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(54) Headphone device.

(57) A headphone device designed to cooperate with the concha of the auditory meatus of the human ear. The headphone device includes a housing (51) containing a speaker, a projection (53) extending from the housing (51) and fitting into the concha of the human ear, an opening (54) formed in the projection (53) at a location facing towards the auditory meatus of the human ear and a headband (41) for supporting the housing (51) in proximity to the human ear.

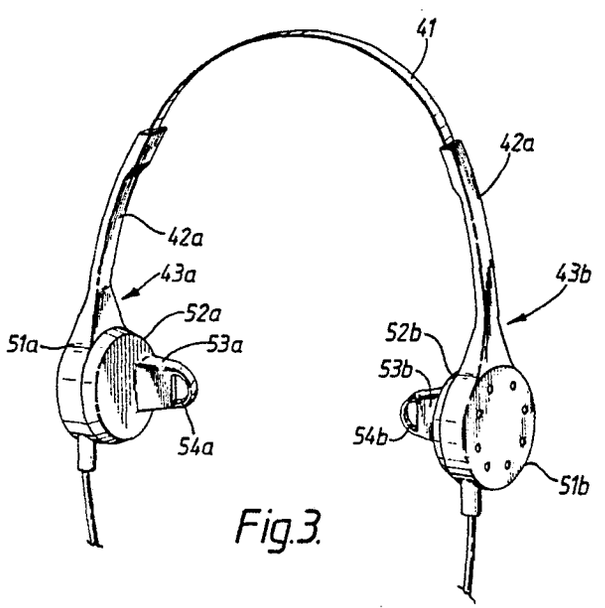

Fig.3.

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HEADPHONE DEVICE

The present invention relates generally to a headphone device, and more particularly to an ear-fit type headphone device.

Figures 1 and 2 respectively show two conventional headphones.

The headphone device, as shown in Figure 1A, is called an "open-air" or "ear-fit" type headphone. This type of headphone device includes a U-shaped elastic head-band 12 and a pair of earspeaker units 14a and 14b. The earspeaker units 14a and 14b are supported on the respective ends of the head-band 12 by two hangers 13a and 13b. The hangers 13a and 13b are slidably attached to the ends of the head-band 12.

Figure 1B shows a cross-section of the lefthand earspeaker unit 14b of the headphone device, representative of the earspeaker units 14a and 14b. In Figure 1B, the lefthand earspeaker unit 14b is illustrated in position against a human ear 11. Each earspeaker unit 14a, 14b is comprised of a housing 22, a speaker 23, a hard cover 24 and an ear pad 25. The housing 22 is attached to the hanger 13b via a ball joint 21. The speaker 23 is housed inside the housing 22. The hard cover 24 is attached on the front face of the speaker 23. Moreover, the ear pad 25 is fitted on the housing 22 so that it covers the hard cover 24 of the housing 22. The ear pad 25 performs the role of a cushion for the external ear 11.

The headphone device of Figure 2 is called a "hermetically-sealed", "ear-muff" or closed type headphone device. This type of headphone device has a pair of earspeaker units 30a and 30b which are constructed similarly to those of the earspeaker units 14a and 14b of the open-air type headphone device (see Figure 14). However, the earspeaker units 30a and 30b have a pair of ring-shaped ear pads 31a and 31b, in place of the ear pads 25. When these headphone devices are in use, these ring-shaped ear pads 31a and 31b cover the human ears.

In the case of the headphone device of Figure 1, the ear pads 25 are made of an air-permeable material. Thus, the ear pads 25 leak a large amount of sound. So that, the open-air type headphone device has the drawback that sound-pressure levels in the range extending from the low sound-frequency band to the middle sound-frequency band are enormously reduced. In order to prevent the problem, an attempt might be made to reduce the gap between the earspeaker unit 14 and the external ear 11. For example, the headband 12 might be given a strong bias so that the earspeaker unit 14 is pressed against the human ear. However, there then occurs another problem, that of the ear hurting due to the strong pressure.

As another way of improving the sound pressure, one might attempt to increase the sound pressure level by lowering the resonant frequency of the speaker 23. However, it is difficult to sufficiently lower the resonant frequency because the cavity of the housing 22 is limited to being small in this open-air type headphone device so as to be able to fit the earspeaker unit 14 into the external ear 11 of the human ear (see Figure 1B).

The hermetically-sealed or closed type headphone device, as shown in Figure 2, has little sound leakage, and has the advantage of high sound-reproduction efficiency in the middle and low sound-frequency bands. However, generally, it is large and heavy, and thus there is a problem that it is not suitable for use over long periods.

The present invention seeks to provide an ear-fit type headphone device which has a light weight and a better fitting to the human ear.

The present invention also seeks to provide an ear-fit type headphone device which has sufficient sound-pressure levels like hermetically-sealed or closed type headphone devices.

A headphone device according to the present invention includes a housing containing a speaker, a projection extending from the housing and fitting into the concha of the human ear, an opening formed in the projection at a location facing towards the auditory meatus of the human ear and a headband for supporting the housing in proximity to the human ear.

For a better understanding of the present invention and many of the attendant advantages thereof reference will be made, by way of example, to the accompanying drawings, wherein:

Figure 1A is a perspective view showing a conventional ear-fit type headphone device;

Figure 1B is a cross-section showing the earspeaker unit of Figure 1A;

Figure 2 is a perspective view showing a conventional hermetically-sealed or closed type headphone device;

Figure 3 is a perspective view showing an embodiment of a headphone device according to the present invention;

Figure 4 is a cross-section of the earspeaker unit of Figure 3;

Figure 5 is perspective view showing a human ear;

Figure 6 is an equivalent-circuit diagram to illustrate the operation of the headphone device according

to the present invention;

Figure 7 is a perspective view showing another embodiment of an earspeaker unit according to the present invention; and

Figure 8 shows graphs of frequency characteristics of the headphone device of Figure 7.

The present invention will be described in detail with reference to Figures 3 to 8.

Referring now to Figures 3 and 4, a first embodiment of the headphone device according to the present invention will be described in detail. In Figure 3, the headphone device has an elastic U-shaped headband 41 and a pair of earspeaker units 43a and 43b. The earspeaker units 43a and 43b are supported on the respective ends of the head-band 41 by two hangers 42a and 42b. The hangers 42a and 42b are slidably attached to the ends of the headband 41.

In Figure 4, the lefthand earspeaker unit 43b is representatively illustrated in position against a human ear. Each earspeaker unit 43a, 43b is comprised of a housing 51b, a speaker 61 and a projection 53b. The housing 51b is integrally formed with the hanger 42b. The speaker 61 is housed inside the housing 51b. The projection 53b has a hollow and an opening 54b.

A large number of air-permeable holes are formed in the back of the housing 51b (see Figure 3). Thus, a cavity of the housing 51b communicates with the outside of the housing 51b. The cavity of the housing 51b also communicates with the hollow of the projection 53b. Thus, the cavity of the housing 51b communicates with the opening 54b of the projection 53b. On the other hand, the front 52b of the housing 51b is closed, i.e. the earspeaker housing is a closed type housing.

The speaker 61 is housed in the housing 51b so as to face the front 52b of the housing 51b. Here, the projection 53b is integrally formed with the front 52b so that the hollow of the projection 53b communicates with the cavity in the housing 51b. The opening 54b is provided at the end of the projection 53b. The righthand earspeaker unit 43a has a similar projection 53a and opening 54a.

The construction of the human ear is illustrated in Figure 5. The ear, seen from outside, has an external ear 71, a concha 72, an antitragus 73, a tragus 74 and an external auditory meatus 75 which leads inside the ear.

When the earspeaker unit 43b is fitted to the ear, as shown in Figure 4, the projection 53b passes between the tragus 74 and the antitragus 73, and penetrates into the concha 72. The sizes of the projection 53b and the opening 54b are designed so that the opening 54b faces the outer end of the external auditory meatus 75.

Referring now to Figure 6, a mechanical acoustic impedance of the earspeaker unit 43b will be described. Figure 6 shows an equivalent-circuit diagram representing a state where the earspeaker unit 43b is worn on the human ear.

In Figure 6, an inductance Md, a capacitance Cd and a resistance Rd represent respectively the mass, the compliance and the mechanical resistance of the diaphragm of the speaker 61. Element Vs is an audio signal applied to the speaker 61. Block Zear is the acoustic impedance of the earspeaker 43b at the opening 54b of the projection 53b. Element Mear is the inertance and element Rear the sound resistance of the gap between the earspeaker unit 43b and the ear. Acoustic impedance Zear from the speaker diaphragm to the eardrum is determined by the inertance Mear and the sound resistance rear of the gap. Moreover, element Cear is the acoustic capacitance of the cavity of the ear seen by the earspeaker. The acoustic capacitance Cear corresponds to the acoustic impedance of the external auditory meatus. Resistances R1 and R2 are parts of the acoustic resistance of the cavity of the housing 51b. Capacitance C1 is the acoustic capacitance of the cavity of the housing 51b.

A capacitance Ch, shown in that branch of the equivalent circuit indicated by the dotted line, corresponds to the acoustic impedance occurring in the conventional hermetically-sealed type headphone device as shown in Figure 2. The capacitance Ch is also present between the earspeaker unit and the external ear when the conventional headphone device is worn on the human ear. Usually the capacitances Cear and Ch obey the following inequality:

$$\frac{1}{\omega . Cear} \geq \frac{1}{\omega . Ch}$$

According to the above embodiment, the projection 53b penetrating into the concha reduces the volume of the cavity of the concha. Thus, the capacitance Cear becomes small. While, according to the conventional hermetically-sealed type headphone device, the cavity of the concha is left as it is. Thus, in the latter case, the capacitance Ch has a relatively large value. By effecting these changes in the

capacitances Cear and Ch, the embodiment of Figure 3 in use gives rise to a much larger acoustic impedance than exists when a conventional headphone device is used.

Therefore, the embodiment of the present invention remarkably improves sound-pressure levels E in the middle and low sound-frequency bands, particularly in the low sound-frequency band. On the other hand, the conventional hermetically-sealed or closed type headphone device of Figure 2 has poorer sound-pressure levels E due to its associated value of capacitance Ch. Thus, the headphone device according to the present invention has a good sound-pressure characteristic, even though the diaphragm of the speaker 61 is small in diameter and short in oscillation stroke.

As a result, the headphone device of Figure 3 gives rise in use to sound pressure levels E in the low sound-frequency band near 100 Hz approximately 20dB above those of the conventional open-air type headphone device of Figure 1 with the same speaker.

Also, since the projection 53b fits into the concha, the earspeaker unit 43b does not easily fall from the ear. Thus the spring bias of the headband 41 can be reduced. Practically, a spring bias of about 50g or less is satisfactory in the embodiment of Figure 3, while the conventional headphone devices of Figures 1 and 2 require a spring bias of about 100g or more. Therefore, when the headphone device according to the present invention is used, comfort is greatly improved. Thus, even when used for long periods, the ears do not hurt as much as with conventional headphone devices.

Also a headphone device having a speaker of 20mm to 30mm diameter according to the present invention is comparable with the conventional hermetically-sealed or closed type headphone device having a speaker of about 40mm diameter.

In respect of structure, the headphone device of the present invention does not need any ear pads. Thus, the headphone device is easy to manufacture and low in cost. Generally, ear pads have several drawbacks. For example, they become dusty and soiled. If such a problem of dust or soiling occurs, it is difficult to reverse. Further, the problem is not desirable in respect of health. Also, they deteriorate as a result of long periods of use, and have to be replaced. The headphone device of the present invention, however, is free of the problems of ear pads. As the housing of this invention can be constructed from plastics, it is easy to keep the housing clean and there is no risk of deterioration.

Also, the projection 53b is provided in a position offset from the centre axis of the housing so that the projection 53b has a smooth fit with the concha, as shown in Figure 4. Accordingly, with reduced headband spring bias the earspeaker unit 43b will press less against the external ear 71 than with a conventional known headphone device.

Referring now to Figure 7, another embodiment of the present invention will be described.

The same symbols are used for parts which are equivalent to those of the headphone device of Figures 3 and 4. In this embodiment, the front 52b of the housing 51b has an opening 80 and an adjuster 81 for adjusting the area of the opening 80.

When constructed in this way, this embodiment has another advantage in addition to the advantages of the previous embodiment of Figures 3 and 4. That is, the frequency characteristic of the sound pressure can be adjusted, as shown by the frequency response characteristics of Figure 8. Graph A shown by the dotted line in Figure 8 is the sound-pressure level characteristic when the opening 80 is closed. Graph B shown by the solid line is the sound-pressure level characteristic when the opening 80 is opened.

When the acoustic impedance of the second embodiment of the headphone device, as shown in Figure 7, is expressed by the equivalent circuit as shown in Figure 6, the impedance Zear is varied as a function of the area of the opening 80.

As described above, the present invention can provide an extremely advantages headphone device.

Claims

1. A headphone device designed to cooperate with the concha of the auditory meatus of the human ear comprising: a housing (51) containing a speaker (61); and means for supporting the housing in proximity to the human ear;
CHARACTERISED IN THAT the headphone device further comprises a projection (53) extending from the housing (51) and fitting into the concha of the human ear and an opening (54) formed in the projection (53) at a location facing towards the auditory meatus of the human ear.

2. A headphone device according to Claim 1, wherein the housing (51) is a closed type housing.

3. A headphone device according to Claim 1, wherein the projection (53} is located offset from the centre of the housing (51).

4. A headphone device according to Claim 1, further comprising a second opening (80) in the housing

(51) and means (81) provided to open or close the second opening (80) to vary the frequency response of the headphone device.

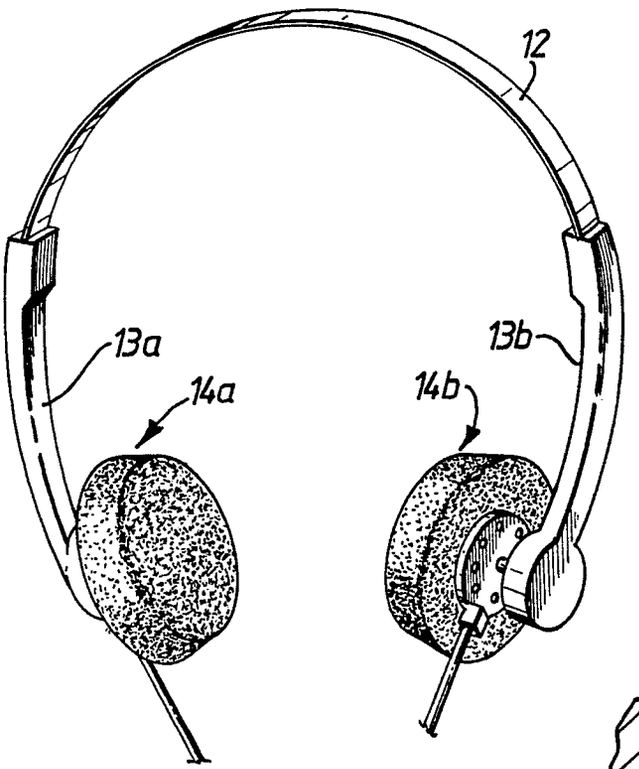

Fig.1A.

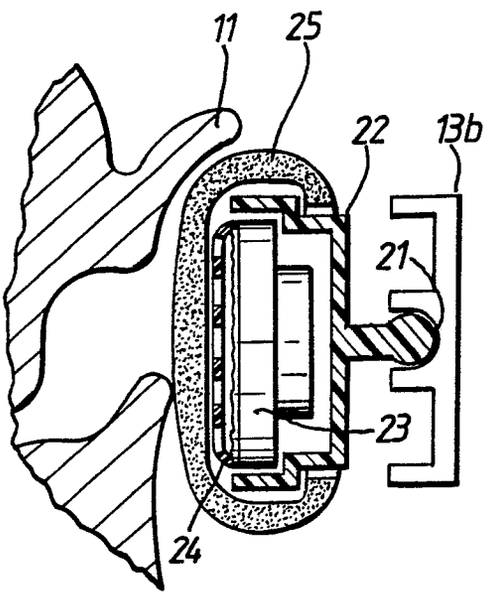

Fig.1B.

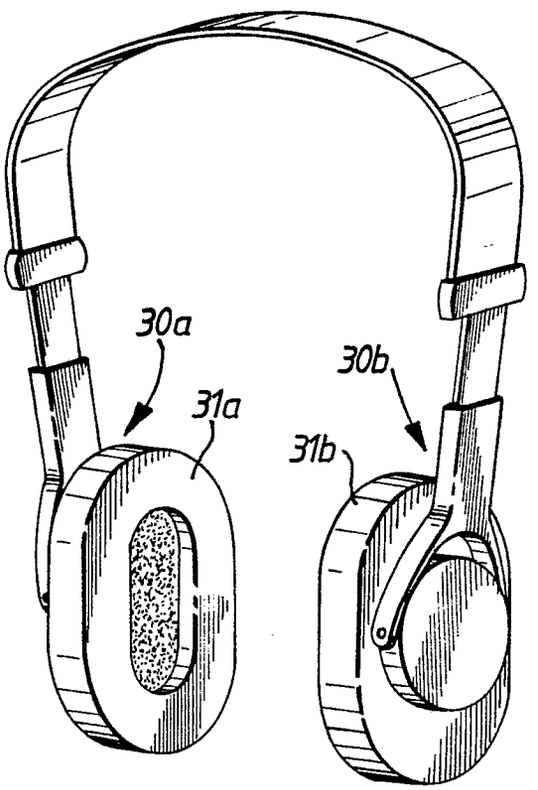

Fig.2.

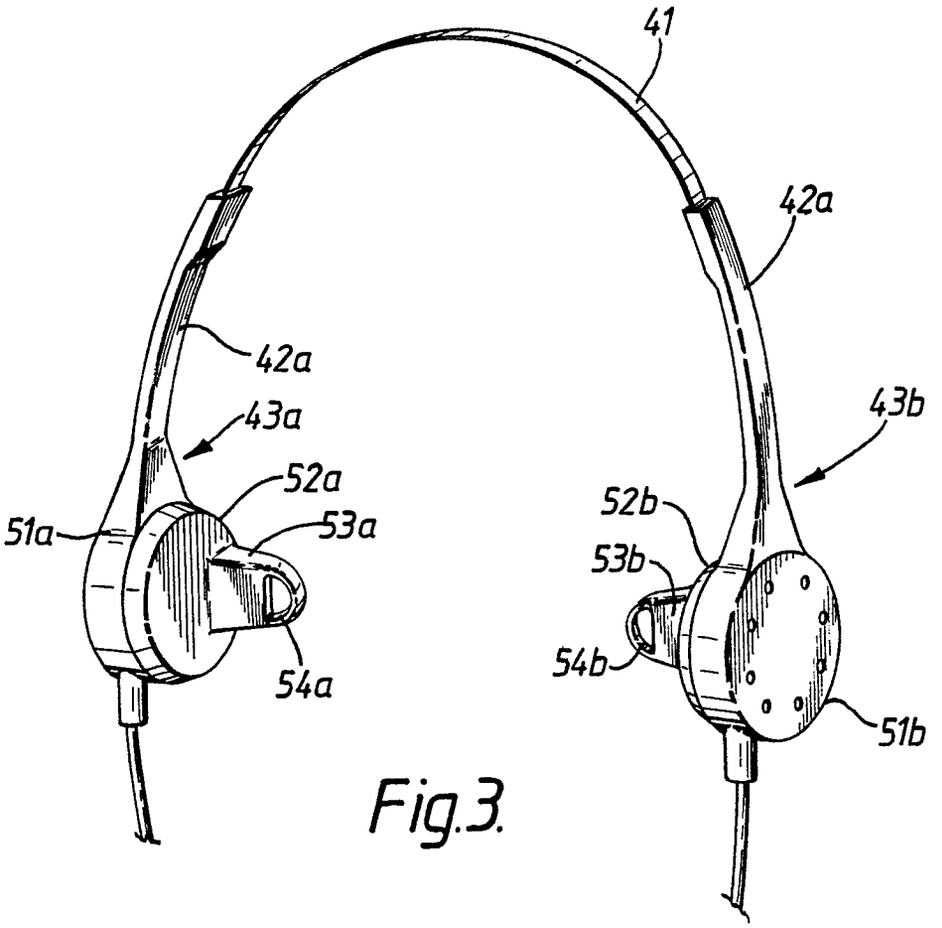
41
42a
42a
43a
43b
52a
52b
53a
53b
51a
54b
54a
51b

Fig.3.

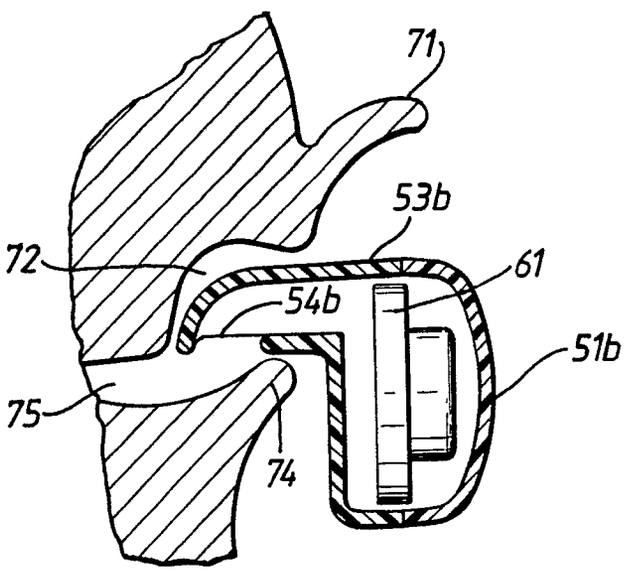
71
53b
72
61
54b
51b
75
74

Fig.4.

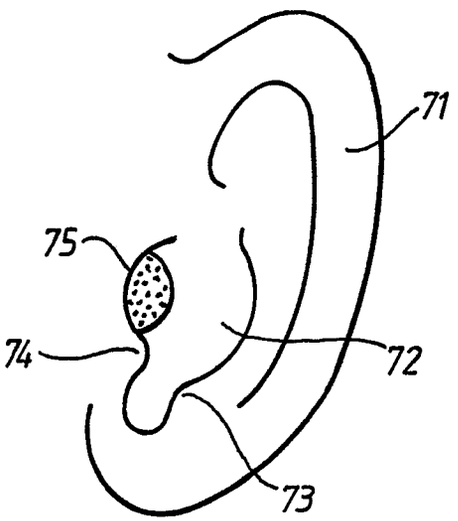
71
75
74
72
73

Fig.5.

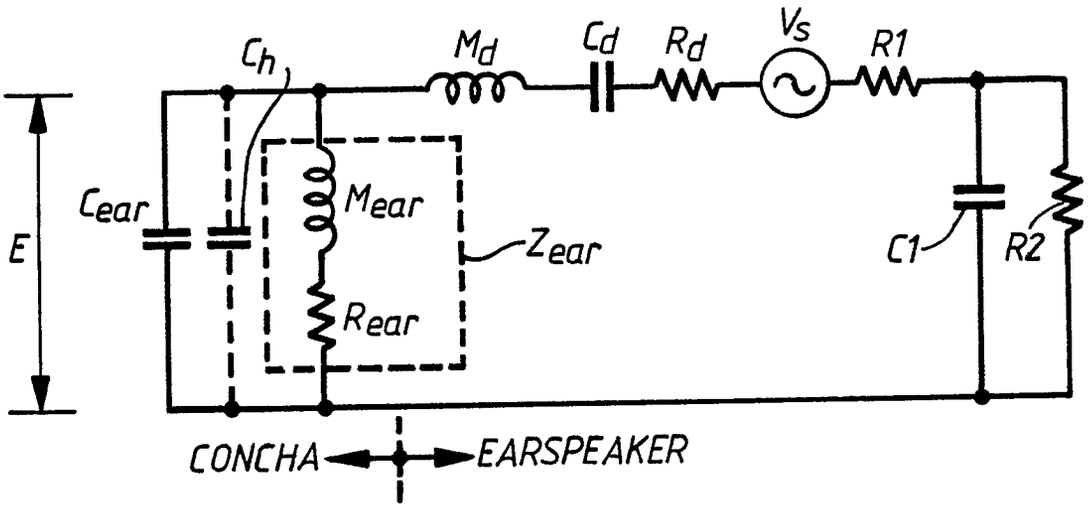
Ch
Md
Cd
Rd
Vs
R1
Cear
Mear
Zear
Rear
E
C1
R2
CONCHA
EARSPEAKER

Fig.6.

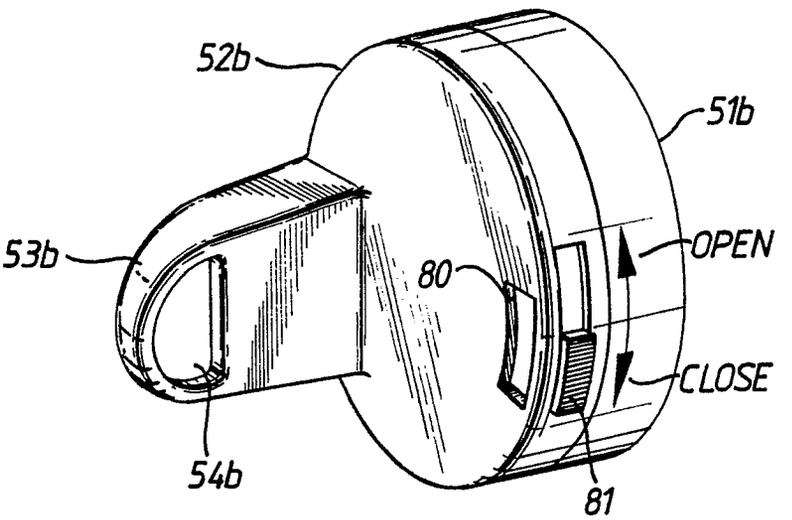
52b
51b
53b
80
OPEN
CLOSE
54b
81

Fig.7.

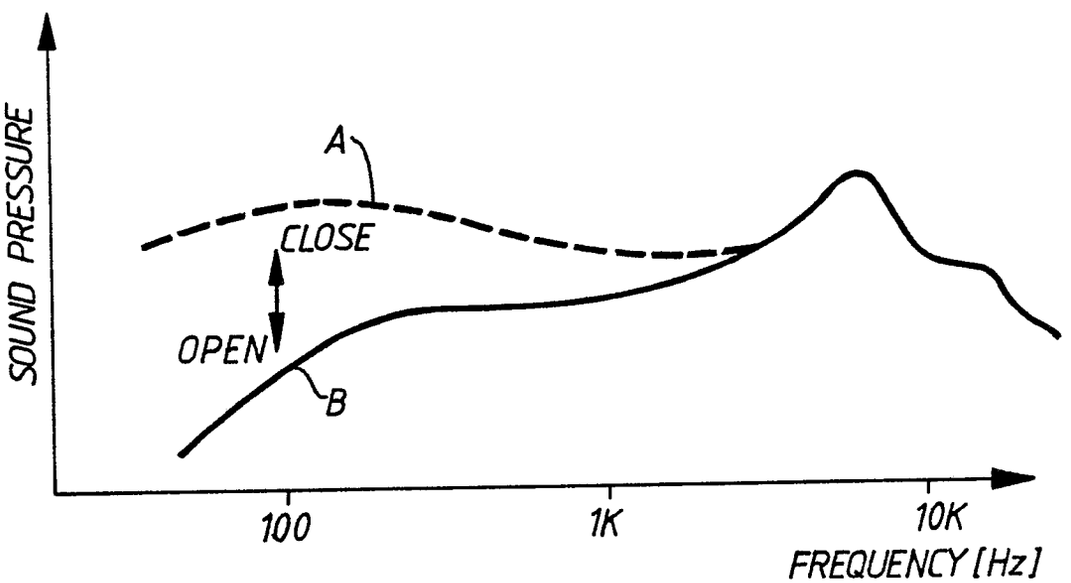
SOUND PRESSURE
A
CLOSE
OPEN
B
100
1K
10K
FREQUENCY [Hz]

Fig.8.