

April 15, 1969

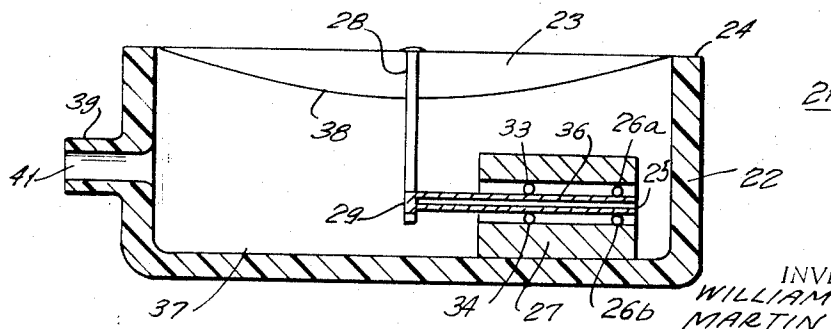
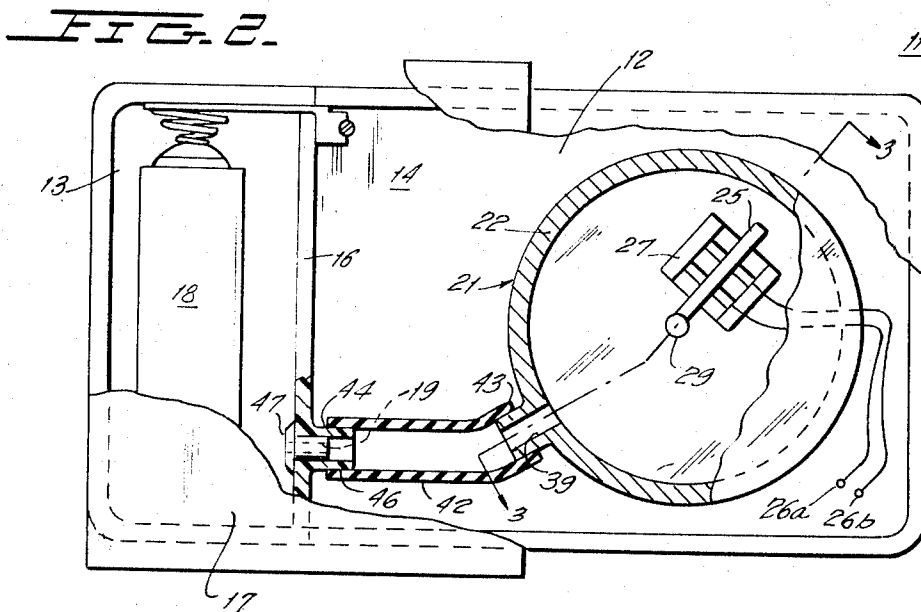
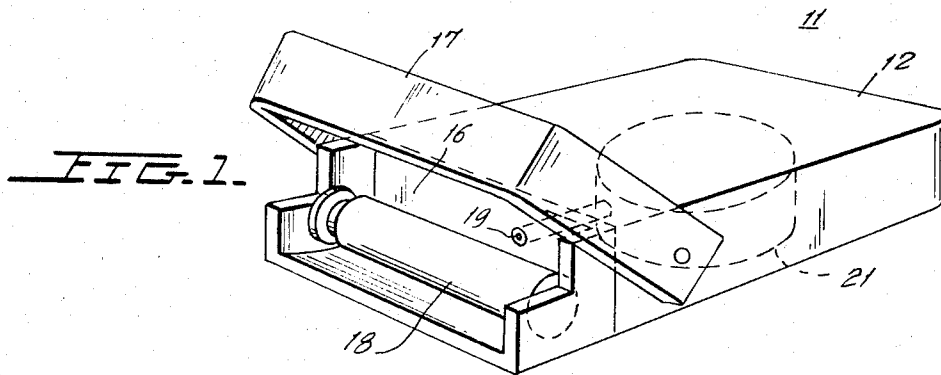
W. F. KNAUERT ET AL

3,439,129

ACOUSTIC FREQUENCY RESPONSE ADJUSTMENT

Filed Jan. 28, 1966

Sheet 1 of 2



INVENTORS
WILLIAM F. KNAUERT
MARTIN MOLLOY

BY
OSTROLENK, FABER, GERB & SOFFEN
ATTORNEYS

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FIG. 4.

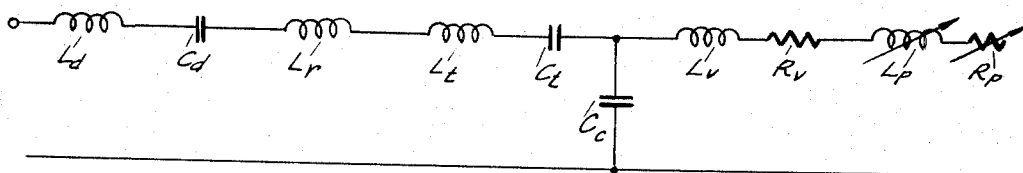


FIG. 5.

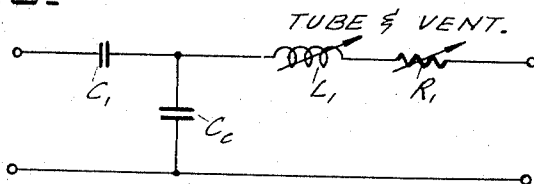


FIG. 6.

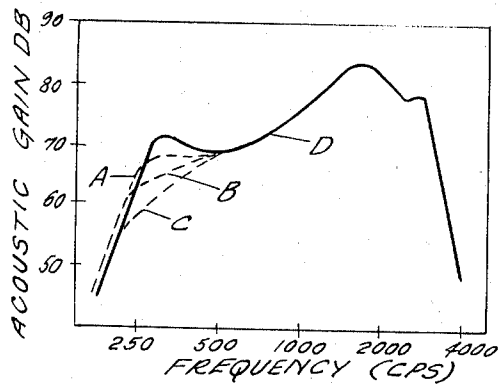


FIG. 7A.

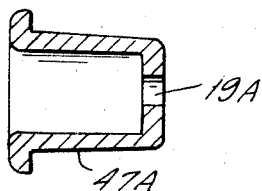


FIG. 7B.

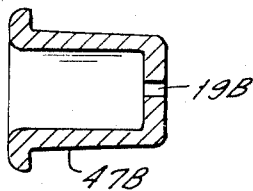
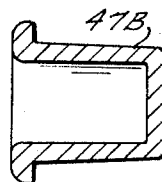


FIG. 7C.



INVENTORS
WILLIAM F. KNAUERT
MARTIN MOLLOY
BY

OSTROLENK, FABER, GERB & SUTHER
ATTORNEYS

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ACOUSTIC FREQUENCY RESPONSE ADJUSTMENT

William F. Knauert, Yonkers, and Martin Molloy,
Ossining, N.Y., assignors to Sonotone Corporation,
Elmsford, N.Y., a corporation of New York

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6 Claims

ABSTRACT OF THE DISCLOSURE

A hearing aid device with microphone in an inaccessible location. A vent tube connects the microphone with one wall. Any of a plurality of vent plugs can be connected at an accessible location to the vent tube to modify the low frequency response of the microphone.

This invention relates to sound translating devices and more particularly to new and improved apparatus for providing adjustable frequency response of a hearing aid microphone assembly over a selected frequency range.

A microphone suitable for use in a hearing aid assembly must, in the usual case, be small and compact to fit in an enclosure of greatly restricted size. The high stiffness of the resulting device results in a high natural resonant frequency and thus in an incompatibility with certain types of hearing aid receivers (particularly of the bone conduction type). Moreover, the limited low frequency response of such compact microphone assemblies renders them unable, without extensive individual adjustment, to accommodate the greatly varying requirements of individual wearers.

Some attempts have been made in the past to improve the low frequency response of a hearing aid microphone by building into the unit an auxiliary cavity in shunt with the main cavity of the microphone below the diaphragm. This type of modification increases the effective compliance of the assembly by a controlled amount and improves the low frequency accordingly. Unfortunately, even where this is done, the inevitable inaccessible location of the microphone within a completely assembled hearing aid unit renders a custom frequency response adjustment, necessary to achieve optimum performance for a particular wearer's hearing defect very difficult. As a result, such adjustment (particularly of the shunt cavity) has either not been provided for at all or has been impossible to implement without obtaining direct manual access to the interior of the microphone assembly by dismantling the entire hearing aid unit.

One object of the invention, therefore, is to provide new and improved apparatus for adjusting the low frequency response of a hearing aid microphone disposed in a manually inaccessible location within a hearing aid unit.

A further object of the invention is to provide inexpensive and reliable field-service adjustment apparatus for tuning the low frequency response of an enclosed hearing aid microphone without dismantling the enclosure.

These and related objects are accomplished by arrangements embodying the principles of the instant invention. Such arrangements include, in their broad aspects, a microphone assembly having a housing defining an enclosed cavity open at one end; air-pressure sensitive means in the form of a diaphragm flexibly closing the open end of the housing cavity and transmitting air pressure variations from the atmosphere to the interior of the resulting enclosed housing; a transducer drive rod connected to the diaphragm for transmitting the diaphragm movement to a mechano-electric transducer means for conversion to an electrical signal; an air-conducting tube fixedly commu-

nicating at one end with the interior of the enclosed housing to provide an acoustic path in shunt with the microphone cavity, the other end of the tube terminating at a manually accessible location; and means removably positioned in the other end of the tube for adjustably varying the acoustic impedance of the shunt tube.

An illustrative embodiment of such arrangement takes the form of a hearing aid detection and power unit having an electrical chassis enclosure, a microphone inaccessibly mounted in the enclosure, and a manually accessible battery holder having an apertured first wall substantially coinciding with one wall of the enclosure. A side vent nozzle is mounted on the microphone housing and communicates with the interior of the back cavity of the microphone below the diaphragm thereof. A vent tube having a length and diameter chosen to yield a predetermined frequency response of substantial low-frequency magnitude is connected at one end thereof to the vent nozzle. The vent tube terminates at the other end in cooperative relation with a second nozzle in and projecting from the rear portion of the first wall of the battery holder to provide an accessible open-ended vent system. A plurality of plugs of controlled acoustic impedance are selectively provided for individual insertion into and removal from the open end of the tube through the aperture, thereby modifying the acoustic impedance of the shunt path. This, in turn, will modify the low frequency response of the microphone and tube assembly by an amount determined by the acoustic impedance of the particular plug selected.

The nature of the present invention, the manner in which it accomplishes the above and related objects, and its various advantages and features are set forth more fully in the following detailed description taken in connection with the drawing, in which:

FIGURE 1 is a perspective view of a hearing aid detection and power unit employing an externally accessible, adjustable microphone venting system in accordance with the invention, partially broken away and with certain details omitted to best show the aspects of the instant invention;

FIGURE 2 is a top view, partly broken away, of the hearing aid unit of FIGURE 1;

FIGURE 3 is a sectional side elevation of the microphone assembly employed in the unit of FIGURES 1 and 2, taken approximately on the line 3—3 of FIGURE 2;

FIGURE 4 is an equivalent electrical circuit of the microphone of FIGURE 3, when loaded by the adjustable venting system in accordance with the invention;

FIGURE 5 is a simplified version of the equivalent circuit of FIGURE 4, applicable at the low frequency end of the frequency spectrum of the vented microphone assembly;

FIGURE 6 is a set of superimposed curves showing the frequency response of the hearing aid unit for various conditions of acoustic impedance loading achieved by the different acoustic impedance plugs; and

FIGURES 7A—C show three various sizes of acoustic impedance plugs, corresponding to the frequency response variations of FIGURE 6.

Referring to the drawing, FIGURES 1 and 2 depict a hearing aid detection and power unit 11 having an enclosed electrical chassis compartment 12 and a juxtaposed battery holder assembly 13. The chassis compartment 12 comprises, for purposes of illustration, an integrally formed cavity 14 open at one end. The open end is sealed during assembly by the attachment thereto, by screws or other convenient means, of a rear wall 16 of the battery holder 13. As thus assembled, the interior of the chassis compartment 12 is manually inaccessible from the exterior thereof.

The battery holder 13 is closed with a hinged cover 17 that permits external access to the holder for purposes of insertion or replacement of a hearing aid battery 18 mounted therein. The opening of the cover 17 also permits manual engagement of an apertured region 19 on the rear wall 16, for reasons to be presently described.

A hearing aid microphone 21 is suspended within the chassis compartment 12 by any convenient means known to those skilled in the art for reduction of vibration. Although not illustrated in the drawing, the chassis compartment 12 also houses a suitable transformer assembly, an amplifier powered by the battery 18, a telephone pick-up coil and an output socket assembly. These and other electrical components are mutually interconnected to provide an electrical output (of the unit 11) that is adapted to drive an external air-conduction or bone conduction transducer (not shown).

As shown in FIGURES 2 and 3, the microphone assembly 21 comprises a metallic cup housing 22; a conical diaphragm 23, typically of metal foil, flexibly supported around the periphery of the top surface 24 of the cup housing 22; an elongated piezoelectric transducing element 25 supported by and insulated from the housing 22 by a U-shaped mount 27; an insulated drive rod 28 rigidly connecting the diaphragm to one end 29 of the element 25; and a pair of electrical output wires 26a, 26b suitably connected to opposite electrodes of element 25. Element 25 is supported in a cantilevered fashion by the wires 26a, 26b in conjunction with supporting wires 33, 34.

A back cavity entrapping a volume of air 37 is formed by the rear surface 38 of the diaphragm 23 and the interior of the housing 22. A vent nozzle 39 is disposed on the external portion of the wall of housing 22 and communicates through an internal passage 41 with the interior of the back cavity 37. The presence of the internal passage 41 provides a means for affecting the build-up of air pressure variations within the closed back cavity 37 and thus effectively modifies the compliance of the microphone assembly 21. As a result, this venting arrangement modifies the frequency response at the low end of the microphone spectrum and thus improves the compatibility of the hearing aid unit 11 (FIG. 1) with its output transducers, and notably with bone-conduction hearing aid receivers. As is well known, such receivers have lower natural resonant frequencies than air-conduction receivers.

In accordance with the invention, an air conduction tube 42, typically of rubber, is connected (as best shown in FIG. 2) at one end 43 thereof to the vent nozzle 39. The tube 42 is brought out to the rear wall 16 of battery holder 13. The other end 44 of the tube 42 is connected to a second nozzle 46 provided with an aperture 19 and projecting from the back of the wall 16. As a result the end 44 of the tube 42 is accessible through the aperture 19 when the hinged cover 17 is lifted to expose the battery holder 13.

As further shown in FIGURE 2, the vent nozzle 39 on microphone 21 and the nozzle 46 on rear wall 16 are positioned so that only a minimum length of tube 42 is required. However, it will be understood that the flexibility of the material of the tube permits the interconnection of the fixed nozzle 46 to the vent nozzle 39 for any orientation of the latter on the housing 22 of the microphone 21, thereby allowing complete freedom of mounting of the inaccessible microphone 21 within chassis compartment 12. In any case the inner diameter of the tube 42, together with the length of the tube 42 required for the particular mounting arrangement, are selected in a manner well known in the art to obtain a predetermined frequency response of the vented microphone 21.

A vent plug 47, typically a nylon bushing, is removably positioned in the end 44 of the tube 42 through the aperture 19 in the wall 16, as shown in FIGURE 2, to provide an adjustment of the low-frequency portion of the response of the microphone 21. The vent plug 47 has an outer diameter that cooperates with the inner wall

of the aperture 19 and the tube 42 to provide a close fit, forming an adequate acoustic seal. The plug 47 has an internal diameter that is selectively chosen to close the open end 44 of the tube 42 by a predetermined amount (as indicated below) to correspondingly vary the degree of coupling of air pressure variations from the back cavity 37 of the vented microphone 21 to the exterior of the end 44 of the tube 42, and thereby vary the acoustic impedance of the vent. In practice, a plurality of the plugs 47A-C, as shown in FIGS. 7A-7C, are provided with varying internal diameters that serve to close the opening at the end 44 of the tube 42 by predetermined amounts. Hence, the plug 47, having the required diameter opening to yield the desired degree of closure to modify the frequency response in accordance with the particular wearer's requirements, is inserted in the end 44. It should, however, be understood that the specific plug material discussed above is for illustrative purposes only, and the broad aspect of our invention contemplates the use of other acoustic damping materials, such as sintered metals, rubber or plastic foam, cloth, felt, wool fiber, etc.

An equivalent electrical circuit for the microphone 21 and its above-described adjustable venting system is shown in FIGURE 4. The circuit comprises a first series path having an inductance L_d representing the effective mass of the diaphragm; a capacitance C_d representing the compliance of the diaphragm 23; and inductance L_r representing the effective mass of the drive rod 28; an inductance L_t representing the effective mass of the transducing element 25; capacitance C_t representing the compliance of the transducing element 25; and a capacitance C_c representing the compliance of the microphone back cavity 37. This portion of the equivalent circuit determines the response over the principal portion of the audio frequency spectrum, other than the low frequency portion. As indicated before, the low frequency response of the microphone system is modified by the venting system, represented by a second series path shunting the back cavity compliance C_c . This second series path includes an inductance L_v and resistance R_v to represent the equivalent mass of the air column within the vent tube 42; and an inductance L_p and resistance R_p representing the equivalent acoustic impedance of the plug 47, and shown variable to represent the ability of the vent system to accommodate plugs of various acoustic impedances.

The effect of the variable acoustic impedance introduced by the use of the selectable acoustic plugs 47A, 47B or 47C (as shown in FIGS. 7A through 7C, respectively) may be best appreciated by considering the simplified equivalent circuit for low frequency operation as shown in FIGURE 5. At such frequencies (typically below 1000 c.p.s.), the impedance contribution of the inductances in the first series circuit can, for all practical purposes, be ignored. Hence, the total impedance of this circuit may be represented by a capacitor C_1 signifying the combined compliance of C_d and C_t . This is in series with back cavity compliance C_c . For further simplification the inductances and resistances of the second series circuit provided by vent tube 42 and plug 47 may be represented by the combined inductor L_1 and resistor R_1 . Considering now the effect of such various acoustic impedances introduced by the plugs 47a, 47b or 47c, reference is now made to the curve of FIGURE 6. This shows the overall characteristics of a typical hearing aid unit incorporating the microphone system of the instant invention. The frequency response characteristics of the unit with a typical vented microphone 21 having an open ended tube 42 (i.e., without any of the plug members 47) is shown as Curve D in FIG. 6. The modification of low frequency response achieved by using vent plugs 47A, 47B and 47C of progressively smaller internal diameter is best seen in curves A, B and C, respectively. These curves, drawn to the same scale as curve D mentioned above, show the modification of low-frequency response of the microphone 21 where the tube 42 is 30% closed, 70% closed, and completely closed at the accessible end 44 by vent plugs

of appropriate acoustic impedance. The closure of tube 42 in these steps leads to drops of 3 db, 6 db and 9 db, respectively, at one point (300 c.p.s.) in the low frequency response without significantly affecting the high frequency response of the hearing unit using the vented microphone 21.

In typical operation, the parameters of the main microphone assembly and the length and diameter of the vent tube 42 are adjusted at the factory. Advantageously, the open-ended venting system terminating at the accessible aperture 19 is adjusted to provide a low-frequency microphone response that is somewhat above the normal magnitude of the desired response for the average hearing aid wearer. In order to further individually adjust the microphone response to the needs of a particular wearer, the consultant or agent lifts the hinged cover 17 of the battery holder 13 to expose the apertured rear wall 16, and successively inserts, in turn, vent plugs 47A, 47B, 47C of progressively increasing acoustic impedance into the accessible end 44 of the tube 42 until a plug that provides the desired response is obtained. The plugs 47A, 47B and 47C are preferably of different colored materials to facilitate their identification.

It will be appreciated that by the use of the apparatus described above, the required low frequency response adjustment may be easily and quickly made in the field without access to the enclosed microphone 21 and thus without the necessity of dismantling the hearing aid unit 11. The use of a simple acoustic impedance adjustment at a fixed easily accessible physical location is far more convenient and versatile than prior art methods of adjusting microphone frequency response by physically changing or displacing an enclosed air mass that is accessible only by manual engagement of the microphone interior. It also represents a most practical solution to the low frequency response adjustment problem in that it does not require tampering with factory-set structural parameters of the microphone to obtain the desired adjustment in the field.

In the foregoing, the invention has been described in conjunction with a preferred illustrative embodiment. Since many variations will now become obvious to those skilled in the art, it is accordingly desired that the breadth of the claims not be limited to the specific disclosure herein contained.

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows:

1. In a hearing aid unit:

an enclosure;

a hearing-aid microphone mounted within said enclosure at a location manually inaccessible from the exterior of said enclosure;

said microphone having a cooperating vibrating system and back cavity yielding a particular frequency response;

an open-ended air-conducting tube acoustically coupled to said back cavity for modifying the response of the microphone at low frequencies;

one end of said tube located at said back cavity and the other end of said tube terminating at a manually accessible location of said enclosure; and

means removably positioned in said other end for locally varying the acoustic impedance of the tube so as to provide a desired one of a plurality of low frequency response adjustments.

2. In a hearing aid unit:

the arrangement in accordance with claim 1 in which said removably positioned means comprise a vent plug of selectable internal diameter;

said plug having a wall surface cooperating with the wall of the tube to form an effective acoustic seal therebetween.

3. In a hearing aid unit:

a microphone assembly comprising a rigid housing open at one end, a diaphragm flexibly closing said one end to form a back cavity, an electroacoustic transducer mounted within said cavity, and means connecting said diaphragm to said electroacoustic transducer;

a vent nozzle mounted on the exterior of said housing and communicating with the interior of said cavity;

an open-ended air-conducting tube connected at one end thereof to said nozzle and having its opposite end at an externally accessible location of said housing;

selectable vent plug means removably positioned in said other end for providing a selectable acoustic impedance termination to said tube.

4. In a hearing aid unit:

a chassis compartment open at one end;

an externally accessible control panel defining a termination for said chassis compartment at said one end, said control panel having an exposed first aperture;

a microphone mounted within said compartment at an externally inaccessible location, said microphone having a back cavity provided with a second aperture through which said cavity may be shunt-loaded;

a flexible air-conducting tube communicating at its ends with the back cavity and the exterior of said compartment through said first and second apertures, respectively; and

means removably positioned through said first aperture in the end of said tube adjacent said first aperture for varying the acoustic impedance of said tube by a controllable amount.

5. In a hearing aid unit:

the arrangement as defined in claim 4, said removably positioned means being a plug insertable in said first aperture for restricting the opening of said tube.

6. In a hearing aid detection and power unit:

an electrical chassis enclosure;

a microphone mounted in said enclosure at a manually inaccessible location;

one of the walls forming said enclosure having an accessible aperture;

said microphone having an opening communicating with an internal back cavity therein;

a vent tube interconnecting said microphone opening and the aperture of said one wall;

a plurality of vent plugs individually positionable from an externally accessible location in the end of said tube adjacent said aperture, said vent plugs having successively different acoustic impedances for externally modifying the low frequency response of said microphone.

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KATHLEEN H. CLAFFY, *Primary Examiner*.

ARTHUR A. MCGILL, *Assistant Examiner*.

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