March 31, 1964 P. J. McGEE 3,126,977

HEARING AID APPARATUS

Filed Jan. 31, 1962 2 Sheets-Sheet 1

FIG. 1

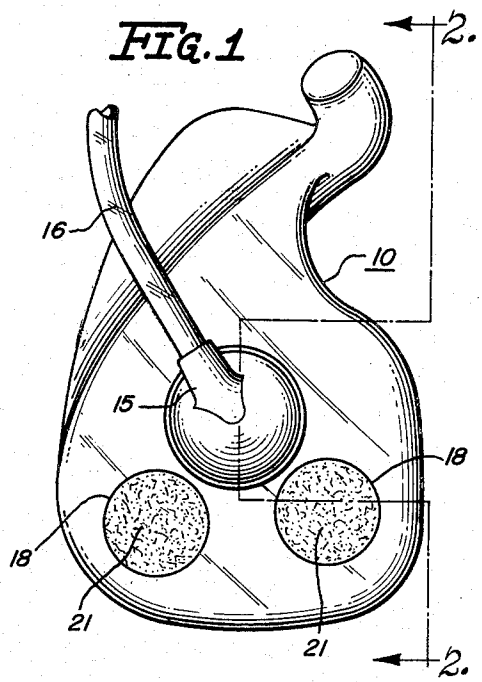


FIG. 2

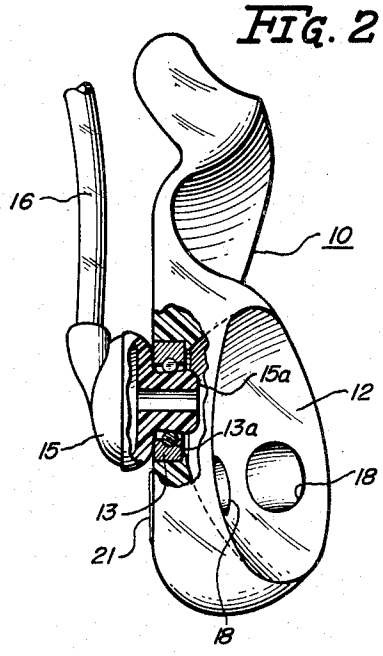


FIG. 3

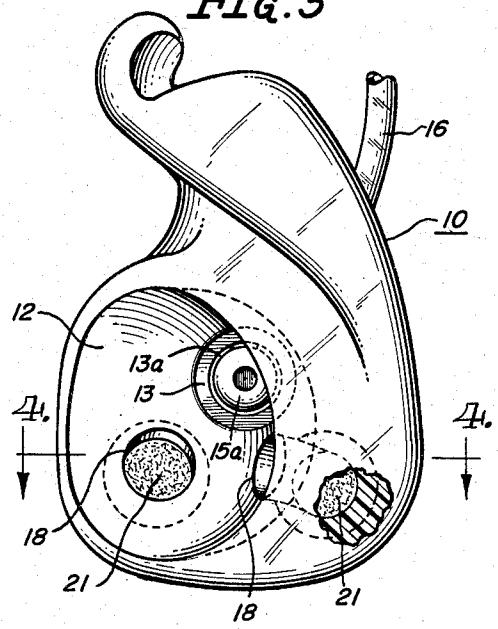
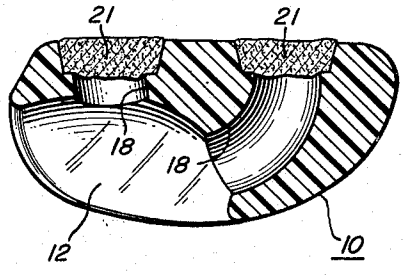


FIG. 4



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March 31, 1964 P. J. McGEE 3,126,977

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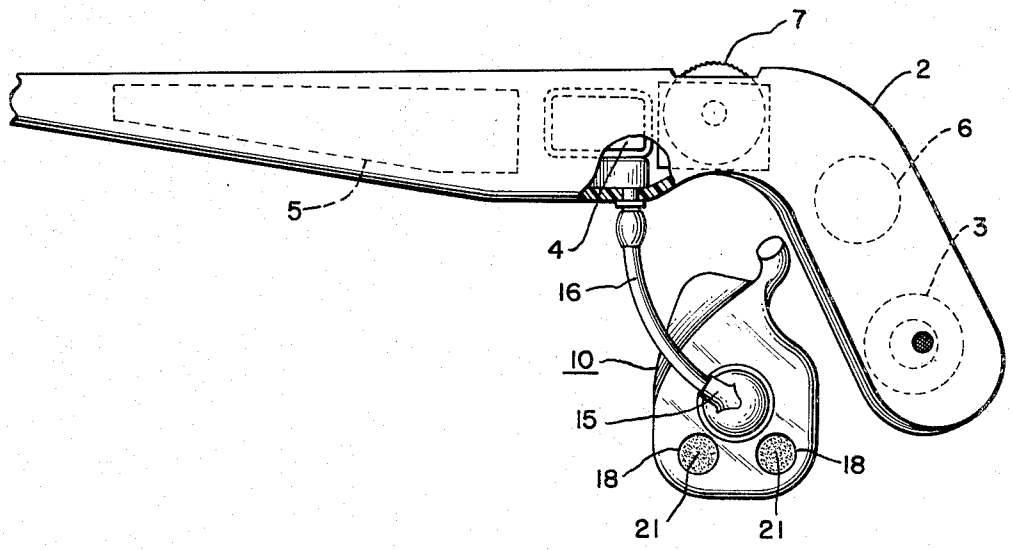
Filed Jan. 31, 1962 2 Sheets-Sheet 2

FIG. 5



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HEARING AID APPARATUS

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4 Claims. (Cl. 181—23)

This invention relates in general to the hearing aid art and more particularly to frequency-selective filtering apparatus for effectively filtering the sound delivered from the output transducer of a hearing aid in order to remove certain frequency components before the sound energy reaches the wearer's auditory canal.

Many hard-of-hearing individuals experience a sensory-neural hearing loss or impairment; namely, normal hearing of the low audible frequencies (for example, below 1,000 cycles per second) is enjoyed, whereas there is a severe loss as to the components in the remainder of the audible frequency spectrum. When those individuals attempt to improve their hearing by means of a conventional hearing aid, it is found that the amplified low frequency components reaching the ear drum are so loud that they mask out the high frequencies. Over-amplification of the low frequency components creates an unpleasant sensation varying from discomfort to pain. As a consequence of such discomfort, a person with a sensory-neural high frequency impairment usually does not use a hearing aid.

Of course, the frequency response characteristic of the input transducer or microphone, the signal amplifying apparatus, and/or the sound reproducer of a conventional hearing aid may be altered to delete the low frequencies of the acoustic energy. However, this has not proved to be an acceptable solution to the problem.

The present invention solves the problem and provides filtering apparatus for removing the low frequency components from the sound produced by the hearing aid output transducer while at the same time permitting those same low frequencies to by-pass the hearing aid entirely and reach the auditory canal in normal fashion.

Accordingly, it is an object of the present invention to provide new and improved apparatus for use in conjunction with a hearing aid or the like.

It is another object of the invention to provide a useful hearing aid arrangement for an individual with a sensory-neural high frequency hearing loss.

It is a further object of the invention to provide a relatively simple and inexpensive filter for removing certain frequency components from the acoustic energy developed in a hearing aid output transducer.

The invention provides, in accordance with one of its aspects, apparatus for use in conjunction with a hearing aid having an input transducer responsive to received acoustic energy having frequency components extending over a given frequency range, and an output transducer, mounted in close proximity to the input transducer, for developing amplified acoustic energy having frequency components extending over substantially the same given range. The apparatus comprises an ear mold for acoustically sealed insertion in a human ear and having a sound passageway therethrough communicating with the auditory canal, plus an acoustic connecting device, coupled to the output transducer, to be attached to the ear mold for extending the sound passageway to the output transducer to channel the amplified acoustic energy to the auditory canal. At least one aperture is provided venting the sound passageway directly to the outside atmosphere effectively to attenuate the relatively low frequency components of the amplified acoustic energy, thereby to permit primarily the relatively high frequency components to reach the auditory canal. Finally, the

apparatus includes a low-pass filter element disposed in the aperture for permitting the translation through the aperture of the low frequency components while preventing the translation of the high frequency components through the aperture in order to preclude acoustic feedback of the high frequency components from the output to the input transducer.

The features of this invention which are believed to be new are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may best be understood, however, by reference to the following description in conjunction with the accompanying drawings, in which FIGURES 1–5 collectively illustrate a hearing aid apparatus constructed in accordance with one embodiment of the invention.

Consideration will now be given to FIGURES 1–5 wherein the invention is illustrated in connection with a conventional eye glass hearing aid of the type in which the input and output transducers and the amplifying circuitry are all contained within a side member or temple bar **2** of a spectacle frame. The input transducer or microphone is designated by numeral **3**, the output transducer or sound-reproducing device by numeral **4**, the amplifying circuitry by indicia **5**, the battery power supply by **6**, and the conventional off-on switch and volume control by **7**. Of course, the details of these components and the connecting circuitry are well known in the art and have not been shown in order to simplify the drawings.

An ear mold **10** preferably is customized to fit tightly in the ear of the particular wearer. In any event, ear mold **10** preferably should form a substantially complete acoustic seal upon insertion in the wearer's ear. Although it is not necessary, in the illustrated embodiment a portion of the canal insert of the ear mold has been cut away and the ear mold has been hollowed out to form an acoustic cavity or chamber **12**. Cavity **12** is provided with an opening surrounded by a metallic ring washer **13** embedded in the ear mold in order that a sound passageway may extend through the ear mold from the external portion thereof in the direction to communicate with the auditory canal of the person's ear when ear mold **10** is properly inserted.

As illustrated, output transducer **4** is not located immediately adjacent ear mold **10** but is positioned a relatively short distance away. Specifically, it is contemplated that the invention will be employed in connection with ear-level hearing aids in which the input and output transducers and the customary signal amplifying circuitry are positioned in close proximity to the wearer's ear, for example being mounted within a spectacle frame as shown in the illustrated embodiment, or within a housing shaped and dimensioned to be positioned behind the wearer's ear. In any case, the output transducer would be only a couple inches away from ear mold **10**.

An acoustic connecting device **15** is attached to ring **13** of ear mold **10** in conventional fashion and is coupled by means of an air conduction tube **16** to output transducer **4** to extend the sound passageway **12** of the ear mold to the output transducer in order to channel the amplified acoustic energy from the transducer to the auditory canal. Connecting device **15** may be constructed of plastic, metal or any suitable material. It has a protruding portion **15***a* which is dimensioned with respect to the inside diameter of ring **13** such that the connecting device may be inserted within the ring with a fairly snug fit. A split spring **13***a* is provided in metal retainer ring **13** in order to provide a conventional snap ring type of connection between connecting device **15** and ear mold **10**.

A pair of apertures **18** are provided in ear mold **10**

for venting sound passageway **12** directly to the outside atmosphere. While two such holes **18** are shown in the illustrated embodiment, in certain cases only one need be employed whereas in others three or more may be found helpful. The length and diameter of each aperture **18**, the number of such apertures, and the volume of cavity **12** determine the frequency response of the filtering apparatus of the invention. A low pass filter element **21**, in the form of common felt, is disposed or inserted in each aperture **18** where those apertures open to the outside atmosphere.

In operation, the input and output transducers and the amplifying circuitry in the ear-level hearing aid function in conventional manner. Briefly, input transducer **3** responds to received acoustic energy having frequency components extending over a given frequency range to develop an electrical signal, amplifier **5** amplifies that signal and translates it to output transducer **4** which in turn responds thereto and develops amplified acoustic energy having frequency components extending over substantially the same given range. In the absence of apertures **18** in ear mold **10**, substantially all of the frequency components of the amplified acoustic energy would be channeled via air conduction tube **16**, connecting device **15**, and sound passageway **12** to the auditory canal.

With the presence of apertures **18**, however, and in accordance with the invention, the output transducer **4** is effectively loaded as to the low frequencies such that those frequencies are attenuated considerably. To elucidate, each of apertures **18** has a certain inertance which is a property of the length and diameter of the hole. Inertance, of course, is the acoustical equivalent of inductance. This inertance appears in shunt with the output of the output transducer. Since the effect of inertance varies with frequency, presenting a lower impedance to the low frequencies with respect to the impedance presented to the high frequencies, holes **18** effectively shunt out to the atmosphere the low frequency components. By proper design, holes **18** may be arranged to have a negligible effect on the high frequencies since the shunting inertance provides a high impedance, and thus all of the amplified high frequency components are delivered to the auditory canal and ultimately to the person's ear drum. In this way, the maximum gain of which the system is capable is utilized to amplify the high frequencies and to provide the individual with a sensory-neural loss the frequency components which he normally cannot hear. On the other hand, the low frequency components, which he can hear normally, are in a sense "dumped" through apertures **18** directly to the outside atmosphere so that they do not reach the person's ear drum and drown out the high frequencies.

Preferably, the ear mold should be customized for the particular wearer in order that an optimum frequency response is realized. Lengthening apertures **18** and/or reducing their diameter increases the inertance and therefore decreases the number of low frequency components (i.e., narrows the band) shunted to the atmosphere. Increasing the number of apertures **18** lowers the effective inertance and therefore widens the band of low frequencies prevented from reaching the person's ear drum. In addition, increasing the volume of cavity **12** decreases the number of low frequency components shunted to the atmosphere. It has been found that optimum results can best be achieved for any given individual with a sensory-neural loss by empirical methods.

While holes **18** preferably should present a high impedance to the high frequency components so that the net effect is that the holes are not even present with respect to the high frequencies, there may be a small amount of high frequency acoustic energy that will tend to leak out through apertures **18**. If the microphone is not mounted in close proximity to the output transducer, these high frequency components will not have any deleterious effect on the operation of the system. However, when the transducers are located relatively close to each other, as is the case when an ear-level aid is employed, the high frequencies that leak out through apertures **18** may possibly cause objectionable acoustic feedback from the output to the input transducer, thereby initiating annoying acoustic feedback oscillations. In accordance with a feature of the invention, such acoustic feedback is precluded by low pass filter **21** in each hole **18** which effectively blocks the high frequencies from reaching the outside atmosphere. Element **21** is frequency selective in that it permits low frequencies to pass therethrough with negligible resistance while at the same time it presents an extremely high resistance to the translation of high frequency sound energy.

The low frequency components translated from cavity **12** to the outside atmosphere via filter elements **21** do not initiate acoustic feedback oscillations. This obtains since the filtering action of apertures **18** causes the system to have insufficient gain at those low frequencies to effect acoustic feedback oscillations.

Since different types of common felt exhibit different frequency response characteristics, the response of filter elements **21** may be optimized by proper selection of the felt material. Once again, it has been found that best results can be obtained by empirical methods.

Of course, it is desirable that low pass filter elements **21** permit the translation therethrough of the amplified low frequencies in order that they may be prevented from reaching the auditory canal. At the same time, elements **21** pass the low frequencies directly from the outside atmosphere through apertures **18** to the auditory canal in normal fashion. Since the person with a sensory-neural high frequency hearing impairment can hear the low frequencies normally, it is extremely advantageous to permit those frequencies to reach the person's ear drum in normal manner, and this is possible by means of apertures **18** and filter elements **21**. Thus, the low frequencies produced in the output transducer are effectively prevented, by means of apertures **18**, from reaching the person's auditory canal, while at the same time the same apertures **18** permit the low frequencies to by-pass the hearing aid system and reach the auditory canal in customary manner.

The invention is obviously not limited to the arrangement in which the connecting device is coupled to the output transducer by way of an air tube but may be applied to the case where the connecting device, to be attached to the ear mold, is rigidly coupled to the output transducer, namely when the output transducer is positioned right at or immediately adjacent the ear mold. In that arrangement, the amplifying circuitry may still be mounted within a spectacle frame or in a casing positioned behind the ear and an electrical connection is provided to the output transducer.

Of course, it is not necessary that apertures **18** be provided in the ear mold itself; all that is necessary is that at least one aperture be positioned at some point along the sound passageway between the output transducer and the auditory canal in order that the passageway is vented directly to the outside atmosphere.

A novel frequency-selective filtering apparatus is thus provided which attenuates the low frequency components developed in the output transducer of a hearing aid, permits those same low frequencies to by-pass the hearing aid and reach the auditory canal, while at the same time prevents acoustic feedback of the high frequencies from the output transducer to the input transducer.

While a particular embodiment of the invention has been shown and described, modifications may be made, and it is intended in the appended claims to cover all such modifications as may fall within the true spirit and scope of the invention.

I claim:

1. Apparatus for use in conjunction with a hearing aid having an input transducer responsive to received acoustic

energy having frequency components extending over a given frequency range, and an output transducer, mounted in close proximity to said input transducer, for developing amplified acoustic energy having frequency components extending over substantially said same given range, comprising:

an ear mold for acoustically sealed insertion in a human ear and having a sound passageway therethrough communicating with the auditory canal;

an acoustic connecting device coupled to said output transducer and to said ear mold for extending said sound passageway to said output transducer;

said ear mold having at least one aperture venting said sound passageway directly to the outside atmosphere effectively to attenuate the relatively low frequency components of said amplified acoustic energy within said frequency range, thereby to permit primarily the relatively high frequency components within said range to reach the auditory canal;

and a low-pass filter element insert disposed in said aperture for permitting the translation through said aperture of said low frequency components while preventing the translation of said high frequency components through said aperture in order to preclude acoustic feedback of said high frequency components from said output to said input transducer.

2. Apparatus for use in conjunction with a hearing aid having an input transducer responsive to received acoustic energy having frequency components extending over a given frequency range, and an output transducer, mounted in close proximity to said input transducer, for developing amplified acoustic energy having frequency components extending over substantially the same given range, comprising:

an ear mold to be coupled to said output transducer and to be inserted in a human ear and having a sound passageway for coupling said output transducer to the auditory canal to channel said amplified acoustic energy to the auditory canal;

said ear mold having at least one aperture venting said sound passageway directly to the outside atmosphere effectively to attenuate the relatively low frequency components of said amplified acoustic energy within said frequency range, thereby to permit primarily the relatively high frequency components within said range to reach the auditory canal;

and a low-pass filter element insert disposed in said aperture for permitting the translation through said aperture of said low frequency components while preventing the translation of said high frequency components through said aperture in order to preclude acoustic feedback of said high frequency components from said output to said input transducer.

3. Apparatus for use in conjunction with a hearing aid having an input transducer responsive to received acoustic energy having frequency components extending over a given frequency range, and an output transducer, mounted in close proximity to said input transducer, for developing amplified acoustic energy having frequency components extending over substantially said same given range, comprising:

an ear mold for acoustically sealed insertion in a human ear and having a sound cavity communicating with the auditory canal;

an acoustic connecting device, coupled to said output transducer, to be attached to said ear mold for communicating said sound cavity with said output transducer to channel said amplified acoustic energy to the auditory canal;

said ear mold having at least one aperture venting said sound cavity directly to the outside atmosphere effectively to attenuate the relatively low frequency components of said amplified acoustic energy within said frequency range, thereby to permit primarily the relatively high frequency components within said range to reach the auditory canal;

and a low-pass filter element insert disposed in said aperture for permitting the translation through said aperture of said low frequency components while preventing the translation of said high frequency components through said aperture in order to preclude acoustic feedback of said high frequency components from said output to said input transducer.

4. Apparatus for use in conjunction with a hearing aid having an input transducer responsive to received acoustic energy having frequency components extending over a given frequency range, and an output transducer, mounted in close proximity to said input transducer, for developing amplified acoustic energy having frequency components extending over substantially said same given range, comprising:

an ear mold device for acoustically sealed insertion in a human ear and having a sound passageway therethrough communicating with the auditory canal;

an acoustic connecting device, coupled to said output transducer, to be attached to said ear mold for extending said sound passageway to said output transducer to channel said amplified acoustic energy to the auditory canal;

one of said devices having at least one aperture for venting said sound passageway directly to the outside atmosphere effectively to attenuate the relatively low frequency components of said amplified acoustic energy within said frequency range, thereby to permit primarily the relatively high frequency components within said range to reach the auditory canal;

and a low-pass filter element insert disposed in said aperture for permitting the translation through said aperture of said low frequency components while preventing the translation of said high frequency components through said aperture in order to preclude acoustic feedback of said high frequency components from said output to said input transducer.

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