$$_{Ek} = 0.5 \times m \times v^2 + 0.5 \times I \times w^2$$

whereby:

m = mass;
v = velocity;
I = moment of inertia;
w = angular velocity or oscillatory frequency.

In order to prevent a critical damping, the pressure P_m must be exerted on the front wall 8 by the sound vibrations, in a point on the front wall, in compliance with the following condition:

$$P_m \leq 0.5 \times m \times v^2$$

When the front wall 8 starts to vibrate, the following conditions must be met:

$$P_m \leq 0.5 \times m \times v^2 + 0.5 \times I \times w^2$$

In order to realize this, the layer 25 is thus provided on the weight. The elastic material from which this layer 25 is made dampens the shock wave and resolves the forces created thereby in one frontal force and several transverse forces. This layer 25 functions so to say as a shock absorber, whereby the force K, generated by the sound vibration of the membrane 3, is damped and resolved in non-interfering transverse forces, as is represented in figures 18 and 19 respectively.

It should be noted that the elastic modulus E of an elastic material can be expressed as follows:

$$E = 3 \times k \times (1 - 2 \times u)$$

$$E = 2 \times g \times (1 + u)$$

whereby:

k = bulk modulus;
u = transverse contraction coefficient;
g = sliding modulus.

For most materials, the bulk modulus is 10^{10} Newton/m^2 or 1% volume reduction at 1,000 atmosphere. The bulk modulus k of the elastic material used at 100% elongation, expressed in N/mm^2, is preferably situated between or is equal to 0.1 and 1 according to the invention, in other words:

$$0.1 \leq k \leq 1$$

The transverse contraction coefficient u of the elastic material used preferably complies with:

$$0 \leq u \leq 0.5$$

Finally, a number of curves of the reproduction of the sound produced by a known electrodynamic reproducer and by a piezo-electric reproducer according to the invention are represented in the accompanying figures 20, 21 and 22. The curves which are marked with ED are hereby related to the electrodynamic reproducer, whereas the curves which are marked with FE are related to the piezo-electric reproducer.

Further, the figures 20, 21 and 22 are related to embodiments having three different diameters, namely of 25 mm, 35 mm and 57 mm respectively.

A comparison of the curves PE and ED clearly indicates that the reproduction by means of an element 1 according to the invention is usually significantly better and stronger as far as sound pressure is concerned than the reproduction by means of an electrodynamic embodiment with similar dimensions.

The present invention is by no means limited to the embodiments described as an example and represented in the accompanying drawings; on the contrary, such an element for reproducing and/or recording sound can be made in all sorts of shapes and dimensions while still remaining within the scope of the invention.

Claims

1. Element for reproducing and/or recording sound, consisting of a membrane (3) which is equipped with a piezo-electric element (5), electric connecting means (6) working in conjunction with the piezo-electric element (5) and a housing (2) for the membrane (3), characterized in that the element (1) contains a wall part (17) situated at a short distance (D1) from the membrane (3), such that the sound vibrations which are generated by the membrane (3) are damped.

2. Element according to claim 1, characterized in that the distance (D1) between the membrane (3) and the wall part (17) is shorter than or equal to 10 mm.

3. Element according to claim 2, characterized in that the distance (D1) between the membrane (3) and the wall part (17) is between 0.5 and 5 mm.

4. Element according to any of the preceding claims, characterized in that the above-mentioned wall part (17) is locally thickened.

5. Element according to any of the preceding claims, characterized in that a chamber (18) is formed along the perimeter.

6. Element according to any of the preceding claims, characterized in that holes (20) are provided in the housing (2).

7. Element according to claims 5 and 6, characterized in that the holes (20) open in the above-mentioned chamber (18).

8. Element according to any of the preceding claims, characterized in that the above-mentioned wall part (17) is part of the housing (2).

9. Element according to any of the preceding claims, characterized in that the above-mentioned wall part (17) is provided with a weighting body or weight (24).

10. Element according to claim 9, characterized in that the above-mentioned wall part (17) consists of a body (24) which is provided between the membrane (3) and a wall of the housing (2) parallel thereto, whereby this body (24) is mounted at a distance from this wall, preferably on a central support (26).

11. Element according to claim 9 or 10, characterized in that the body (24) consists of a disc made of material with a large density, preferably a disc made of metal, in particular copper, brass, lead or an alloy.

12. Element according to any of the preceding claims, characterized in that one or several composing parts thereof are provided with a damping layer (21-25).

13. Element according to claim 12, characterized in that the above-mentioned damping layer (21-25) is carried out according to any of the following possibilities or a combination of two or more of the following possibilities:

- as a damping coat (21) on the membrane (3), preferably on the side directed towards the above-mentioned wall part (17);
- a partial coat or no coat at all on the membrane so as to promote the higher frequencies;
- as a damping coat (25) provided on the above-mentioned wall part (17) on the side directed towards the membrane (3);
- in the case where the wall part (17) is provided with a weighting body (24), as a damping layer (25) situated on the side of this body (24) which is directed towards the membrane (3).

14. Element according to any of claims 12 or 13, characterized in that the damping layer (21-25) is made of an elastic material, in particular silicone, silicone rubber or an elastomer, preferably having a thickness in the order of 1 mm.

15. Element according to any of the preceding claims, characterized in that the membrane (3) consists of a support (4) formed of a thin metal plate and a piezo-electric element (5) in the shape of a piezo-crystal fixed upon it.

16. Element according to any of the preceding claims, characterized in that the membrane (3) is fixed on a collar (10) provided in the housing (2) with its edges by means of an adhesive (11), preferably an elastic adhesive.

17. Element according to any of claims 1, 2 or 3, characterized in that the housing (2) contains a housing part (7) with a front wall (8) having a reinforced and/or thickened wall part (17) situated at a short distance (D1) from the membrane (3), and a side wall (9) provided with a collar (10) upon which the membrane (3) is fixed; that a chamber (18) is formed at least around this wall part (17) which is deeper than the above-mentioned distance (D1), whereby openings are provided in the front wall (8) at the height of this chamber (18); in that a damping layer (21) is provided on the membrane (3); and in that the housing (2) is provided with a cover plate (16) on the back side which is equipped with connecting means (6).

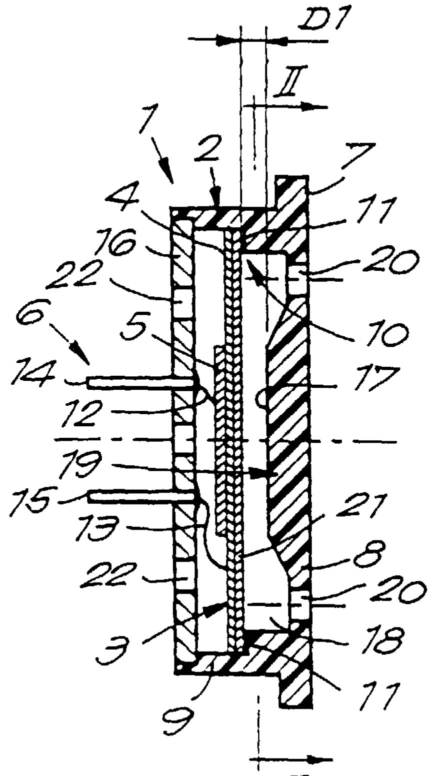


Fig.1

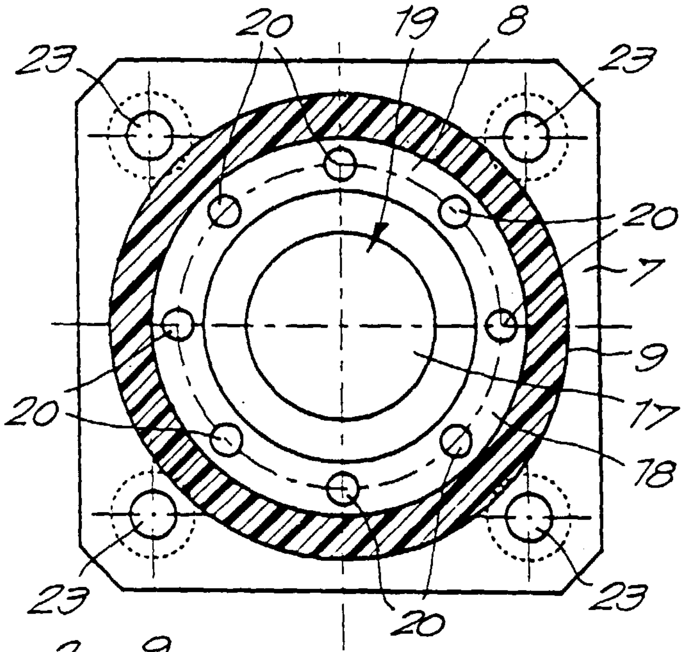


Fig.2

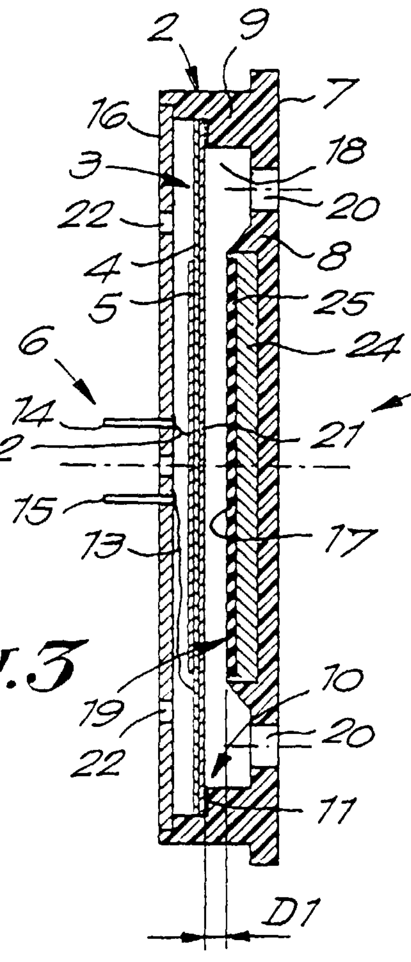


Fig.3

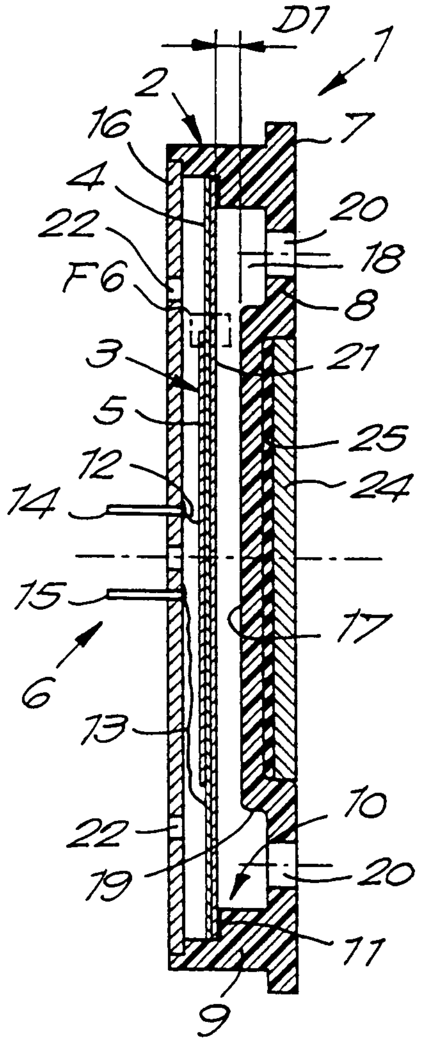


Fig.4

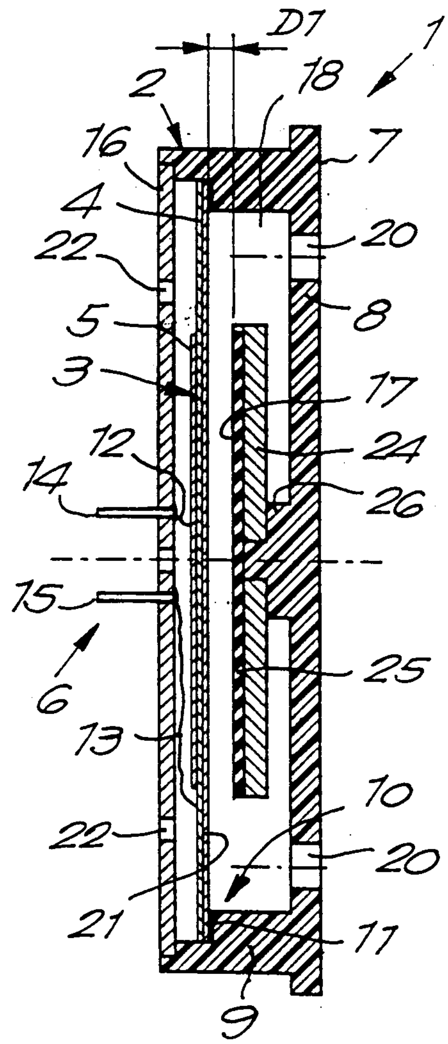
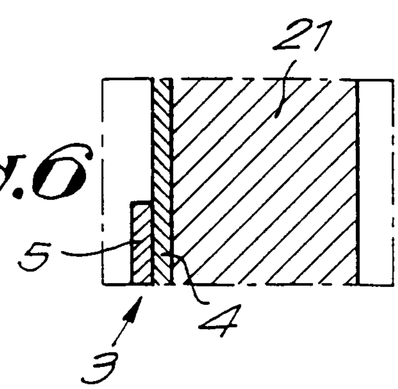


Fig.5

Fig.6



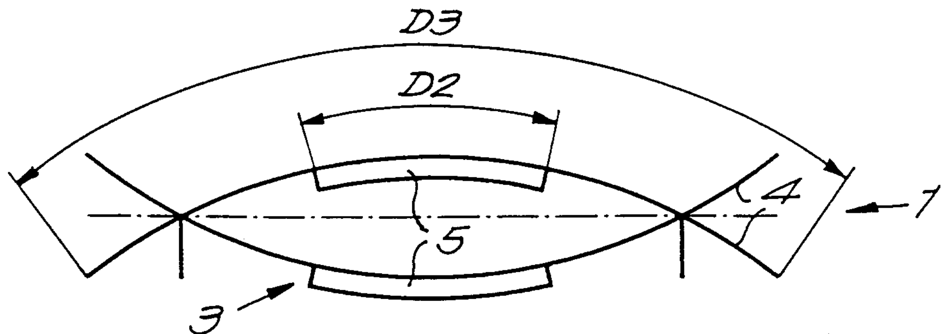


Fig.7

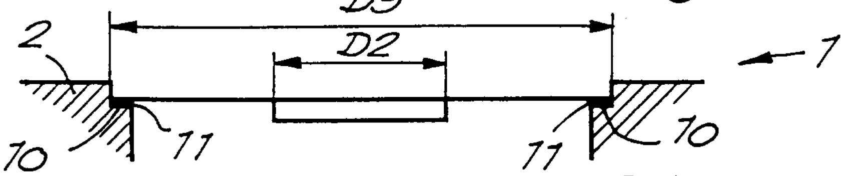


Fig.8

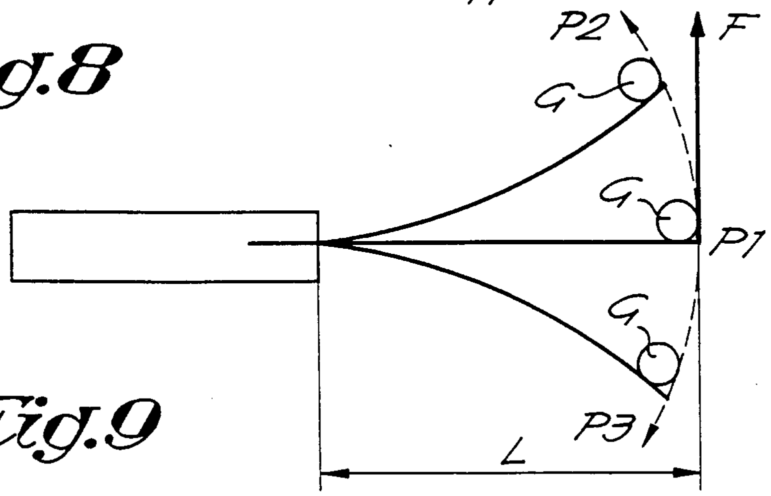


Fig.9

Fig.10

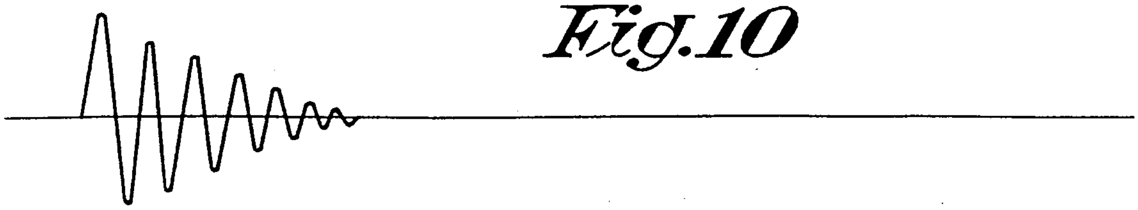
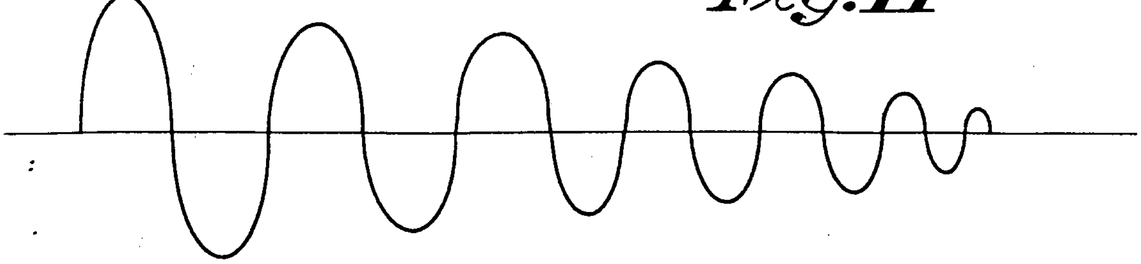


Fig.11



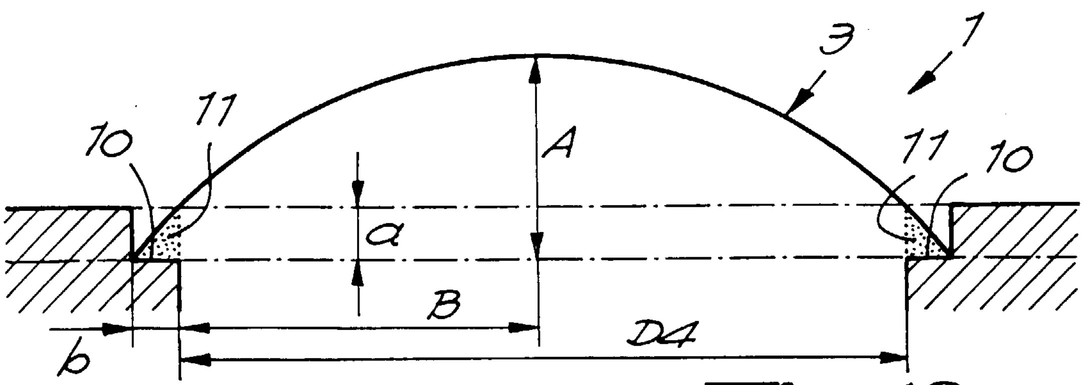


Fig.12

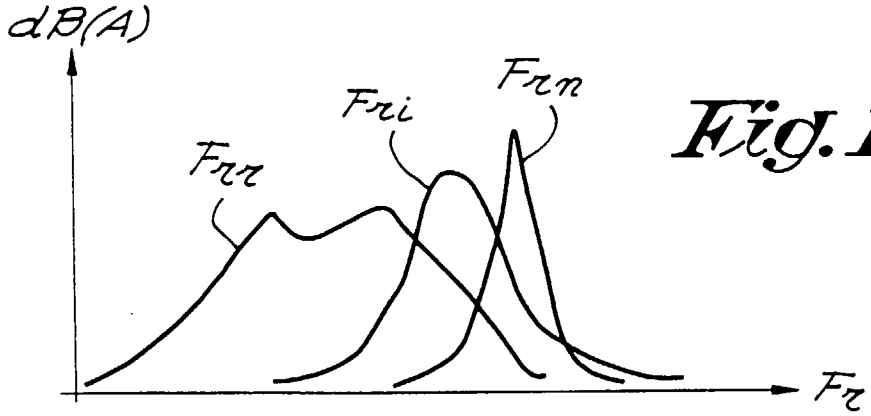


Fig.13

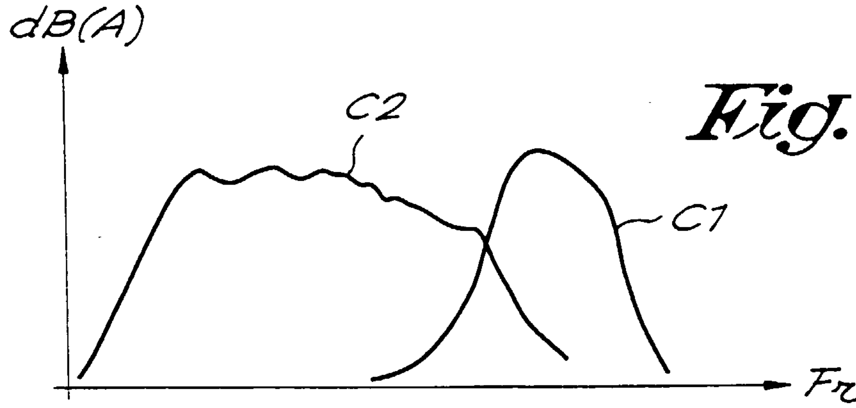


Fig.14

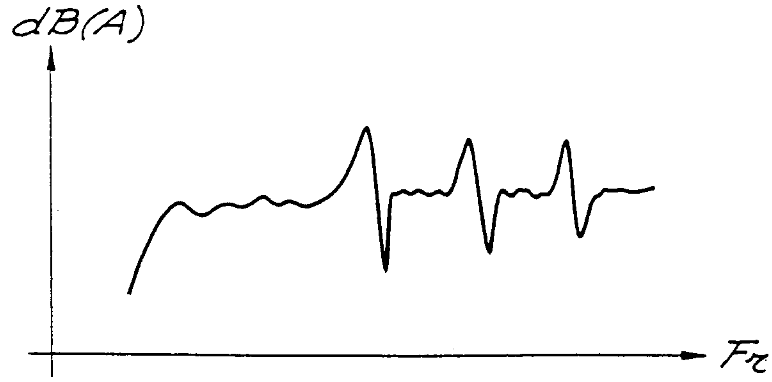


Fig.15

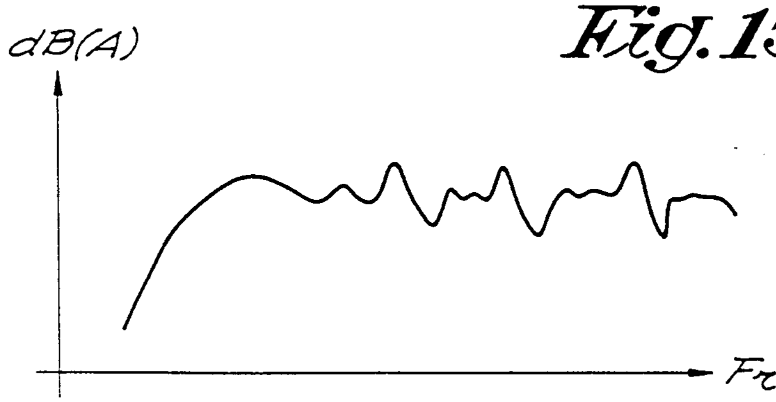


Fig.16

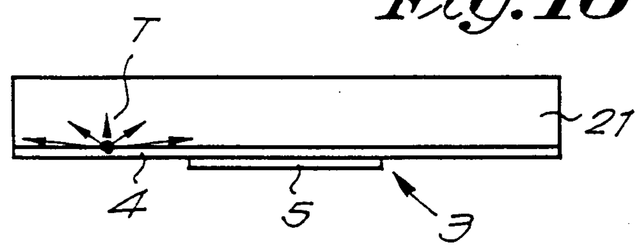


Fig.17

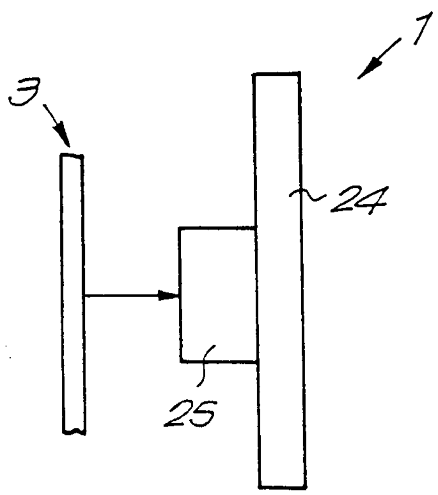


Fig.18

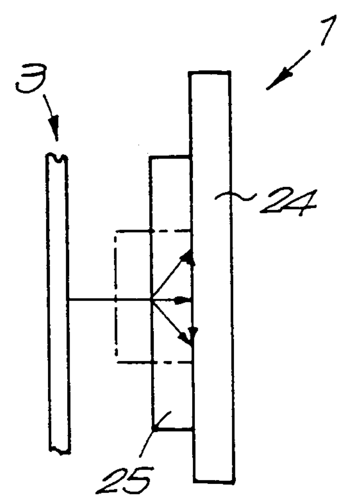


Fig.19

Fig.20

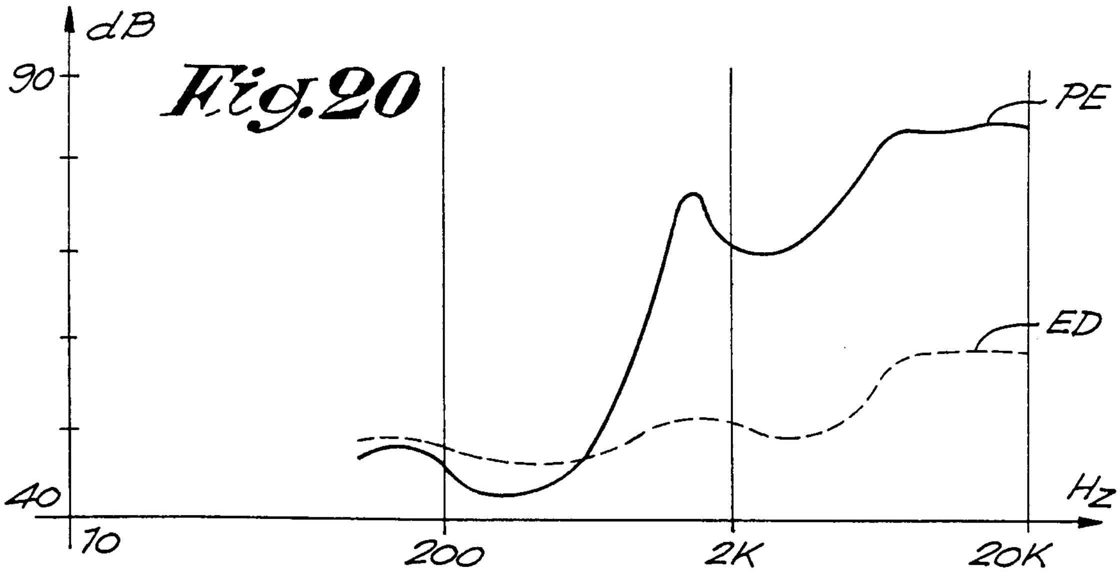


Fig.21

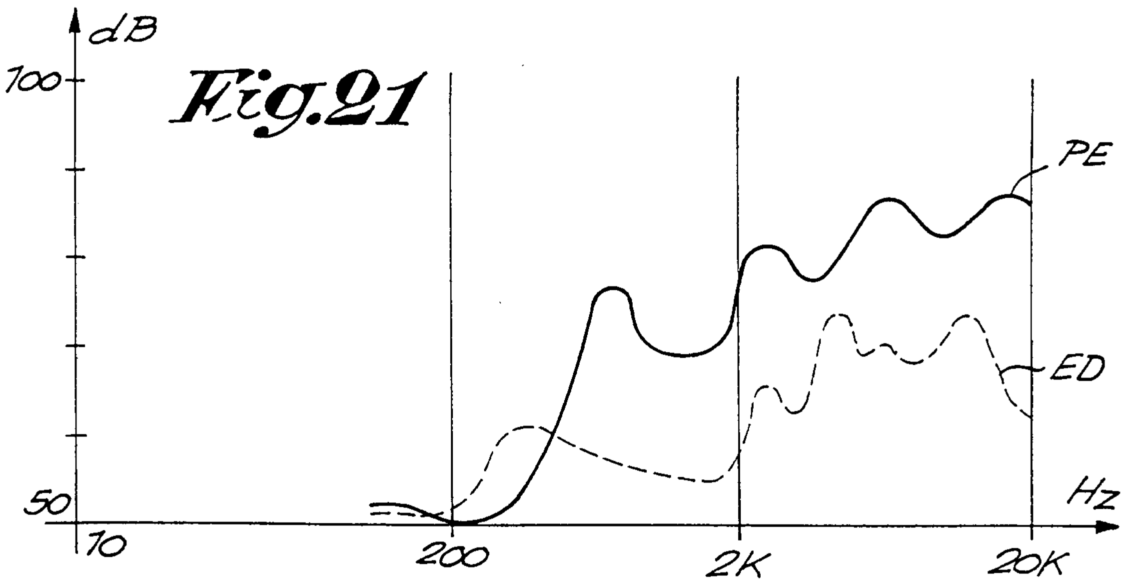
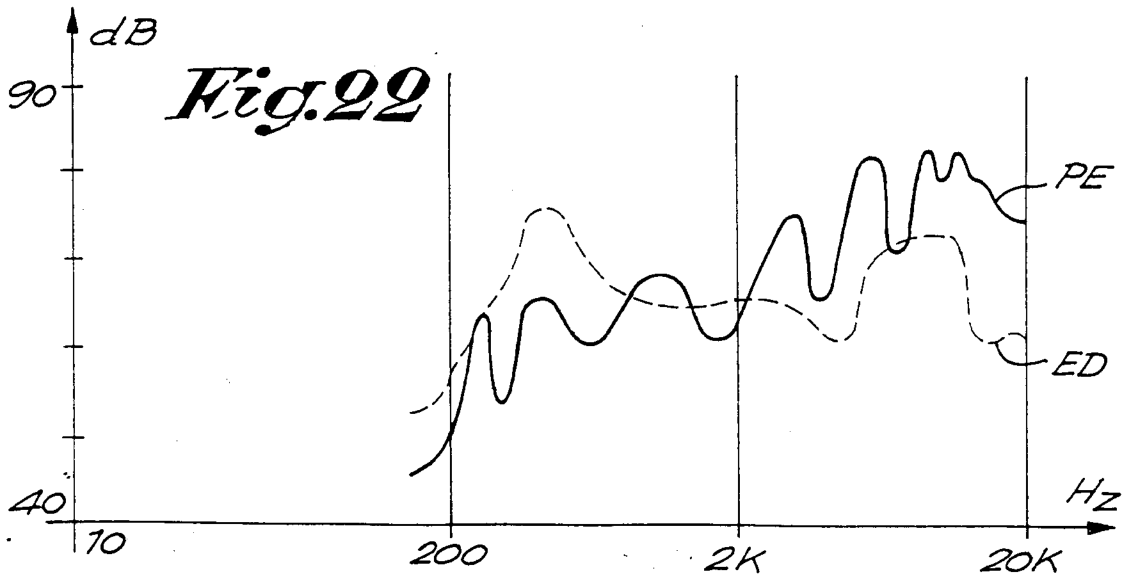


Fig.22



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 20 0716

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.6)
X A	PATENT ABSTRACTS OF JAPAN vol. 096, no. 005, 31 May 1996 & JP 08 019096 A (MATSUSHITA ELECTRIC IND CO LTD), 19 January 1996 * abstract *	1,4,6,8 2,3,5	H04R17/00 H04R1/22
X	US 3 654 402 A (ROOS JAN) 4 April 1972 * column 2, line 4 - line 18; figures *	1,12-15	
X	PATENT ABSTRACTS OF JAPAN vol. 009, no. 244 (E-346), 30 September 1985 & JP 60 096093 A (MATSUSHITA DENKI SANGYO KK), 29 May 1985 * abstract *	1	
A	US 4 607 145 A (RAVINET PIERRE ET AL) 19 August 1986 * column 2, line 50 - column 4, line 37; figures *	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	FR 2 542 550 A (THOMSON CSF) 14 September 1984 * page 4, line 19 - page 5, line 14; figure 1 *	1	H04R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	28 July 1998	Gastaldi, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
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)