Jan. 10, 1961 M. AUBERT ET AL 2,967,913

ELECTRONIC INTENSIFYING EAR-DRUM

Filed April 24, 1957

Fig.1.

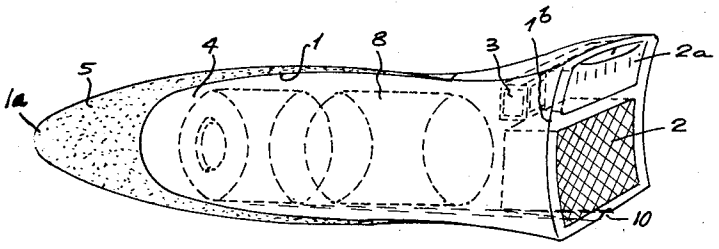


Fig.2.

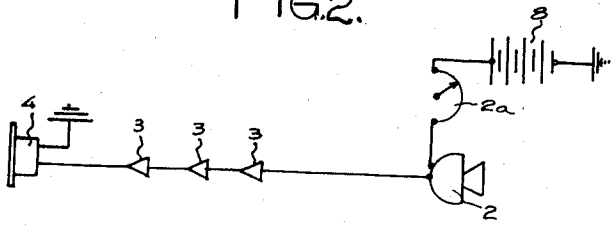
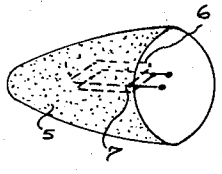


Fig.3.



INVENTORS:
Maurice Aubert
and
Eugène Miquelis
By
Walter Zuber
Patent Agent

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ELECTRONIC INTENSIFYING EAR-DRUM

Maurice Aubert and Eugène Miquelis, both of 4 Ave. de Verdun, Nice, France

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Heretofore, acoustic prosthetic appliances have been based on bone conduction or on transmission of sound waves through air. Because of this, there is a loss with such appliances that may be put at about 25 decibels. This is considerable loss when it is borne in mind that the best devised of these appliances produce only about 40 decibels.

Appliances of the nature referred to are usually in the form of pins, clips, spectacles, etc., and are all based on the same principles as pointed out above, with their efficiency being approximately identical.

The principle of the electronic ear drum of the present invention is three-fold:

(1) On the one hand, it is made for directly transmitting sound waves by way of solid and liquid mediums to the tympanum or ear drum, i.e., directly to the entrance of the middle ear.

(2) On the other hand, it is entirely self-contained, being powered, for example, by a thermoelectric couple or a battery.

(3) Lastly, its small dimensions enable it to be worn completely inside the ear.

The transmission of sound waves emitted by the apparatus may be made through the air or through the bone structure.

In the case of aerial transmission of waves, an air wave is utilized forming a buffer which is confined between the internal end of the apparatus and the tympanic membrane or ear drum.

In the case of bone transmission, i.e., by the internal ear method, the vibrations emitted are transmitted to the labyrinth by means of the bony, cartilaginous or membraneous walls of the external auditory passage, or the tympanic frame or ossicles, or walls of the ear drum.

Transmission of sound waves

Sound waves reaching the outer ear are collected by a microphone, intensified by a transistor amplifying system and are re-emitted by a suitable receiver. The piezo-electric type of receiver is particularly satisfactory. The receiver is connected to a vinyl chloride sponge block or any other hydrophoric, flexible, light material which is non-irritant to the tympanic membrane or the mucous membranes of the ear drum.

This plastic block is in contact with the tympanic membrane, or, when the latter is destroyed or when the deaf person has undergone mastoid surgery leading to such loss, such as an operation on the pietro-mastoidian portion of the temporal bone is located at the entrance of the middle ear. The block can be saturated in a liquid solution which will act as a sound wave transmitter, or serve to form, level with the entrance of the middle ear, the air bubble which will come into resonance and transmit the sound waves to the labyrinth when the tympanum has been destroyed.

One end of the block will press on the tympanum, or ear drum. The other end will be in contact with the receiver. Owing to the variety of shapes that can be

imparted to the contact block, the apparatus can be modified so as to strengthen either high-pitched or low-pitched sounds, according to the need indicated by the patient's audiogram.

The liquid, which may be called a "coaptation" liquid because it acts to fit the block to the ear, saturates the water-retaining block to a sufficient extent, in the case of a destroyed tympanum, to be able to cover the end of the ear drum with a liquid layer and confine an air bubble level with the entrance to the middle ear. This quantity of liquid may be reduced to a simple moistening in the case of an intact tympanum, or even eliminated, if the plastic material in contact with the tympanum is sufficiently flexible and adherent.

To prevent its evaporation, the liquid should have a high viscosity, and the addition of silicone or the like will diminish this evaporation. It should be renewed by the wearer of the apparatus as soon as hearing becomes more difficult.

Lastly, the liquid and any additioner should be non-irritant for the mucous membranes and preferably slightly antiseptic.

This apparatus utilizes the progress that has been obtained by the apparatus which formed the subject of French Patent No. 1,142,120, for an artificial ear drum.

It will comprise:

The receiver,
The amplifier and the body in which it is mounted,
The microphone, with a volume control,
The electrical supply.

Appearance of the apparatus

Although the device can be any shape if worn outside the ear, the small dimensions of the entire apparatus permit it to be formed to be placed completely inside the ear.

It is this configuration for use inside the ear which is the most desirable and best adapted for ordinary use.

The apparatus produced will have the following shape: A cylinder of 6 mm. maximum diameter whose tympanic end will be slightly tapered and the external end widened out to reach the diameter of the outer end of the auditory canal and the inside of the external ear.

Its internal or tympanic end will be adjusted in length a few millimeters according to whether it is to be used by a deaf person with an intact tympanum or a destroyed tympanum.

The body of the apparatus will be hollowed out with ducts extending therealong in a longitudinal direction enabling liquid secreted by the ear or an excess of "coaptation" liquid to drain off.

Its external end, containing a microphone, will be widened out so as to assume the shape of the auditory canal and the extreme inside of the external ear.

The entire apparatus will be about 28 mm. long, while being slightly variable in length according to the purposes for which it is intended (normal or destroyed tympanum, hollowed out mastoid cavity, children).

The device will have a slight curvature along the curve of the external ear passage or auditory canal.

The section of the apparatus containing the various electronic elements may be formed by a metal or plastic tube with the water-retaining block attached to its inner end.

In one design contemplated, there is a block of vinyl chloride sponge of cylindro-conical shape in which the electronic elements and conductors are embedded. The microphone is supported on the block by a tight-fitting barrier of collar form. The block acts both as a sound wave transmitter through its tympanic end and may also act as a thermoelectric or electrochemical energizing source.

One form of embodiment of the invention is shown, by way of example, in the attached drawing.

Figure 1 is a perspective view illustrating one embodiment of the present invention.

Figure 2 is a diagrammatic circuit diagram.

Figure 3 is a fragmentary view showing a modification.

The hearing appliance shown in Figure 1 is of such dimensions that it may be completely inserted into the outer ear passage and auditory canal.

This apparatus consists of a hollow cylinder **1** of small diameter having a slight curvature, thus adapting the cylinder to the curvature of the outer ear passage or auditory canal.

The end **1***a* of the cylinder **1**, called the internal or tympanic end, is cone-shaped and has a rounded top. This end **1***a* is adjusted in length depending on whether it is to be used by a deaf person with an intact ear drum or by a person with a destroyed ear drum.

The external end **1***b* of the cylinder **1** is widened out for assuming the shape of the meatus of the external ear passage and to reach the diameter of the external ear.

The body of the apparatus is hollowed out with one or more longitudinal ducts **10** for draining off liquids from the ear, such as secretions, or an excess of liquid from the block.

At its external end **1***b*, the hollow cylinder **1** contains the microphone **2** preferably of the piezo-electric type with an adjustment shutter or rheostat coil **2***a* for control purposes. In the center part of the cylinder **1** there is a transistor amplifying stage **3** and, at its internal end a receiver **4**. The receiver **4** is not directly in contact with the ear drum. A block **5** of vinyl chloride sponge or any other water-retaining, flexible, light substance, non-irritant for the tympanic membrane or the mucous membranes of the drum, forms a buffer between the receiver **4** and the tympanic membrane, or ear drum, if the deaf person has no tympanum, or if he has undergone a mastoid operation that modified the ear.

The plastic block **5** is soaked in a liquid to a sufficient extent, in the case of a destroyed tympanum, to be able to coat the bottom of the ear drum with a liquid coating and confine an air bubble level with the entrance to the inner ear. When the tympanum is intact, the plastic block **5** is merely moistened. If the plastic material in contact with the tympanum membrane is sufficiently flexible and adherent, even the moistening can be eliminated.

The liquid in the block has a high viscosity so as to delay its evaporation which can be still further diminished by adding silicone or the like, so long as the liquid is not an irritant for the mucous membranes and is preferably slightly antiseptic.

The shape of the plastic contact block **5** is capable of modifications which have the effect of strengthening high-pitched or low-pitched sounds according to the needs indicated by the patient's audiogram.

The apparatus works in the following manner:

The sound wave reaching the outer ear are collected by the microphone **2**, then intensified by the transistor stage amplifier **3** and re-emitted by the receiver or sound emitter **4**. The water-retaining plastic block **5**, saturated or not with liquid, acts to transmit sound waves between the receiver and the tympanic membrane, or encloses, level with the entrance of the middle ear, an air bubble which comes into resonance and thus transmits the sound waves to the labyrinth when the ear drum is destroyed.

The electric current feed of the various electronic elements contained in the body of the apparatus described above can be effected in various ways. A feed by a voltage derived from a thermocouple utilizes the internal heat of the ear and the difference in temperature existing between the ambient temperature and that of the interior of the ear. For example a cold junction may be fixed on the external end of the device and a hot junction embedded therein adjacent the internal end with wires joining the junctions in circuit to the amplifier.

Use may also be made of the reaction set up by two different metals by the liquid which impregnates the interior of the apparatus. As there may be used liquid, for example, sodium borate to which glycol or glycerine is added which will form a battery by the addition of two light plates of different metals. Such a battery is shown by the plates **6** and **7** in Figure 3.

If necessary, small batteries such as are at present used in prosthetic apparatus can be easily placed in the exterior, or the entrance, of the apparatus or in any other suitable part of the apparatus. A battery of this nature is illustrated at **8** in Figure 1.

The body of the apparatus containing the various electronic elements is made of a metal or plastic tube to which the block of water-retaining material is attached at the end.

According to one alternative embodiment of the invention, the apparatus is only a single block of vinyl chloride sponge of cylindro-conical shape in which the electronic elements and conductors are embedded. In this case, the microphone is supported by a tight-fitting barrier in the form of a collar. The block acts both as a sound wave transmitter by means of its tympanic end and a thermoelectric or electrochemical energizing source.

Directions for use

The appliance held between the thumb and first finger is gently inserted in the external ear, after its end has been dipped in liquid, if this method is used, until it comes into contact with the tympanum or end of the ear drum. The deaf person becomes aware of this contact by a special tactile feeling and by being able to hear. It may be kept indefinitely in the ear. It is only necessary to take it out from time to time for cleaning it and moistening it with liquid when the latter has evaporated.

The present invention also contributes a new extremely important advance in the art, namely that the electrical energy for operating the device may be derived:

(*a*) By thermocouple means utilizing the internal heat of the ear and the difference in temperature existing between the ambient temperature and that inside the ear;

(*b*) Or use may also be made of the reaction set up by two metals by the liquid with which the apparatus is impregnated. Such liquid may be, for example, sodium borate, to which glycol or glycerine is added to form a battery by the addition of two light plates of various metals;

(*c*) Or miniature batteries similar to those now used in prosthetic appliances can be used which would be placed outside or at the entrance to the ear, or in any other suitable part of the apparatus, integral with the apparatus or connected thereto by wires.

In the receiver and microphones, reception and transmission of sound waves can be obtained by barium titanate, a material which possesses the advantage, by its low impedance, of permitting a direct link with the transistor without a transformer.

The output receiver can be mounted so as to produce flat or focused waves enabling a given point to be excited with great accuracy and increased power.

We claim:

1. In combination in an electric ear drum for deaf persons: a tubular body formed with at least a portion thereof insertable in the ear passage of the outer ear, a microphone in said tubular body at one end thereof, a plastic water-retaining body in axial alignment with said tubular body and mounted on the other end thereof, liquid in said plastic body, a transistorized amplifying unit within said tubular body connected with said microphone to receive signals therefrom, and a receiver interposed between said plastic water-retaining body and said amplifying unit connected with the amplifying unit to receive signals therefrom and operable to develop vibra-

tions in said plastic body, and means for supplying electrical energy to said microphone, amplifying unit and receiver.

2. In combination in an electric ear drum for deaf persons: a tubular body formed with at least a portion thereof insertable into the ear passage of the outer ear, a microphone in said tubular body at one end thereof, a plastic water-retaining body in axial alignment with said tubular body and mounted on the other end thereof, liquid in said plastic body, a transistorized amplifying unit within said tubular body and adjacent said microphone, a receiver interposed between said plastic water-retaining body and said amplifying unit operable to develop mechanical vibrations in the plastic body, conduit means extending along said tubular body for discharging liquid from the ear, and means connecting said microphone, amplifying unit, and receiver in circuit including means to supply electrical energy thereto.

3. In combination in an electric ear drum for deaf persons: a tubular body formed with at least a portion thereof insertable into the ear passage of the outer ear, a microphone in said tubular body at the outer end thereof, a flexible light water-retaining vinyl chloride sponge non-irritant to the tympanum membranes and the mucous membranes on said body at the inner end thereof, a transistorized amplifying unit within said tubular body and adjacent said microphone, a receiver interposed between said water-retaining sponge and said amplifying unit operable to actuate the sponge when energized, and means connecting said microphone, amplifying unit, and receiver in circuit including means to supply electrical energy thereto.

4. In combination in an electric ear drum for deaf persons; a tubular body formed with at least one portion thereof insertable in the ear passage at the outer ear, a microphone in said tubular body at the outer end thereof, a plastic water-retaining body in axial alignment with said tubular body and mounted on the other and inner end thereof, a high viscosity liquid in said water-retaining body, a transistorized amplifying unit within said tubular body and adjacent said microphone, a receiver interposed between said plastic water-retaining body and said amplifying unit operable to actuate the sponge when energized, and means connecting said microphone, amplifying unit, and receiver in circuit including means to supply electrical energy thereto.

5. An electric ear drum according to claim 4, in which the said liquid also contains silicone.

6. In combination in an electric ear drum for deaf persons: a tubular body with at least a portion thereof insertable into the air passage of the outer ear, a microphone in said tubular body at the outer end thereof, a plastic water-retaining body in axial alignment with said tubular body and mounted on the other and inner end thereof, a liquid in said water-retaining body, a transistorized amplifying unit in said tubular body and adjacent said microphone, and a receiver interposed between said plastic water-retaining body and said amplifying unit operable to actuate said plastic body when energized, and means connecting said microphone, amplifying unit, and receiver in circuit, including means for supplying electrical energy thereto, said means for supplying electrical energy comprising thermocouple means having hot and cold junctions respectively positioned for utilizing the internal heat of the ear and the ambient temperature.

7. In combination in an electric ear drum for deaf persons: a tubular body with at least a portion thereof insertable into the air passage of the outer ear, a microphone in said tubular body at the outer end thereof, a plastic water-retaining body in axial alignment with said tubular body and mounted on the other and inner end thereof, a liquid in said water-retaining body, a transistorized amplifying unit in said tubular body and adjacent said microphone, and a receiver interposed between said plastic water-retaining body and said amplifying unit operable to actuate said plastic body when energized, and means connecting said microphone, amplifying unit, and receiver in circuit, including means for supplying electrical energy thereto, said means for supplying electrical energy comprising a battery in the tubular body.

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