

June 21, 1966

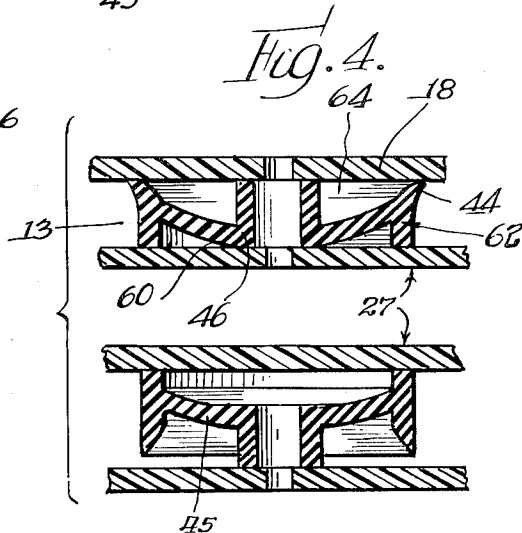
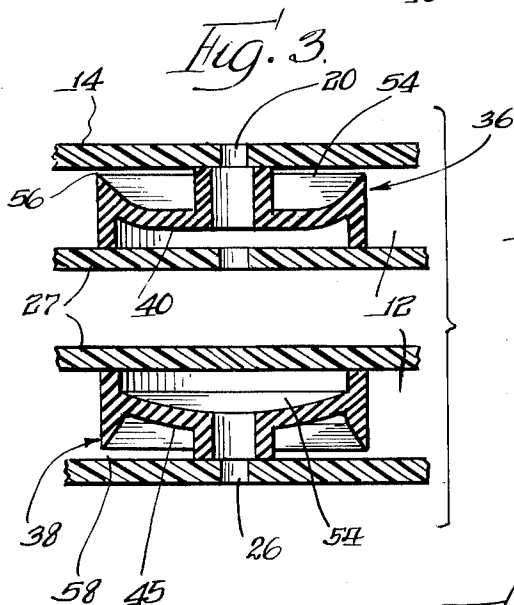
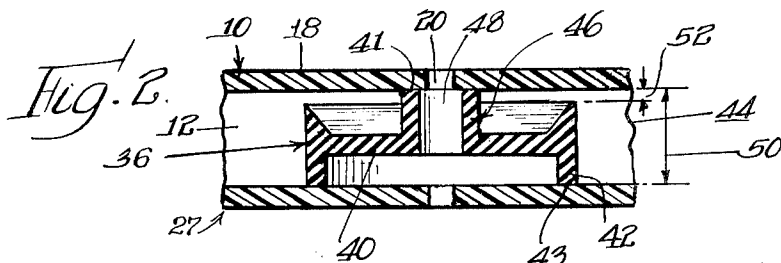
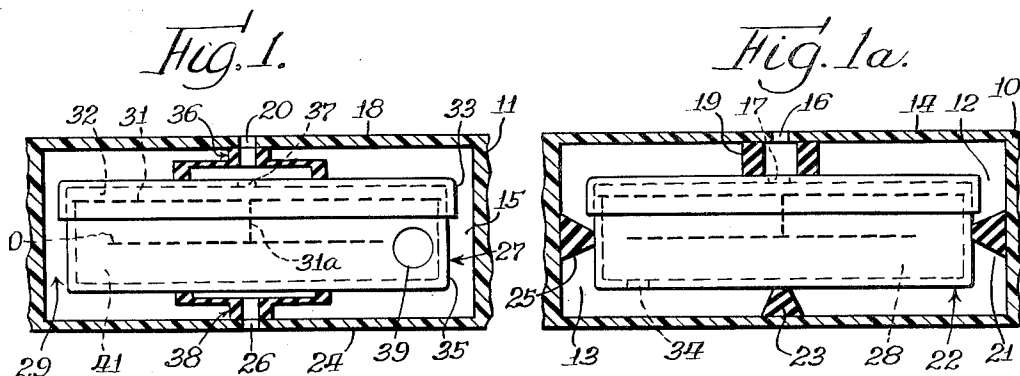
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3,257,516

COMBINED INSTRUMENT AND TRANSDUCER MOTOR CAVITIES
FOR ACOUSTIC INSTRUMENT

Filed June 25, 1962

5 Sheets-Sheet 1



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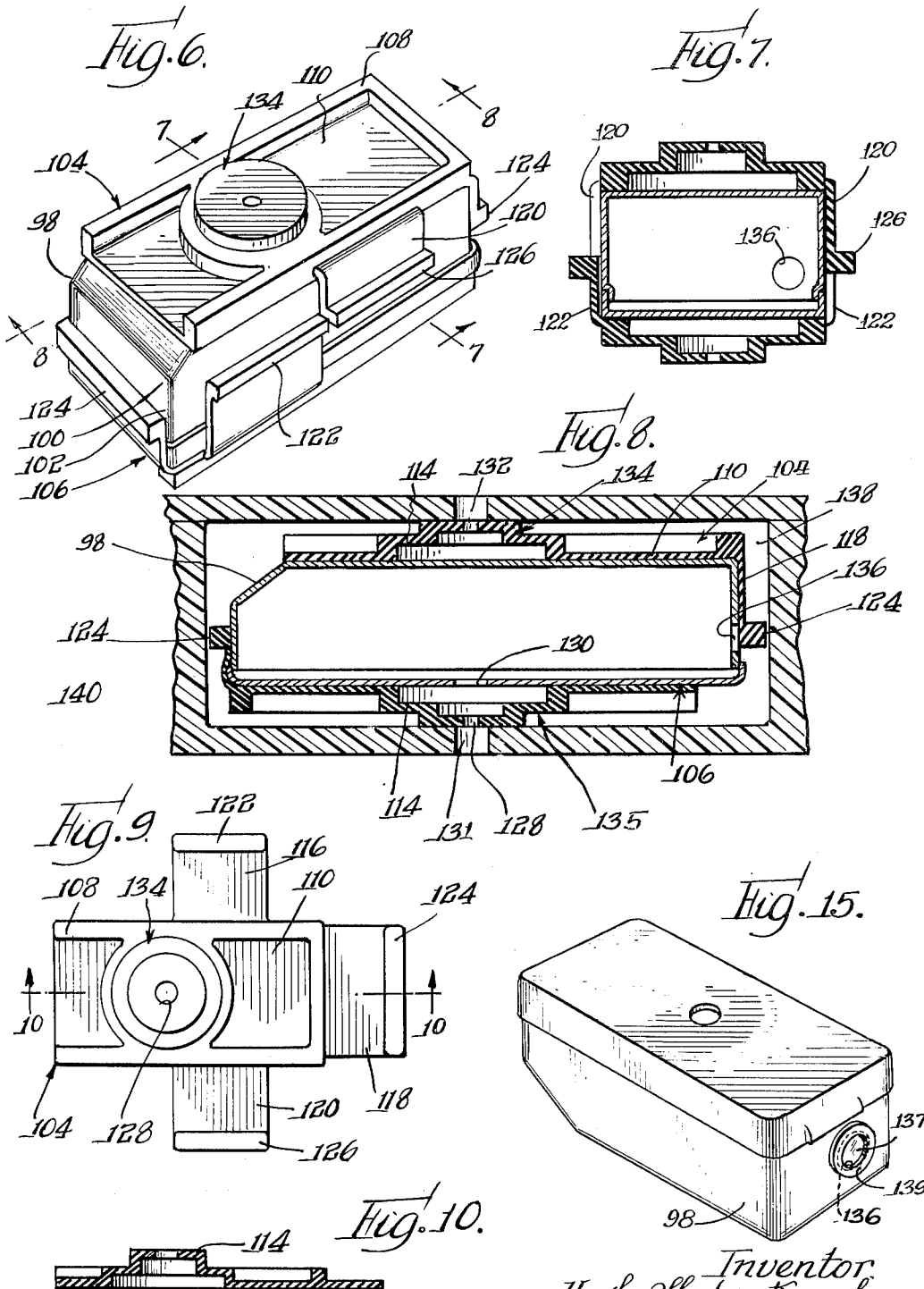
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5 Sheets-Sheet 2



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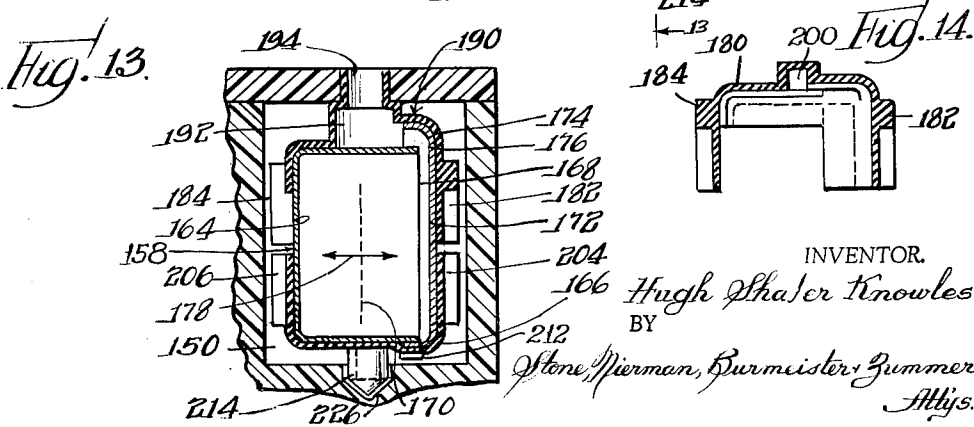
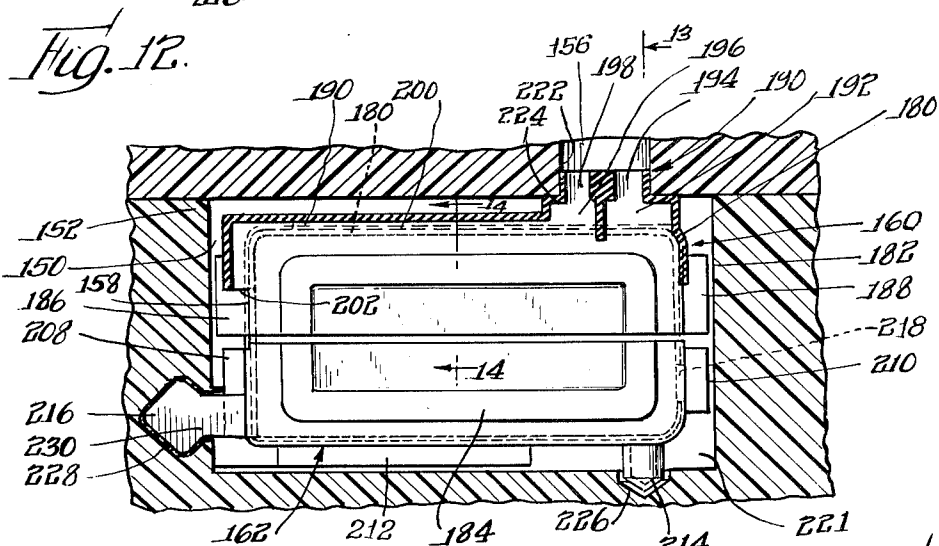
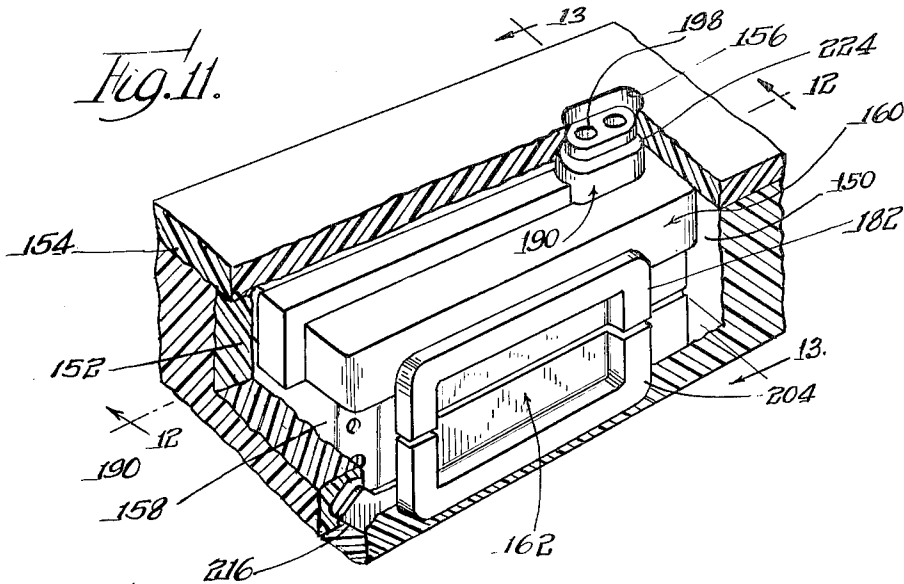
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5 Sheets-Sheet 3



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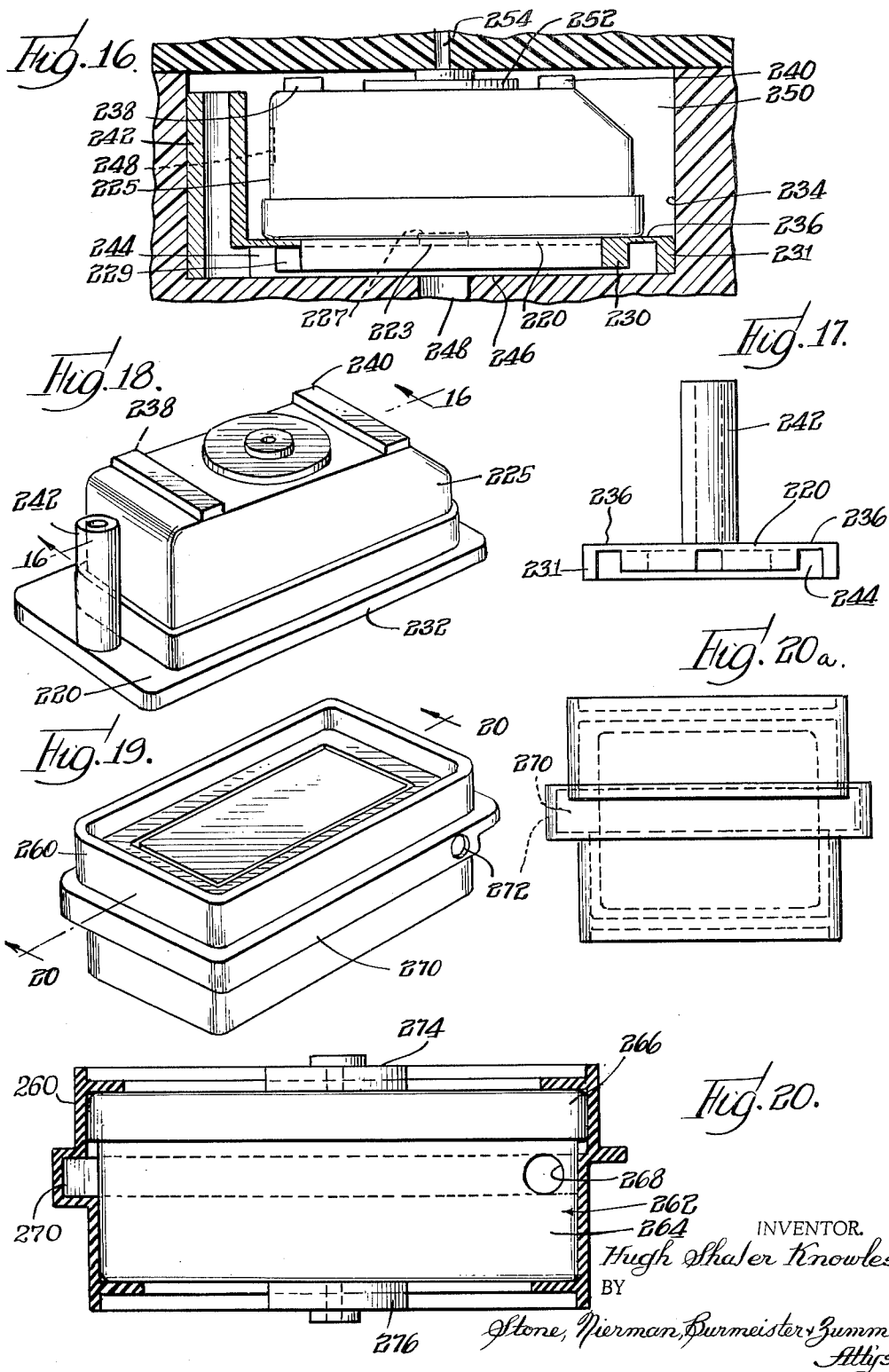
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H. S. KNOWLES
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Filed June 25, 1962

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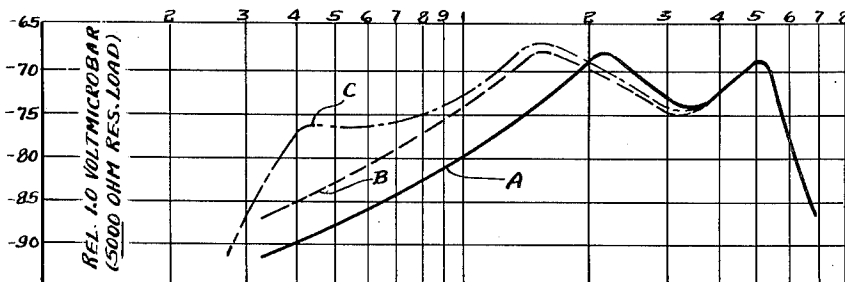
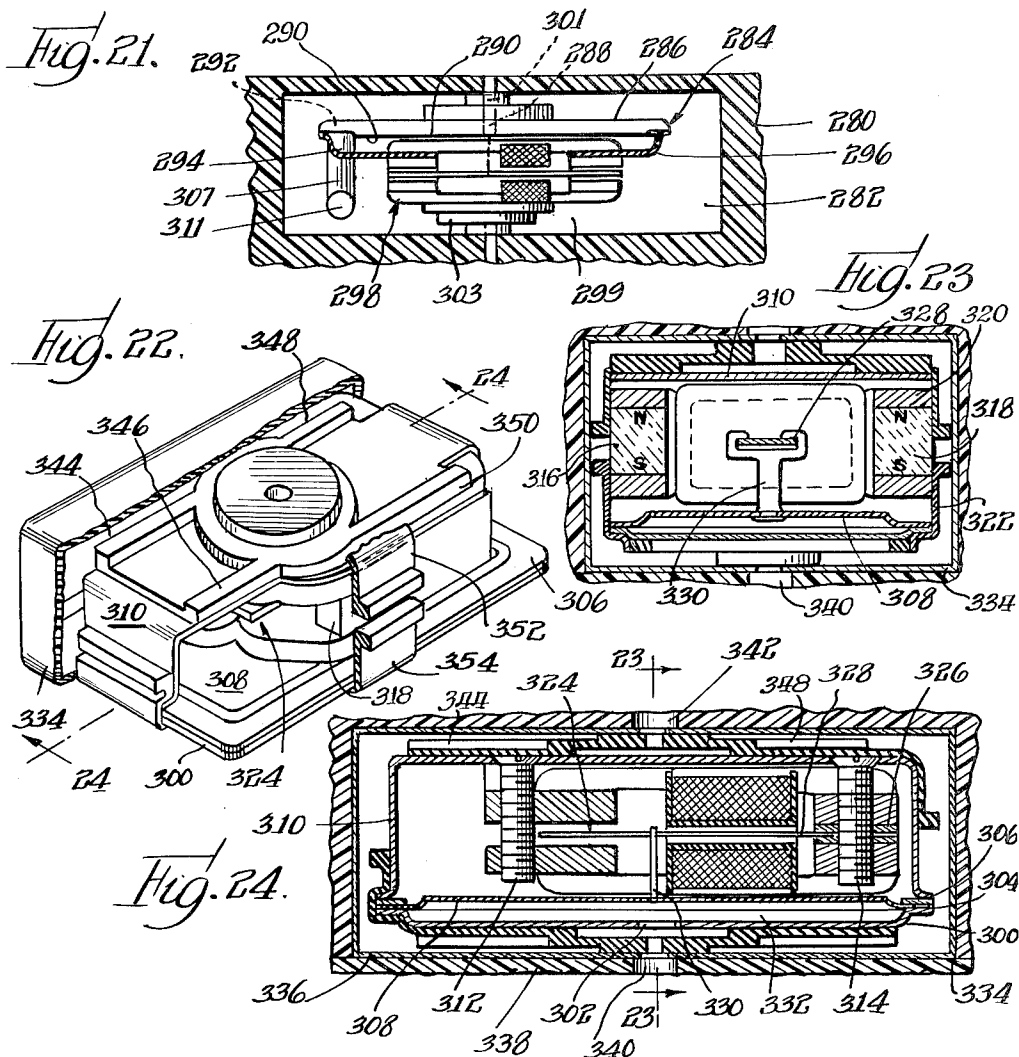


Fig. 25.

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3,257,516

COMBINED INSTRUMENT AND TRANSDUCER
MOTOR CAVITIES FOR ACOUSTIC INSTRUMENT

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Filed June 25, 1962, Ser. No. 204,942
37 Claims. (Cl. 179-180)

This invention relates to a vibration- and shock-resistant miniature transducer, and to the mounting of the transducer in a substantially sealed cavity of a consumer instrument so as to utilize all available space of the cavity of the instrument as part of the back cavity of the transducer. A transducer is mounted in an instrument that has a specific consumer use. That consumer use for the applicant is primarily a hearing aid, although his transducers are used in consumer instruments which have other acoustic purposes. More particularly, this invention relates to a transducer wherein the back or motor cavity includes the maximum space or volume made available by the consumer instrument, because the greater the volume of the back cavity of the transducer, the lower will be the resonant frequency of the transducer.

As will appear, applicant utilizes for the back cavity of the transducer the entire space made available by the consumer instrument as the back or motor cavity of the transducer, and his invention including the vibration- and shock-resistant features applies to three constructions: (1) where the transducer is housed within a case which is positioned in a substantially sealed cavity except for a sound port (in microphones, also an inertance tube port) of a consumer instrument, with an interspace between the case and the cavity walls to permit the mounting of isolators that absorb the energy resulting from vibration and shocks; (2) where the transducer consists of a diaphragm having a wall connected to the periphery of the diaphragm on one side so as to form a front cavity, with a motor positioned on the other side of the cavity without a case or housing so that the cavity back of the instrument, hereinafter called the "back cavity," is to be supplied by the cavity of the consumer instrument; and (3) where the transducer, like (2) has a front cavity but no back cavity, but is mounted between vibration- and shock-resistant isolators in a case which fits snugly in the cavity of the consumer instrument. In all three types, the maximum space made available by the cavity of the consumer instrument is included in the back cavity of the transducer, i.e., all space becomes part of the acoustic system of the transducer.

In this application, the word "transducer" generally means a device which converts electrical energy into mechanical movement or vice versa. The words "transducer assembly" mean a diaphragm having a wall with a sound port positioned at one side to provide a front cavity, and a motor drivingly connected to the diaphragm mounted on the other side of the diaphragm. The wall of the front cavity may act as the frame and the motor may be mounted thereon. The word "motor" includes both a motor and a generator because applicant's transducers may be used as receivers, where the motor acts as a motor, or may be used as microphones where the motor acts as a generator.

The problem solved by applicant as first encountered stems from a desire to isolate from vibration and shock an electroacoustic transducer enclosed in a case and mounted in a hearing aid cavity of greater dimensions than the transducer case so that there is an interspace between the case and the cavity, and concurrently to utilize this acoustically unused interspace to increase the volume of the back cavity of the transducer. Describing an existing typical design shown schematically and referring to

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FIGURE 1a, the numeral 10 identifies a consumer instrument in which a cavity 12 is substantially sealed excepting for a sound port 16. Mounted in this cavity 12 is a transducer, microphone or receiver, housed in a case 22 and having a sound port 17. Between the transducer case 22 and the inside of the wall 10 is an interspace 13. The sound port 17 is connected to the port 16 by an O-ring 19 made of elastic material such as natural or synthetic rubber. The transducer case 22 floats in the cavity 12 on several isolators such as 21, 23 and 25, which are pads of elastic material that absorb the energy produced by relative movement of the case and cavity during operation—that is, produced by vibrations which if not suppressed cause feedback to other equipment in the consumer instrument or transit vibrations from other equipment to the case 22. The interspace 13 may be principally occupied by sponge rubber. The thickness of the interspace 13 in standard hearing aid design varies from 0.020" to 0.045", and the solid material of the isolators occupies, volumetrically, perhaps one to five percent of this interspace. Typically, the volume of this necessary interspace, which is acoustically wasted, is one-half the volume of the back cavity of the transducer.

Until now, this acoustically unused interspace has been accepted as an unavoidable incident to use of the isolators. The adjacency of this space to the outer wall of the transducer, however, has come under the scrutiny of applicant. As microphones and receivers have become smaller, the back cavity 28 has declined in volume and has become increasingly stiff. This stiffness has raised the natural resonance of the diaphragm system, typically to 2000 or more cycles per second. A desirable resonant frequency for this type of transducer is approximately 1000 cycles per second. If the diaphragm mass is constant, the total effective stiffness must be reduced by a factor of four to reduce the resonant frequency by a factor of two. The stiffness of the air in the back cavity varies inversely with the net air volume. The high air stiffness reduces the sensitivity to an undesirable extent.

By enlarging the back or motor cavity, the natural resonance of the transducer will be lowered. A port 34 through the back of the case 22 accomplishes this, but such a port is not used because experimentation shows that venting the back cavity into a cavity of a hearing aid, even though the latter is sealed, results in objectionable low frequency noise when the aid is vibrated even slightly as by the wearer's clothing or by motion of the wearer.

Applicant investigated this effect resulting from the use of a port such as 34, and reached the conclusion that the volume of the interspace 13 enclosed by the washer O-ring 19 when contracted or expanded in response to relative movements between the case 22 and the wall 14 varied, and that this variation in the volume of the interspace 13 in turn varied the volume and the pressure in the back cavity 28. This fluctuation in pressure introduced the aforesaid low frequency noise which vitiated the improvement in sensitivity and response provided by enlargement of the back cavity.

One object of this invention is, therefore, to provide a means for maintaining constant the volume of the interspace 13 during vibratory movements as contrasted with shock so that a port 34 in the case wall establishing communication between the back cavity and this normally acoustically unused interspace will produce an enlarged back cavity of substantially constant volume irrespective of relative movements between the transducer and the hearing aid cavity due to vibration. Applicant presents two means for effecting this object. Firstly, where the axis of vibration, caused, for example, by an armature, is parallel to the axis of the sound port 17, as in FIGURE 1a, applicant provides two bellows interposed between two opposite walls of the hearing aid cavity and opposite sides

of the case. The bellows are such that when one axially expands, the volume enclosed by it increases by the same amount that the volume enclosed by the opposed bellows decreases when it axially contracts. The volume of the interspace 13 remains constant irrespective of movements of the transducer case with respect to the walls of the hearing aid cavity. Secondly, where the axis of vibration is parallel to the axis of the sound port 17, applicant mounts the transducer assembly or case on a pivot remote from the source of vibration and parallel to the axis of vibration, and then uses a constant volume leaf or tongue connecting the transducer assembly to the consumer instrument cavity, said tongue being movable parallel with the axis of vibration of the transducer assembly.

The second object of this invention is to accomplish the same result where the transducer has no back cavity, that is, the generator or motor is not encased. In this design, the diaphragm is enclosed by a cover or lid, which alone or with the other members constitutes a frame, thereby forming a shallow front cavity with a sound port, and the generator or motor is mounted on the frame, but on the opposite side of the diaphragm. This unit constitutes a transducer assembly, which however, lacks a back cavity. The sound port in the top is coupled to the sound port of the cavity of the hearing aid case by a bellows. A second bellows is mounted between the opposite side of the transducer and the opposite wall of the cavity. The cavity of the hearing aid case thereby becomes the back cavity of the transducer.

A third object of this invention is to utilize all available space by inserting the bellows between a transducer assembly and the inside walls of a case which itself fits snugly into a hearing aid cavity. Applicant refers to this construction as a cartridge because vibration resistance, shock resistance, maximum constant volume back cavity, and inertance tube where required, are all within the case. The fully protected transducer is seated snugly in a hearing aid cavity.

In each of the foregoing structures, applicant utilizes the interspace as a part of the acoustic system. Additionally, particularly for microphones, an inertance or Thuras tube may be desired for the purpose of improving the response below the natural resonance of the system. A further object of this invention, therefore, is to utilize this interspace in whole or in part to house an inertance tube.

A further object of this invention is to provide an isolator, which will perform the function of the pair of bellows in utilizing the interspace 13, but which additionally will differentially counteract vibration and shock. As will appear in connection with embodiments showing a transducer in a case positioned in a hearing aid cavity, the isolator not only maintains the interspace 13 at a constant volume during vibratory movements, but differentially counteracts vibration and shock. Vibration of a transducer case is derived from vibrations of the walls of the hearing aid cavity. These vibrations are extremely minute. They generate very little energy. To isolate the case from the hearing aid cavity requires a highly complaint mounting which may be made of many substances, as for example, natural or synthetic rubbers. Applicant's investigation shows that vibration, including that resulting from walking, does not cause a relative movement between the case and the hearing aid cavity walls in excess of 0.004" and that provision for an excursion of 0.005" is ample. If the transducers are of the magnetic armature- or reed-type, the sensitivity to vibrations of the case is substantially greater along lines at right angles to the plane of the vibrating armature than along lines parallel to the length of the armature. Here again, applicant's studies indicate that the vibrations of the case caused by the vibrating armature cause the case to move by much less than 0.005". Hence, another object of this invention is to provide an isolator that has a high compliance during

a movement of the case toward the walls of the hearing aid cavity along the axis of vibration up to 0.005".

Shock is a large sudden movement of the acoustic transducer with respect to the walls containing it. It is usually caused by the dropping of the consumer instrument, i.e., a hearing aid, and applicant has determined that a transducer weighing one gram and dropped four feet onto a hard surface generates at the moment of impact a force several thousand times that of gravity. This high energy must be absorbed by something of comparatively high stiffness, which is to be contrasted with the low stiffness required to prevent communication of vibration. Another object of this invention therefore, is to provide an isolator having a highly compliant section to absorb the energy from vibration and another section which, upon the attempted movement of the case toward a wall of a hearing aid cavity in excess of 0.005", will provide sufficient resistance to absorb the energy caused by shock. Specifically, applicant provides a stiffness on the shock component which initially is 50 times as great as the stiffness of the portion of the isolator counteracting vibration.

As will appear, applicant incorporates vibration and shock mounts into the bellows which provides constant volume in the enlarged back cavity so that what is commonly called an isolator performs all three functions.

A further object of this invention relates to the first embodiment in which the case has a port into the back cavity and, particularly for microphones, an inertance tube is vented to the outside of the consumer instrument. The object is to provide great low frequency response control. By sealing the port into the back cavity, one response will be obtained. By opening the port, a different response will be obtained. By plugging the outlet in the inertance tube, still a third response can be obtained. A feature of the first embodiment is a readily removable or replaceable seal over the port into the back cavity and the positioning of the external outlet of the inertance tube so that the user may easily close it.

These and such other objects as may hereinafter appear are attained in the several embodiments of the invention described in connection with the drawings, wherein:

FIGURE 1a is a schematic showing of a standard mounting of an encased transducer in a cavity of a hearing aid;

FIGURES 1 through 20 present several structural designs of the first embodiment of the invention;

FIGURE 1 is a view in section showing an encased electroacoustic transducer mounted between isolators in a cavity of larger dimensions of, for example, a hearing aid;

FIGURE 2 is a vertical section of one of applicant's isolators in unstressed position;

FIGURE 3 is a view of two of applicant's isolators on opposite sides of a microphone case illustrating their respective configurations on a movement of the case toward the upper wall of the hearing aid cavity during vibration;

FIGURE 4 is a sectional view illustrating applicant's isolators resisting shock;

FIGURE 5 is a sectional view of an alternative form of isolator;

FIGURES 6 through 10 present a commercial isolator particularly useful for a microphone, which is shown with the sound opening directed downwardly; FIGURE 6 being a perspective view; FIGURE 7 being a view taken on the line 7—7 of FIGURE 6; FIGURE 8 being a view taken on the line 8—8 of FIGURE 6, but positioned in the cavity of a consumer instrument; FIGURE 9 being a plan view of an isolator before mounting; and FIGURE 10 being a view taken on the line 10—10 of FIGURE 9.

FIGURES 11 through 14 present an isolator of the first embodiment of the invention particularly adapted for a microphone wherein FIGURE 11 is a perspective view of the isolator and transducer positioned in perspective in a cut-away cavity of a consumer instrument; FIGURE 12 is a view taken on the line 12—12 of FIGURE 11; FIG-

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FIGURE 13 is a view taken on the line 13—13 of FIGURE 11; and FIGURE 14 is a view taken on the line 14—14 of the upper isolator only in FIGURE 12;

FIGURE 15 is a perspective view of the transducer case used in all of the commercial embodiments shown in FIGURES 1 through 20;

FIGURES 16, 17 and 18 are perspective views of an isolator containing an inertance tube for a microphone wherein FIGURE 16 is a view taken on the line 16—16 of FIGURE 18; FIGURE 17 is an end view of the isolator alone; and FIGURE 18 is a perspective view showing the relationship of the isolator to the case;

FIGURES 19, 20 and 20a are views of another commercial embodiment of an isolator containing an inertance tube for microphones, and to be used in conjunction with bellows of the type shown in FIGURES 1—5; FIGURE 19 being a perspective view of the sleeve alone; FIGURE 20 being a view taken on the line 20—20 of FIGURE 19, but with a transducer case positioned therein; and FIGURE 20a being an end elevation;

FIGURE 21 is a sectional view of the second embodiment of the invention, the structure being shown largely schematically excepting for the relationship of the isolators to the transducer assembly;

FIGURES 22—24 present the third embodiment of the invention wherein FIGURE 22 is a perspective view cut away of a transducer assembly mounted within shock mounts in a case to form a cartridge that fits snugly in the cavity of a consumer instrument; FIGURE 23 is a view taken on the line 23—23 of FIGURE 24; FIGURE 24 is a view taken on the line 24—24 of FIGURE 22, but with the cavity of the consumer instrument shown partly cut away; and,

FIGURE 25 is a graph showing three different response curves available to designers of consumer instruments utilizing the first embodiment of the invention.

Encased electroacoustic transducers positioned in an acoustically sealed cavity of larger dimensions and employing the vibration isolator or interspace as part of the back cavity and/or for an inertance tube

The first embodiment of this invention utilizes the space between the inside walls of a hearing aid cavity and the outside surface of a transducer case. It applies, therefore, to the present commercial situation where transducers are mounted in sealed cases which are delivered, for example, to hearing aid manufacturers who mount the transducer in a cavity of greater dimensions with vibration isolators between the cavity walls and the case.

Referring to FIGURE 1, the invention is shown in its simplest form. The numeral 11 identifies that portion of a hearing aid case having a transducer cavity 15. The wall 18 carries a sound port 20 and diametrically opposed in wall 24 is a vent port 26. Disposed in the cavity 15 is a transducer in a case 27, with the clearance between the walls of the case 27 and the inside walls of the cavity 15 ranging from 0.030" to 0.045" to form an interspace 29. The dash lines 30 indicate the plane of the vibratory armature or reed and the line 31 indicates the plane of the diaphragm of the transducer. The diaphragm is connected to the armature by a drive pin 31a. The diaphragm substantially seals a back cavity 41 from a shallow front cavity 32. The cover 33 is mounted by any suitable means on an open-sided cup 35. Port 37 opens into the front cavity 32. There are two ports, one on each side of the transducer cup 35, as 39, connecting the back or motor cavity 41 to the interspace 29. The encased acoustic transducer is shown in outline. The components of the transducer are all mounted rigidly with respect to the case 27 at least at some point, the diaphragm at its perimeter, and the armature at least at one portion, usually an end. The axis of vibration is parallel to the drive pin 31a.

The case 27 is held between two isolators 36 and 38, which may be generally described as bellows. These iso-

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lators are illustrated in FIGURES 2 through 4, in section. Referring to FIGURE 2, the isolator 36 comprises a disk having a web 40, a perimetric wale 42 around one side and a perimetric wale tapering to a thin edge 44 on the other side. Inwardly of the web 40 is a hub 46. This hub 46 extends above the edge of the wale 44. A through port 48 is on the axis of the hub 46. The outer end 41 of the hub is adhered to the inside wall 18 of the cavity 12 around the port 20 and the circular edge 43 of the wale 42 is adhered to the wall of the case 27. When the transducer is at rest, the web 40 is stressed in neither direction. The isolator 38 is like 36, but inverted, see FIGURE 3.

Assuming that the distance 50 is 0.030", the distance 52 is 0.005". During vibration, the isolators flex mostly in the webs 40 and 45. In FIGURE 3, the case 27 is shown closer to the wall 14 of the hearing aid cavity. The flexibility is determined by the thickness of the webs 40 and 45 which can be varied to attain that flexibility desired. The isolator 38 is reversed in position with respect to isolator 36. Any diminution in the volume of the cavity 15 by reason of the alteration of the enclosed volume displacement of the isolator 36 because of the case 22 moving toward the wall 14 will be compensated for by the movement of the web 45 in the isolator 38 in the same direction. The port 26 permits air to move freely into or out of the space 54. If the clearance 56 is reduced from 0.008" to about 0.005", then the clearance 58 is increased from say 0.005" to 0.008". The combined displaced volume of the two isolators 36 and 38 remains the same. Hence, the volume of the interspace 29 remains the same. By means of the port 39, the volume of the back cavity 28 has been increased by all of the space around the transducer case 22, which is independent of the position of the case 22.

The isolators are made of an elastic material such as natural or synthetic rubbers.

In the event that a shock is transmitted to the wall 18 of the case, the wall 18, referring to FIGURE 4, first engages the sharp edge wale 44 and ultimately the hub 46 engages the case 22 at 60. The area engaged is great and what may be referred to as the "rim" 62 of the isolator acts as a column with the result that a great stiffness and resistance is immediately and increasingly applied and the isolator takes up the energy. When the shock occurs, the principle of maintaining the interspace 29 at a constant volume is abandoned. The annular volume 64 is segregated from the interspace 29 which segregates that much volume from the back cavity when in the position shown in FIGURE 4. However, shock protection is of such great importance that this is immaterial. Moreover, shock is rare and occurs usually when the hearing aid is not coupled to the ear. The resistance to shock is at least 50 times as great as the resistance of the web 40 to movement.

A wide variety of the double bellows designs can be provided, and one is shown in FIGURE 5. Here, the rim 66 of the isolator 68 is not beveled to a fine edge so that when shock occurs, full resistance is immediately effected by the rim acting as a column. The essential quality is that within the limits of vibration, changes in the external volume of one varies uniformly and complementary with changes in the volume of the other. The design would include two simple opposed rings which together possess the foregoing quality.

Referring to FIGURE 1, the isolators are mounted on opposite sides of the plane of the armature 30 to provide compliant mounting through their axes because vibration is detrimental primarily along lines normal to the surface of the armature—that is, parallel to its line of movement.

FIGURES 6 through 10 show two commercial complementary isolators embodying the features of applicant's invention mounted on an acoustic transducer case used as a microphone. The transducer comprises a case 98.

Two identical isolators 104 and 106 are mounted in reverse relationship on the top and the bottom of the case 98. One such isolator in its shape when formed is shown in FIGURES 9 and 10. The material is rubber and the shock absorber is much larger than in the isolators of FIGURES 1-5. Referring to FIGURES 9 and 10, the isolator 104 comprises a base 110 of thin material around the periphery of which is a heavy wale or shock pad 108. A differential vibration shock isolator 134 of the type shown in FIGURE 5 is formed integrally with the base 110 and pad 108 with the web 114 lying in the plane of the outer surface of the shock pad 108. The vertical dimensions follow those described for FIGURE 2. Integrally formed along three edges of the isolator are flexible tongues 116, 118 and 120 which have on their outer ends shock pads 122, 124 and 126 respectively. The isolator is designed so that its central opening 128 will register with the sound opening 130 of the case 98 and with a sound port 131 in the wall of a hearing aid cavity.

A hearing aid manufacturer provides an opening 132, referring to FIGURE 8, which permits free movement of the isolator 134 to pick up or discharge air so that isolator 134 may function under the same pressure conditions as isolator 135. The case has a port 136. One isolator is positioned on the top and the tongues bent down the sides, and then the other isolator is positioned on the bottom but reversed with the resulting assembly illustrated in FIGURES 6 to 8. The shock pads 122 and 126 align themselves as do the pads 124, see also FIGURE 8. This is a commercial product and the isolators are adhered to the case by an adhesive before shipment so that they need simply be slipped into the receiver cavity of a hearing aid. The space 138 is maintained at a constant volume by the isolators 134 and 135 so that this space communicating with the inside back cavity 140 of the sealed transducer enlarges that back cavity and improves the sensitivity of the instrument.

In FIGURE 15, the transducer 98 is shown in perspective, but inverted, with the end carrying the port 136 in view. Mounted over the port 136 is a seal 137 having rim 139 which is adhered to the outer surface of the case 98 around the port 136. By removing the seal, the hearing aid manufacturer can alter the response curve of the transducer in the hearing aid.

The second commercial structure of the first embodiment of the invention is illustrated in FIGURES 11-14. This embodiment of the invention provides the same features of utilization of a housing cavity to enlarge the back cavity of the encased transducer, of vibration resistance and of shock resistance, but additionally shows an inertance tube positioned in the isolator and shows a vibration mount which effects the general object of this invention. This second commercial embodiment points up the relationship between the axis of the sound duct and the vibratable axis of the armature including the relationship physically of the two axes to each other. It also points up the use of acoustically unused interspace, not only to enlarge the back cavity of the transducer but also to house an inertance tube.

The mountings of a transducer must fit a cavity in a consumer instrument and the design of a consumer instrument may require a sound port coming from a certain side of the transducer. Where the sound port is on an axis parallel to the vibratable axis of the armature, the vibration and shock isolators of the first commercial embodiment may be used. Where the consumer instrument requires a sound port at a side of the transducer case, then the isolator of the second structure may be used. Thus, where a transducer is used in a hearing air temple, the design of the hearing aid may permit the use of a sound passage that leaves the front cavity at right angles to the diaphragm. In such a design, the first embodiment of FIGURES 6-10 may be employed. Where the

design of a hearing aid requires the sound passage to be in a plane parallel to the diaphragm, this second structure of the first embodiment of the invention illustrates how this may be done while still attaining the important objectives of the invention.

The second structure specifically is directed to isolators for a microphone. In addition to effectively utilizing the interspace required for shock and vibration in the hearing aid cavity as part of a back cavity of a transducer, it utilizes the interspace to house an inertance tube. In general, it may be stated that the first embodiment, FIGURES 6-9, is designed for application wherein an inertance tube is not used, and the second embodiment, FIGURES 11-14, is designed to accommodate easily an inertance tube. However, either can be modified so as to orient the sound duct with respect to the axis of vibration of the armature and the means for resisting vibration may be selected in accordance with the axis of vibration.

In FIGURE 11, a transducer 158 is shown in a cavity 150 of an instrument such as a hearing aid. This cavity is partially cut away. The cavity 150 is formed in housing 152 which may be part of the temple member of hearing aid spectacles. The numeral 154 indicates a cover which has a sound port 156. The cavity 150 is substantially sealed.

Referring to FIGURE 13, the transducer case 158 consists of a receptacle 164 covered by a lid 172. The plane of its diaphragm is along the dash line 168 and is parallel to the plane of a vibratable armature 170. The lid 172 is extended at 174 so that there is a port 176. In FIGURE 13, the size of the port is slightly exaggerated. The line of principal vibration sensitivity therefore is along the line indicated by the arrow 178.

This embodiment consists of two similar and complementary boots 160 and 162. Both are molded from a compliant, elastic material such as natural or synthetic rubber, the components of each boot being integral with one another. The boot 160 contains both a sound duct and an inertance tube. Referring to FIGURE 12, the boot itself is formed of a comparatively thin wall 180 which fits snugly over the transducer 158 to which it is usually adhered. For purposes of resisting shock, it carries U-shaped shock pads 182 and 184 on each side, see FIGURE 14, and smaller pads 186 and 188 on each end. On the long upper surface of the boot is a turret 190 containing a sound passage 192 communicating with a sound port 194 and a passage 196 communicating with an inertance tube port 198. A duct 200 extends from the chamber 196 around the end of the boot and opens at 202. As indicated in FIGURES 12, 13 and 14, these chambers and passageways are formed outwardly of the boot itself so that when the boot is placed in position, the wall of the transducer case forms one side of the inertance tube 200 and the chambers 196 and 192.

The boot 162 is similar to the first boot carrying complementary shock pads 204 and 206 on its side and pads 208 and 210 with a bottom pad 212. A compliant post 214 is mounted diametrically opposite to the turret 190. The boot carries a tongue 216, see FIGURES 11 and 12. This tongue is thin and highly compliant at right angles to its plane. Referring to FIGURE 12, there is a port 218 in the wall of the case.

The two boots are adhered to the case 158 by an adhesive. The user provides a cavity 150 which has dimensions slightly greater than the over-all dimensions of the five sides having the shock pads, as shown in FIGURE 13, but the upper wall of the cavity through which a port 156 is provided seats flush on the elliptical shoulder 224 of the turret 190. There is also a socket 226 in the cavity wall 152 to receive the post 214 and a shallow socket 228 to receive the tongue 216. The back cavity of the transducer communicates by the port 218 with the sealed cavity 150 of, for example, a hearing aid. The inertance tube 200 connects the interspace 221 with the air adjacent the sound duct 194. The slight clearance

between the shock pads and the inside walls of the cavity is sufficient to limit vibration communication to the tongue 216, post 214 and the turret 190, but inasmuch as vibration is felt primarily along lines at right angles to the armature 170, substantially no vibration is transmitted through the neck 230 of the tongue 216. The armature is fixed in this transducer near the right-hand side of the case as shown in FIGURE 12 so that vibration occurs primarily at the left side. Consequently, the turret 190 and post 214 act as a pivot for the booted transducer with tongue 216 absorbing the energy.

The transducer when shipped carries the seal 137, FIGURE 15, and the boots 160 and 162. The port 136 provides a great advantage to the manufacturer of the consumer instrument, particularly where the transducer is used as a microphone. The design engineer now has available to him low frequency response control never before available. Not only can the low frequency cut-off be controlled over a range of almost one octave, but the general response shape can be easily modified once the cut-off characteristic is determined.

Applicant's microphone as shipped from the factory will have a low frequency response characterized by a 6 db per octave slope below 1000 c.p.s., Curve A, FIGURE 25. Placing the microphone in a specified sealed cavity in the hearing aid housing and removing the small port seal 137 on the end of the microphone will enhance the microphone's low frequency sensitivity by 6 db, Curve B, FIGURE 25. When the cavity is vented to the outside of the hearing aid housing by a small inertance tube or channel 198, FIGURE 11, the low frequency response will be further increased as much as 8 db at certain frequencies, Curve C, FIGURE 25. Thus, by placing the microphone in a specified cavity, sealing the cavity, and venting the cavity to the outside of the hearing aid housing by a small tube, maximum low frequency sensitivity is achieved.

To further the flexibility of the hearing aid utilizing the vented cavity a shift in response shape from that of Curve C to Curve B is easily accomplished by merely closing or plugging the vent tube at 198. Immediately the response is changed from one characterized by a low frequency rise in the 400 to 750 cycle range, Curve C, to a 6 db per octave slope, Curve B. With this minor operation two different performance characteristics can be made available without increasing the inventory of finished instruments.

For microphones, applicant presents two additional isolators. In FIGURES 16, 17 and 18, a pipe inertance tube is mounted on a base which provides differential vibration and shock protection while enlarging the back cavity. A base 220 of thin flexible material with a port 223 is adhered to that wall of a transducer case 225 carrying the sound port 227, the ports 223 and 227 being in registry. Formed integrally with and externally of the base 220 are shock pads 229 and 231 which may be connected to each other to form a rectangular wale, and a perimetric wall 232 having dimensions such that it will nest in the cavity 234 of a consumer instrument. The perimetric wall 232 is deeper than the shock pads so that the base may vibrate in the annular web 236, there being opposing shock mounts 238 and 240. An inertance tube 242 extends at right angles to the base 220, is formed integral therewith, and opens into the labyrinthic space 244 defined by the perimetric wall 232 and the shock pads 229 and 231. The wall 246 of the cavity closes the space 244. The port in the cavity wall is at 248. To maintain a constant volume in the interspace 250, a large bellows 252 is used in association with a port 254 in the cavity wall. Since flexing occurs in the annular web 236, a larger bellows 252 is employed to compensate and maintain constant volume.

In FIGURES 19, 20 and 20a, the isolator is a sleeve 260 which fits snugly to four walls of the transducer case 262. The case comprises a receptacle 264 and a lid 266

with a port 268 through the wall of the case 262. Around three sides of the waist of the sleeve is an inwardly directed channel 270 which with the wall of the case forms an inertance tube. One end of the channel registers with port 268 and at the other end of the channel is a port 272 which opens into the cavity in which the instrument is mounted. Applicant's standard bellows 274 and 276 may be used to provide vibration and shock protection and a constant volume of the interspace.

The last three commercial embodiments of the invention wherein an inertance tube is housed in the interspace reduces the volume of the transducer case and eliminates construction problems arising from mounting an inertance tube primarily in the back cavity of a transducer. Ordinarily, a microphone for a hearing aid requires an inertance tube, and usually a receiver does not, although in some applications it may be used; otherwise, the major parts of the instruments are identical and require the same volume. But it is practical to have the microphones and receivers of the same external size. By moving the inertance tube into the interspace, the case can be designed to meet the minimum dimensions of the receiver instead of the larger minimum dimensions of the microphone.

Transducer assembly positioned in sealed cavity of consumer instrument

The second embodiment of this invention utilizes the cavity of the consumer instrument as the sole back cavity of the transducer. Referring to FIGURE 21, the consumer instrument 280 contains a cavity 282. A transducer assembly 284 consists of a lid 286, with sound port 288, to the periphery of which is mounted a diaphragm 290, the lid and diaphragm forming a front sound cavity 292. A pair of brackets 294 and 296 fastened to opposite edges of the lid support on the lower side of the diaphragm a motor 298 which is generally identified only. On the bottom of the motor 298, parallel to the plane of the lid 286, is mounted a plate 299. Between the lid 286 and the upper wall of the cavity 282 is disposed a bellows 301 of a type of FIGURES 1-5, and a similar bellows 303 is positioned between the plate 299 and the lower wall of the cavity 282. Constant volume is attained as well as vibration and shock resistance. A rigid inertance tube 307 may be mounted on the lid, connecting the front cavity to the back cavity by openings at 309 and 311. The cavity 282 of the consumer instrument becomes the back or motor cavity of the transducer. The complete transducer is the combination of the transducer assembly and the cavity of the consumer instrument.

This embodiment enables the manufacturer to provide a back cavity of the volume he considers desirable for a particular hearing aid. A maximum volume cavity in the hearing aid can be reduced by inserts, i.e., thin plates of plastic adhered to a wall of the cavity, to provide a net volume for a desired operating resonance of the transducer. The transducer assembly will be shipped in a sealed bag and the manufacturer must assemble the transducer assembly under such condition that dust is not included in the instrument during and after assembly. The responsibility for operation of the transducer will belong to the consumer instrument manufacturer and not to the transducer assembly manufacturer.

Vibration and shock protected transducer cartridge

The third embodiment of this invention is set forth in FIGURES 22, 23 and 24 which present a transducer cartridge. The external dimensions of the cartridge are substantially the maximum dimension made available to the transducer manufacturer by the manufacturer of the hearing aid; therefore, the cartridge is to be positioned in substantially flush engagement with walls of a cavity in the hearing aid, and not spaced therefrom. There may be a

permanently viscous plastic in a spacing of $\frac{1}{1000}$ to $\frac{2}{1000}$ of an inch around the case of a transducer. In this embodiment, vibration and shock resistance and a constant size back cavity are provided. In short, the isolators are moved into a permanent transducer case, and as will appear, they space the transducer itself from the case which if magnetic will dissipate less flux than where the case is very close to the transducer, as in present structures. Also, the case acts as a shield against outside flux.

The physical structure of the third embodiment is the same as the second embodiment, excepting that a permanent case is substituted for the cavity of the consumer instrument. This enables the transducer manufacturer to sell a sealed transducer which he can guarantee.

The transducer cartridge shown in FIGURES 22, 23 and 24 is based upon the Knowles twin-magnet structure shown in United States Letters Patent No. 2,912,523. The frame of the transducer itself is a lid 300 having a central port 302. The lid 300 has a peripheral flange 304 upon which is mounted a rectangular flat plate or rim 306, but between the plate 306 and the flange 304 is mounted a diaphragm 308. A U-shaped yoke 310 is mounted on the plate 306, and from this yoke 310 by bolts 312 and 314 is suspended a motor utilizing two transverse magnetized magnets 316 and 318 between O-shaped pole pieces 320 and 322 forming a working gap 324 and a fixed gap 326, with an armature or reed 328. The reed 328 is connected to the diaphragm 308 by a driven pin 330. This electroacoustic transducer is complete insofar as it possesses a front cavity 332, but as can be seen in FIGURE 22, there is no back cavity because the working components of the motor are completely exposed. In this application, this is called a transducer assembly. The specific type of motor is unimportant. For the purpose of this invention, any type of transducer motor may be used.

The motor is mounted in a magnetic case 334 and in its simplest form would be spaced from the case by a pair of diametrically aligned bellows of the type shown in FIGURES 1-5 which perform both the vibration and shock functions. The case itself has a volume and hence the available space for a back cavity is slightly less than that shown in the second embodiment of this invention because the walls of the hearing aid cavity do not participate in the acoustic function. However, the magnetic case has two advantages. Firstly, it acts as a shield, and being spaced from the transducer elements by a greater distance than the spacing shown in the U.S. Patent 2,912,523, FIGURE 2, there is less dissipation of flux energy from the transducer into the case. Secondly, the case protects the transducer from accidental damage which is desired by users of the transducer. The cavity of the hearing aid is indicated by the rectangular line 336 which is bounded by the walls, usually of plastic, and cut away. The plastic wall 338 has a sound opening 340 and in order to prevent compression of air inside the bellows, there is a complementary opening 342 of the hearing aid.

In the embodiment shown in FIGURES 22-24, the bellows is part of an isolator which fully protects the transducer. This isolator is of the type shown in FIGURES 9 and 10, each of the two isolators being identical. The shock members 344 through 350 lie along the outside boundaries of the O-shaped pole piece 320 and the yoke or bracket 310 has been shaped to cover the pole piece so that the isolator has a flat surface or plate upon which to rest. The member 310 is made of material of low flux conductivity. The isolator shown has slightly different side tongues 352 and 354, but all sides of the transducer are spaced from the case by shock pads. In general, vibration is important only along lines at right angles to the surface of the armature or reed and it is for this reason that the vibration-resistance component of the isolator is mounted only on opposite sides of the

armature. They could be mounted on all six sides of the unit.

Having thus described the invention, applicant claims:

1. In combination with a housing having a substantially sealed cavity having a sound port through the housing, an electroacoustic transducer assembly movably disposed in said cavity so as to form an interspace therearound, said transducer assembly comprising a diaphragm, a wall substantially sealed to the periphery of the diaphragm to form a front cavity on one side thereof, a motor mounted on the other side of the diaphragm and drivingly connected thereto, the space occupied by the motor being in communication with the sealed cavity of the housing, a sound port into the front cavity of the transducer assembly, a duct connecting the sound ports of the housing and the front cavity to each other; and flexible means disposed in the interspace for maintaining the cavity of the housing at a substantially constant volume during movements of the transducer assembly relative to the walls of the cavity.

2. In combination with a housing having a substantially sealed cavity having a sound port through the housing, an electroacoustic transducer assembly disposed in said cavity with an interspace therearound, said transducer assembly comprising a diaphragm, a wall substantially sealed to the periphery of the diaphragm to form a front cavity on one side thereof and a motor mounted on the other side of the diaphragm and drivingly connected thereto, the space occupied by the motor being in communication with the sealed cavity of the housing, a sound port into the front cavity of the transducer assembly, a duct connecting the sound ports of the housing and the front cavity to each other; and means supporting the transducer assembly in said interspace for differentially resisting vibration and shock during relative movements of the transducer assembly and the cavity.

3. In combination with a housing having a substantially sealed cavity having a sound port through the housing, an electroacoustic transducer assembly disposed in said cavity with an interspace therearound, said transducer assembly comprising a diaphragm, a wall substantially sealed to the periphery of the diaphragm to form a front cavity on one side thereof and a motor mounted on the other side of the diaphragm and drivingly connected thereto, the space occupied by the motor being in communication with the sealed cavity of the housing, a sound port into the front cavity of the transducer assembly, a bellows connecting the sound ports of the housing and of the front cavity to each other, and a like bellows positioned between the motor and the opposite wall of the cavity, the two bellows having the characteristic of varying the external volume enclosed by the bellows uniformly with axial expansion of contraction whereby during relative vibratory movements between the case and the cavity, when the volume enclosed by one is reduced, the volume enclosed by the other is complementarily increased.

4. The combination of claim 1 wherein the transducer assembly has a major axis of vibration and the means for maintaining the interspace at a constant volume is a web connecting the housing to the transducer assembly and vibratable parallel to the axis of vibration of the transducer assembly.

5. The combination of claim 1 wherein the means for maintaining the interspace at a constant volume comprises an elastic duct positioned between the housing cavity and the motor side of the transducer assembly and wherein the volume enclosed by this duct varies inversely directly with the volume enclosed by the duct connecting the front cavity to the housing sound port.

6. The combination of claim 1 wherein the duct connecting the housing sound port to the front cavity sound port is an elastic ring compressible or expandable along its major axis, and the means for maintaining the interspace at a constant volume is a like ring positioned substantially in the same axis as the first ring but between

the motor side of the transducer assembly and the cavity of the housing together with a port through the housing wall into the last-named ring.

7. The combination of claim 1 together with shock pads mounted in the interspace but of a dimension normal to the surfaces of the case less than the axial length of the duct to permit relative vibratory movement between the housing cavity and the transducer assembly without engaging the shock pads.

8. The combination of claim 1 wherein the duct connecting the front cavity to the housing port is a ring having a circumferential wall of sufficient thickness to act as a shock pad, a second ring axially positioned at one side of the first ring and connected to the first ring by a vibratable web, and wherein the means for maintaining the interspace at a constant volume is a like twin-ring assembly disposed between the motor side of the transducer assembly and the housing cavity in axial alignment with the sound duct, there being a port through the housing wall into said second twin-ring assembly.

9. The combination of claim 1 wherein the transducer motor carries a vibratable armature and the duct connecting the housing sound port to the front cavity sound port and the means for maintaining the interspace at a constant volume are on a common axis that passes through the vibratable portion of the armature and is normal thereto.

10. The combination of claim 1 wherein the transducer assembly has an armature fixed at one portion with respect to the transducer assembly and vibratable at a point spaced from the fixed portion, and wherein the axis of the sound duct connecting the housing sound port to the front cavity sound port passes through the fixed portion of the armature parallel to its line of vibration and the means for maintaining the interspace at a constant volume is a vibratory tongue of constant volume lying substantially in the plane of the armature and connecting the wall of the housing cavity to the transducer assembly near the vibratory end of the armature.

11. The combination of claim 1 wherein the transducer assembly is supported in the housing cavity by the duct and by the means for maintaining said interspace at a constant volume and wherein shock pads are positioned in the interspace with an open space between them and either the cavity wall or the transducer assembly approximately equal to the maximum relative vibrational movement of the transducer assembly and housing cavity.

12. The combination of claim 1 together with an inductance tube positioned in the interspace with one end opening through a port through the housing.

13. The combination of claim 1 wherein the duct connecting the housing port to the front cavity sound port is an elastic ring mounted on a base of elastic material adhered to the outside of the wall forming the front cavity, wherein the means for maintaining a constant volume in the interspace is a like ring mounted on a flexible base on the outer side of the motor, and wherein on both of said bases are mounted outwardly projecting shock pads whose outer sides are nearer the transducer assembly than the outsides of the rings, the flexibility of said rings being such as to absorb the energy of vibrations while supporting the transducer assembly in the housing cavity.

14. In combination with a housing of an acoustic instrument having a substantially sealed cavity with a sound port through the housing, a case of smaller dimensions than the dimensions of the cavity positioned in the cavity with an interspace therearound, a diaphragm in the case positioned so as to form a front cavity on one side and a motor cavity on the other, a motor drivingly connected to the diaphragm, a sound port into said front cavity, a port in the case wall of the motor cavity connecting the interspace to the motor cavity, a sound duct connecting the sound port of the cavity of the acoustic instrument to the sound port into the front cavity, and means in said interspace for maintaining said interspace at a constant

volume during relative vibration of the case and the cavity.

15. In combination with a housing of an acoustic instrument having a substantially sealed cavity with a sound port through the housing, a case of smaller dimensions than the dimensions of the cavity positioned in the cavity, a plurality of flexible isolators positioned between the case and the walls of the housing cavity to form an interspace, a diaphragm in the case positioned so as to form a front cavity on one side and a motor cavity on the other, a motor drivingly connected to the diaphragm, a sound port into said front cavity, a sound duct connecting the sound port of the cavity of the acoustic instrument to the sound port into the front cavity, a port through the wall of the case connecting the motor cavity to the interspace; and means in the interspace for maintaining the interspace at a substantially constant volume during movements of the case with respect to the cavity walls of the acoustic instrument.

16. The combination of claim 15 together with a removable seal over the port connecting the interspace to the motor cavity.

17. In combination with a housing of an acoustic instrument having a substantially sealed cavity with a sound port through the housing, a transducer assembly comprising a diaphragm, a wall substantially sealed to the periphery of the diaphragm to form a front cavity on one side thereof, and an open motor mounted on the other side of the diaphragm and drivingly connected thereto, said transducer assembly being spaced from the inside walls of the cavity of the acoustic instrument, a sound port into the front cavity, a duct connecting the sound port of the cavity of the acoustic instrument to the sound port into the front cavity of the transducer assembly, and flexible means positioned between the transducer assembly and an inside wall of the case for maintaining the inside of the cavity at a constant volume during relative vibratory movements of the transducer assembly and the sealed cavity.

18. An electroacoustic transducer comprising a case, a transducer assembly consisting of a diaphragm, a wall substantially sealed to the periphery of the diaphragm to form a front cavity on one side thereof and a motor mounted on the other side of the diaphragm, a sound port into the front cavity, a sound duct connecting the sound port of the case to the sound port into the front cavity, a port in the case wall in the motor cavity connecting the interspace to the wall cavity, and flexible means positioned between the transducer assembly and the case for absorbing vibrations during relative movements of the case and the transducer assembly.

19. The electroacoustic transducer of claim 18 wherein the flexible means carry shock pads.

20. An electroacoustic transducer comprising two substantially parallel plates positioned on opposite sides of the transducer, elastic means whose enclosed volume remains constant when expanded or contracted along a selected axis mounted externally on one plate, and like means mounted on the external side of the other plate.

21. A vibration-resistant transducer comprising a case, an electroacoustic transducer mounted in said case, a sound port in the wall of the case, a boot adhered to the outside of the case, means for absorbing vibration mounted on the outer side of said boot, and a sound part through the boot registering with and connected to the sound port in the case.

22. A vibration- and shock-resistant transducer comprising a case, an electroacoustic transducer mounted in said case, a sound port in the wall of the case, a boot adhered to the outside of the case, means for absorbing vibration mounted on the outer side of said boot, a sound port through the boot registering with and connected to the sound port in the case, and shock pads mounted on the outer side of the boot.

23. A vibration-resistant transducer comprising a case, an electroacoustic transducer mounted in said case including an armature fixed at one portion and vibratable in another portion, a sound port in that wall of the case near the fixed portion of the transducer, a boot adhered to the outside of the case, a sound duct in the boot near the fixed end of the transducer, normal to the axis of vibration of the armature and near one end of the case, and a leaf disposed in that portion of the boot at the other end of the case near the vibratable end of the armature, said leaf being flexible along a line substantially at right angles to the line of movement of the vibratable end of the armature.

24. The vibration-resistant transducer of claim 23 together with shock mounts positioned on the outside of the boot.

25. The vibration-resistant transducer of claim 24 together with a port in the wall of the case and an inertance tube in the boot.

26. A vibration-resistant transducer comprising a case, an electroacoustic transducer mounted in said case and including a diaphragm separating the inside of the case into a front cavity and a back cavity, a port through the case wall into the back cavity, a sleeve around said case, means for absorbing vibration mounted on said sleeve, and an inertance tube in said sleeve opening at one end into said port and at the other end into the atmosphere.

27. A vibration-resistant transducer comprising a case, an electroacoustic transducer mounted in said case and including a diaphragm separating the inside of the case into a front cavity and a back cavity, a sound port through the case wall into the front cavity, and a port through the case wall into the back cavity, and an isolator having a base of flexible material mounted on that wall of the case carrying the sound port, said isolator having a closed, peripheral, flexible wall outwardly directed from the base and forming an opensided chamber, an annular shock pad mounted on the base within the closed wall and having an outer surface less distant from the base than the outer edge of the wall, and an inertance tube extending from that side of the base opposite the chamber, one end of the inertance tube opening into the chamber and the other end opening adjacent a wall of the case.

28. An isolator for an electrical instrument having an armature vibrating at frequencies in excess of 100 cycles per second comprising a flat frame enclosing an opening, a vibratable web closing said opening, and means associated with the frame and means associated with a portion of the web for engaging respectively a wall of the electrical instrument and a wall of the housing for the instrument, the free portion of the web having a flexibility such that the energy of vibration from the armature transmitted to the isolator will be absorbed by the web.

29. The isolator of claim 28 wherein the frame constitutes a shock mount and is made of a material having a resistance to deformation in excess of 30 times the resistance of the web.

30. An isolator for an electrical instrument having an armature vibrating at frequencies in excess of 100 cycles per second comprising a compliant ring, a vibratable web closing the opening in said ring, a post mounted centrally of said web and extending beyond the plane of one side

of the ring, and a sound port axially positioned in the post, the web between the post and the ring having a flexibility such that the energy of vibration from the armature transmitted to the isolator will be absorbed by the web.

31. The isolator of claim 30 wherein the ring is formed in association with a flat base and wherein shock mounts are disposed on that side of the base on the same side of the post but extending from the base for a distance short of the outer end of the post.

32. An isolator comprising an open-sided boot, shock mounts disposed on the outer sides of the boot, and a vibrating mount disposed on the same side of the boot and extending outwardly to a plane beyond the plane of any shock mounts on the same side of the boot.

33. An isolator comprising an open-sided boot, shock mounts disposed on the outer sides of the boot, a port through a wall of the boot, and a sound duct mounted around the port and extending outwardly beyond the plane of the outer walls of the shock mounts on the same side of the boot.

34. An isolator comprising a boot, an elongated shock mount disposed on the outer side of said boot, and an internal duct constituting an inertance tube extending along said shock mount, and a port into the duct near each end on the outer side of the boot.

35. An isolator comprising a boot, a sound port through the wall of said boot, an elongated shock mount disposed on the outer side of said boot and extending away from said sound port, and an internal duct extending along said shock mount with one end open near the sound port and the other end open on the outer side of the boot.

36. An isolator comprising a sleeve, a shock mount disposed around the sleeve, an internal duct extending along the inside of the shock mount, and an opening into the duct through the wall of the sleeve near one end of the shock mount and an external opening into the duct near the other end of the shock mount.

37. An isolator comprising a flat base, a closed compressible wall mounted on one side of said base and forming therewith an open-sided chamber, and a pipe mounted on said base laterally extending therefrom, the mounted end of the pipe being open into the chamber and the other end of the pipe being open.

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