May 6, 1952 D. E. RUTTER ET AL 2,595,489

INSERT EARPHONE AND OPERATIVE SUBASSEMBLY THEREFOR

Filed Oct. 3, 1945 2 SHEETS—SHEET 1

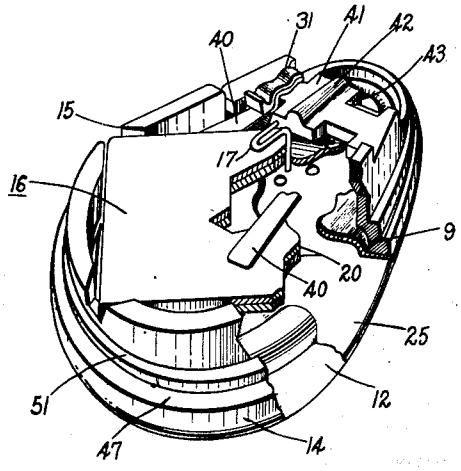

FIG. 1

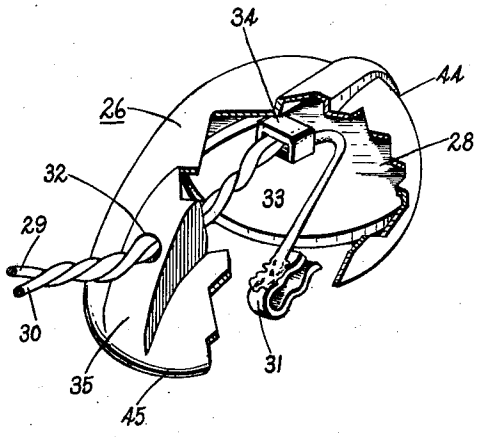

FIG. 2

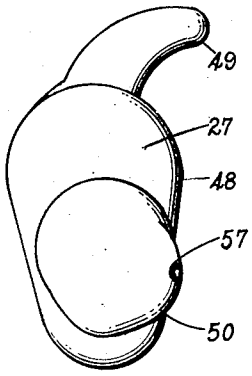

FIG. 3

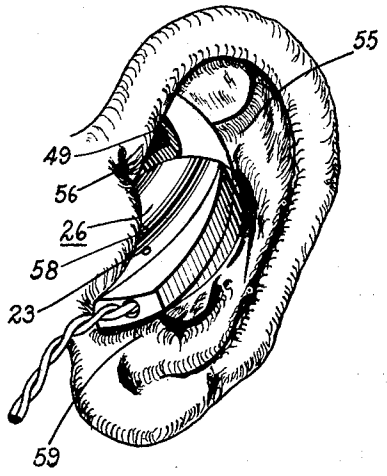

FIG. 4

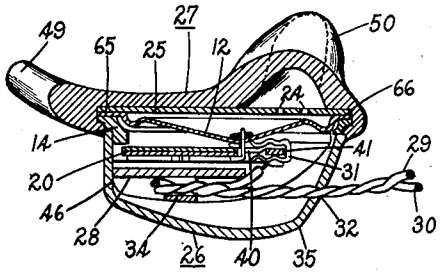

FIG. 5

FIG. 6

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INSERT EARPHONE AND OPERATIVE SUBASSEMBLY THEREFOR

Filed Oct. 3, 1945 2 SHEETS—SHEET 2

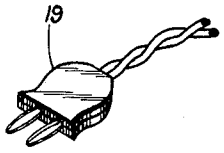

FIG. 13

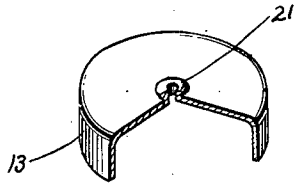

FIG. 7

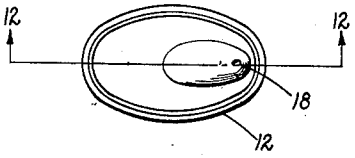

FIG. 8

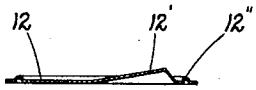

FIG. 12

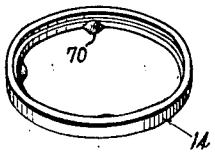

FIG. 9

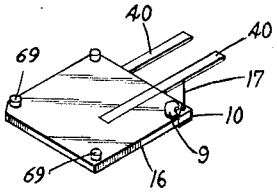

FIG. 10

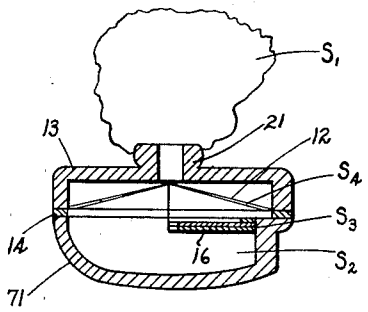

FIG. 15

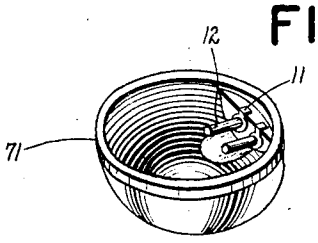

FIG. 11

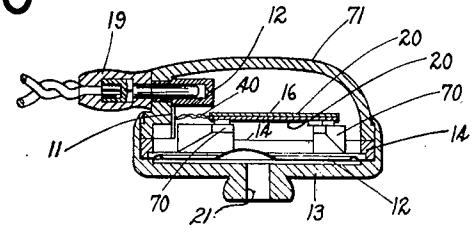

FIG. 14

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Patented May 6, 1952

2,595,489

UNITED STATES PATENT OFFICE

2,595,489

INSERT EARPHONE AND OPERATIVE SUBASSEMBLY THEREFOR

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Application October 3, 1945, Serial No. 620,118

9 Claims. (Cl. 179—107)

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This application is a continuation-in-part of our application Serial No. 402,608, filed July 16, 1941, granted as Patent No. 2,391,924 on January 1, 1946, for Phone and Method of Making Same.

Our invention pertains to earphones and more particularly to the small type of phone which is adapted to fit in a person's outer ear.

Another object of our invention is to provide an insert type piezoelectric earphone shaped to accommodate a relatively large crystal unit and in which the shape of the case cooperates with retaining means to hold the device in the wearer's ear.

Still another object of our invention is to provide a piezoelectric earphone which is easily and quickly assembled.

It is another object of our invention to provide an insert type earphone subassembly primarily adapted to be placed in a mass production case which will fit many different ears but which may readily be placed in a special case moulded to fit an unusual ear.

Still another object of our invention is to provide an insert type earphone subassembly which is operable without an enclosing case.

A further object of our invention is to provide a new and improved method of assembling an earphone.

Another object of our invention is to provide a diaphragm of large area for an insert type earphone and to position the diaphragm drive pin to obtain the maximum volume of displacement for a given amount of movement of the drive pin.

It is also an object of our invention to provide an insert earphone which is more sensitive than previous insert earphones.

A further object of our invention is to provide an insert earphone whose back radiation is low thereby permitting the use of a high-gain amplifier in the hearing aid device.

Another object of our invention is to provide a novel diaphragm for an insert earphone.

Other objects and a fuller understanding of our invention may be had by referring to the following detailed description and claims, taken in conjunction with the accompanying drawings in which:

Figure 1 is an enlarged isometric view of an earphone subassembly with portions broken away to more clearly illustrate the parts.

Figure 2 is an enlarged isometric view of another earphone subassembly with portions broken away.

Figure 3 is an enlarged plan view of the portion

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of the earphone which is adapted to fit against the wearer's ear.

Figure 4 is a slightly enlarged view showing an earphone in position in the wearer's ear.

Figure 5 is a sectional view taken along line 5—5 of Figure 3, and

Figure 6 is a cross-sectional view of the diaphragm used in our earphone.

Figures 7 to 11, inclusive, are isometric views of parts of another type of earphone.

Figure 12 is a sectional view taken along line 12—12 of Figure 8.

Figure 13 is an isometric view of the phone connector cord and plug.

Figure 14 is a sectional view through the assembled phone, and

Figure 15 is a schematic view showing the various cavities and parts whose stiffnesses must be considered when designing a phone of maximum sensitivity.

In the construction and assembly of piezoelectric earphones which are adapted to be inserted in a person's outer ear it is very important that the parts be accurately positioned with respect to each other, and especially important that the diaphragm and the crystal unit be accurately positioned with respect to each other. To effect this accurate positioning of parts for an earphone which is adapted to be made by mass production methods we have devised a novel earphone subassembly.

In our invention we provide an annular frame 14 to which we connect three corners of a rectangular piezoelectric crystal element 16 and a diaphragm 12. The crystal 16 is mounted on one side of the frame 14 and the diaphragm on the other side and the drive pin 17 which is connected to the fourth or unmounted corner of the crystal 16 is connected to the apex of a conical portion of the diaphragm. Thus, there is formed an operative subassembly which can be mounted in a housing to make an insert earphone.

Details of the phones may vary considerably; Figures 1 to 5 illustrate an earphone embodying the subassembly type of construction, and Figures 7 to 15 show another earphone embodying the same subassembly type of construction but with entirely different constructional details.

The frame 14 which forms the basis for assemblying the operative subassembly may be formed of a plastic or other suitable material, and preferably is somewhat compliant for reasons to be explained later.

Figure 1 shows how three corners of the crystal unit 16 are mounted in notches 15 in the frame

14 and the fourth corner is connected by means of a drive pin 17 to the diaphragm 12 whereby the diaphragm will be actuated in accordance with alternating current potential applied to the crystal. The frame has a quirk or shoulder 9 for positioning the diaphragm 12, and the peripheral edge portion of the diaphragm is secured by an adhesive to the frame to prevent the passage of air through the opening in the frame. The diaphragm, which preferably is formed of metal, thus serves as a moisture-resisting barrier to help protect the crystal unit, as will be apparent from other portions of this description. The shoulder 9 in the frame accurately positions the diaphragm and the notches 15 accurately position the crystal unit, thus assuring that the drive pin which is connected to the crystal unit is in exact alignment with the apex of the conical portion of the diaphragm.

After the earphone subassembly consisting of frame 14, diaphragm 12, and crystal unit 16 has been constructed, a guard plate 25 is secured by an adhesive or other suitable means to the edge of the diaphragm 12 to protect the diaphragm from deformation and puncturing during subsequent assembly work and while the earphone is being worn.

The diaphragm 12 may be on the order of .0008 to .002 of an inch thick and the crystal is on the order of .030 of an inch thick. Accordingly, the subassembly must be handled carefully but when it is provided with a guard plate 25, and when the top surface of the crystal unit 16 is below the edge of the mounting frame 14 (as illustrated in Figure 4) extreme care which slows down subsequent assembly work does not have to be exercised. The subassembly may be handled to position it in an earphone case or it may be packed to ship it to manufacturers who prefer to use their own earphone cases. This is highly desirable as many units may be mounted in standard mass production earphone cases which will fit most persons' ears, but other units may be mounted in earphone cases moulded to fit ears which require special cases in order to provide sufficient support to hold the earphone in the user's ear. Therefore, in order to provide an earphone for all persons who might desire one it is necessary to have an operative subassembly which can be mounted into a special case without requiring the services of a specialist to do so, and which may be mounted in standard types of mass production cases.

The crystal unit 16 is comprised of two connected piezoelectric plates such as Rochelle salt crystal slabs 20, and two leads 40 are attached to the slabs 20 to connect the earphone into an electrical circuit which applies an alternating current to the crystals 20 to cause the crystals 20 to vibrate and actuate the diaphragm 12 according to the well-known piezoelectric manner. For more detailed description of the piezoelectric action reference may be made to Charles B. Sawyer's Reissue Patent No. 20,680, and for a more detailed description of a three-cornered mounting reference may be made to A. L. W. Williams' Patent No. 2,105,011. The leads 40 are very thin and in order to connect them into the electrical circuit we provide the mounting frame 14 with a terminal bar 41 about which the leads may be wrapped to provide a firm base for terminal clips 31. The terminal clips 31 (only one is shown) are connected in the electrical circuit and slide over the terminal bar 41 with a lead 40 positioned between each clip 31 and the terminal bar 41. The mounting frame 14 is preferably formed of a plastic material and, accordingly, no insulator is needed in the terminal bar between the two clips 31. However, if the terminal bar were made of a conductive material an insulator to electrically separate the two leads 40 could be added. A ridge 42 or notches 43 can be added to the terminal to prevent the two terminal clips 31 from sliding into engagement with each other.

Figures 2 and 3 illustrate two halves of an earphone case which is adapted to fit in many ears of different size and shape to hold the earphone in place. Figure 2 shows an outside portion 26 of an earphone case, and Figure 3 shows an inside portion 27 of an earphone case. The outside portion 26 constitutes that part of the case which can be seen in the ear of a wearer as is illustrated in Figure 4, and the inside portion 27 constitutes the part of the case which lies against the wearer's ear to help hold the earphone in place.

The outside portion 26 of the case is assembled with a circular guard plate 28 which is adapted to protect one side of the crystal slabs 20, a pair of wires 29, 30, and a pair of terminal clips 31 (only one shown) one for each wire 29, 30. The wires 29, 30 are connected in the electrical circuit which supplies the earphone, and pass through a hole 32 in a raised portion 35 in the case 26, through a hole 33 between the guard plate 28 and a raised lug 34, and connect to the terminal clips 31.

The case portion 26 is "egg" shaped in plan with a first end portion 44 and a second end portion 45. The end portions 44 and 45 are shaped as arcs of circles, the arc of the first end 44 having a radius which is greater than the radius of the arc of the second end portion 45, and the sides of the case may be substantially straight lines tangent to the two arcs, or slightly curved lines joining the two arcs. The guard plate 28 is circular and has a radius slightly less than the radius of the first end portion 44 of the case portion 26. Accordingly, when the guard 28 is placed in the first end of the case it will stay in that position, and a pull on the twisted cord 29, 30 will cause the guard plate to wedge into a narrower part of the case 26 to prevent further movement. An adhesive 46 may be placed around the edge of the guard plate 28 where the plate engages the case portion 26 to prevent the guard plate 28 from moving after it has been placed in the case 26.

To connect the operative subassembly to the case portion 26, the guard plate 28 is positioned over the crystal 20 and the operative subassembly and the case portion pushed together. The edge of the case portion 26 fits outside of a step 51 constituting part of the edge of the mounting frame 14.

The inside case portion 27 (Figure 3) is adapted to engage the diaphragm guard 25, the outside edge of the diaphragm 12, and a step 47 on the edge of the mounting frame 14, and lie between the outside case portion 26 and the wearer's ear. Suitable adhesive means may be applied between the frame 14 and the outside case portion 26, and between the frame and the inside case portion 27 to hold them together and to prevent moisture from entering the earphone.

A feature of our invention is to transfer a pull on the earphone cord 29, 30 with respect to the earphone case to the case without damaging the operating parts. This is effected by

mounting the guard plate 28 directly to a portion of the case and by providing the raised lug 34 which operates as a snubber post. Figure 2 best illustrates the operation of the lug 34 as a snubber post. The cord 29, 30 enters the earphone through the hole 32 in the raised portion 35 of the outside case portion 26, passes through the hole 33 between the lug 34 and the guard plate 28, bends back upon itself around the lug 34, and is connected to the terminal clip 31 in such a manner that a pull on the cord 29, 30 causes the terminal clip 31 to more closely engage the terminal bar 41, and hence to more closely engage the lead 40. Most of the force of the pull on the wire 29, 30 is taken by the guard plate 28 and transferred to the case 26 and the rest of the pull is taken by the terminal bar 41 and transferred to the case 27.

The inside case portion 27 is comprised of a body portion 48 shaped in plan substantially the same as the plan of the outside case portion 26, a horn-shaped lug or ear engaging portion 49 connected to the body portion, and a snout 50. The lug 49 is adapted to lie in the groove between the helix 55 and the antihelix 56 of the ear and engage the bottom and both sides of the groove. It may be composed of a soft plastic material in order that it will adjust itself to slightly different shaped ears and aid in holding the earphone in place. By forming the lug 49 of a soft formable plastic material, it will engage the bottom and both sides of the groove without excessive spring pressure against either the helix or the antihelix which in time is apt to cause discomfort no matter how slight the pressure is. The body portion 48 is formed of a yieldable plastic material which is fairly thick around the edges where it engages the mounting frame 14. The snout 50 is adapted to project into the ear canal which joins the outer ear with the inner ear. The snout 50 is formed of a soft yieldable plastic material and with a cross section which tapers from fairly thick at the location where it joins the body portion 48, to thin at the apex. The apex may be completely sealed or it may have an opening 57 as is illustrated in Figure 3. By forming the snout 50 of a yieldable material with a cross section tapering to thin at the apex discomfort to the wearer's ear is reduced. When the earphone is placed in the wearer's ear the snout 50 yieldably assumes the direction of the ear canal with very little pressure on the walls thereof and substantially completely seals the ear canal against extraneous sound entering from the outside and against sound from the earphone leaking to the outside. The body portion 48 and the snout 50 of the case portion 27 are soft and yieldable. Accordingly, a careless person handling the earphone might squeeze it too hard and damage the diaphragm 12 and the crystal 20 were it not for the diaphragm guard 25. Further, in an earphone having a sound snout with opening 57 in its end it is probable that the wearer will at some time try to clean the earphone with a match, toothpick, or pin. The diaphragm guard 25 is positioned to prevent damage from this source. The guard 25 may be made of sheet metal or plastic material with holes 24 through it as is illustrated in Figure 4.

By forming the engaging portion 49 and the snout 50 of formable soft plastic material which yieldably conforms to the shape of the wearer's ear, and by shaping the case larger at the top than at the bottom, an earphone has been produced which can be successfully connected in many ears although the ears vary to a certain extent in size and shape. The smaller end portion 45 of the case is adapted to lie in the concha of the ear with the tragus 58 and the antitragus 59 engaging the top portion of the outside case 26, and with the raised portion 35 extending slightly out from between the tragus 58 and the antitragus 59. The curve of the engaging portion 49 and the snout 50 cooperate with the general wedge shape of the earphone case to prevent the earphone from sliding downward in the ear even though a fairly hard pulling force is exerted on the cord 29, 30.

The diaphragm 12 has a shape in plan substantially the same as the plan shape of the body portion 48 of the inside case portion 27. The end 65 of the diaphragm 12 is an arc of a circle and the end 66 of the diaphragm is an arc of a circle having a smaller radius than the radius of the end 65 and having a different center. Each of the two sides of the diaphragm 12 is a straight or slightly curved line joining the two arcs. This shape provides a diaphragm of maximum area for the earphone, but, if the diaphragm is flat, introduces a compliance along the major axis which reduces the efficiency of the piston action of the diaphragm. The major axis may be defined as the centerline of the diaphragm extending through the centers of the arcs which describe the ends of the diaphragm, or the major axis may be defined as the axis about which the diaphragm is symmetrical. To increase the efficiency of the piston action we have provided a diaphragm which is substantially conical in cross section and which is driven by the crystal unit 16 from off-center. The distance from the large end 65 to the apex of the diaphragm being greater than the distance from the small end 66 to the apex. This combination of an off-center drive for a conical diaphragm which is "egg-shape" in plan provides substantially the maximum air displacement for a given movement of the crystal drive unit 16. By connecting the drive pin off-center the shorter side of the diaphragm becomes more stiff than the longer side and tends to act as a lever to increase the movement of the longer side of the diaphragm thereby increasing the total volume displaced by the entire diaphragm. Further, it provides space for a larger crystal unit 20 thereby increasing the amount of movement at the apex of the diaphragm.

If it is desired that the earphone be used in airplanes where the pressure around the earphone is subject to rapid changes we provide a pressure equalizing hole 23 in the outside case portion 26. The hole 23 communicates with the inside of the earphone on the convex side of the diaphragm to establish an air passage for equalizing the internal air pressure with the external air pressure. A small amount of air leakage between the snout 50 and the walls of the ear canal will enter the inside of the earphone on the concave side of the diaphragm through the opening 57 in the snout thereby equalizing the air pressure on both sides of the earphone diaphragm 12. The air pressure on both sides of the diaphragm of the wearer's ear will also be substantially equalized due to a slight amount of leakage around the snout 50.

In another form of our invention, shown in Figures 7 to 14, the frame 14 includes three integral platforms 70, and the three crystal corners

are mounted on these platforms 70 by means of mounting pads 69 which are affixed to the platforms and to the crystal by means of an adhesive. The diaphragm 12 is connected to the other face of the frame 14 by means of adhesive, and the drive pin 17 which is connected to the crystal 16 by means of the little corner cap 10 extends through the hole 18 in the diaphragm 12. A drop of adhesive material on the inside of the conical portion where the drive pin extends through connects the drive pin to the diaphragm and the operative subassembly is formed. With the subassembly held up away from the cup-shaped housing 71 each of the leads 40 is soldered to one of the soldering lugs 11, and the frame 14 is then cemented to the edge of the housing 71. The diaphragm 12 and frame 14 thereby seal the crystal within the housing 71 to prevent the entrance of moisture. The diaphragm is preferably non-porous, such, for example, as metal or some of the plastics. One excellent material is duraluminum which, when about .002 inch thick, is substantially non-porous.

In order to improve the frequency response and sensitivity of the earphone a small weight 9 is connected to the corner of the crystal at the drive pin.

Each of the solder lugs 11 is connected to a banana plug socket 12 which extends to the outside of the housing 71. These sockets 12 are solid metal tubes molded into the housing (which may be made of plastic material) and therefor no moisture can enter the housing where electrical contact is made with the crystal leads 40, thus assuring a long life for the moisture sensitive crystal 16. A cap 13, preferably formed from aluminum, is cemented on the housing 71 with the deep downwardly turned edge thereof overlapping the upper edge of the housing. Cement throughout the overlapping area prevents moisture from entering, thereby prolonging the life of the phone. The cap 13 includes a sound outlet 21, and an integral connector button. The earphone may have a special ear piece molded to fit the individual wearer's ear and this ear piece is snapped onto the connector button to complete the earphone. A cord and banana plug connector 19 shown in Figure 13 completes the earphone assembly.

The crystal 16 has its corner opposite the drive pin cut-off, thereby permitting the use of a somewhat larger crystal within a given sized housing. With the large crystal which is necessary for maximum phone sensitivity from a given sized phone housing the diaphragm must be driven off center, and because we provide such a large crystal in such a small housing it results in the diaphragm being driven from a point which is about 1/7 of the way across the active portion of the diaphragm. When driving a diaphragm so far off center certain precautions must be taken to assure good reproduction, and certain advantage can be gained. For maximum efficiency true piston action should be present in a diaphragm. That is—every portion of the diaphragm with the exception of the edge by which it is held should move in phase and at the same amplitude and the amplitude should be substantially the amplitude of motion of the drive wire. With an off-center drive this is not possible unless the diaphragm is stiffened by a central stiffening portion 12', which may be in the form of a shallow conical depression with the apex of the cone at the drive point of the diaphragm. We have found that if such a stiffened diaphragm is driven off-center a lever action is obtained which increases the amplitude of vibration of the long leg of the diaphragm; the short leg of the diaphragm acting as a fulcrum for the lever. This lever action may advantageously be used. We have also found that by adding an annular corrugation 12'' to the diaphragm just inside the peripheral edge portion which is clamped between the frame and the housing that the lever action is reduced due to the compliance of the annular groove and a more nearly true piston action is obtained.

Because the crystal unit 16 and diaphragm are mounted on the frame 14 and the frame in turn is connected to the hard housing 71 back radiation of sound vibrations is apt to exist to an undesirable degree unless certain precautions are taken. We have found that it is advisable to make the frame 14 somewhat compliant as it greatly reduces the back radiation from the phone, thereby permitting the use of a high gain amplifier in the hearing aid device without introducing sustained oscillation.

In order that maximum phone sensitivity be obtained there must be an appreciable volume between the crystal unit 16 and the back wall of the housing 71. This has been achieved in an insert earphone for the first time, so far as we know, by the modification shown in Figures 1 to 6, and has been improved in the phone shown in Figure 14 due to the use of a banana plug connector with the female parts molded into the housing 71. By this construction sufficient volume is provided to raise the sensitivity above the phone shown in Figures 1 to 6 yet the phone is sufficiently thin to meet the exacting requirements of the hearing aid trade which is well aware that thick earphones are too conspicuous and tend to make the wearer self-conscious.

Figure 15 schematically illustrates an earphone being worn in an ear. S_1 represents the stiffness of the wearer's ear cavity, S_2 represents the stiffness of the housing cavity, S_3 represents the crystal stiffness and S_4 represents the diaphragm stiffness. In a given small phone for optimum phone sensitivity and for optimum sound output into the wearer's ear, S_1 should approximately equal S_2, and S_3 should approximately equal the sum S_2+S_2, and S_4 should be small compared to S_3.

While we have described our invention with a certain degree of particularity it is to be understood that it has been only by way of example and that many changes in the parts and their arrangement can be made without departing from the spirit and scope of our invention.

We claim as our invention:

1. In an insert earphone, an annular frame, a crystal plate mounted directly on said frame, a diaphragm having a peripheral edge portion secured directly to said frame and having an inner portion connected to said crystal forming an operative sub-assembly, and a housing within which said sub-assembly is mounted, said housing providing substantially an air-tight enclosure for said crystal except for an opening which, when the insert earphone is being worn, is directed into the wearer's ear.

2. In an insert earphone, an annular frame, a crystal plate mounted directly on said frame, a diaphragm having a peripheral edge portion secured directly to said frame to prevent the passage of air through the opening in said frame and having an apex connected to said crystal forming an operative sub-assembly, a housing having an

opening in one side thereof through which, when the earphone is being worn, sound is directed into the wearer's ear, said sub-assembly being mounted within said housing and forming together with a portion of said housing an air-tight enclosure within which said crystal is positioned.

3. In an insert earphone as set forth in claim 1, the further characterization that the crystal is mounted on one side of said annular frame and the diaphragm is mounted on the other side of said annular frame, and that the sub-assembly is mounted within said housing to form together with a portion of the housing an enclosure which is air tight, and said crystal is positioned within said air tight enclosure.

4. In an insert earphone, an annular frame, a crystal plate mounted directly on one side of said frame, a diaphragm having a peripheral edge portion secured directly to the other side of said frame to prevent the passage of air through the opening in said frame, means extending through the opening in said frame and connecting said crystal to said diaphragm to form an operative sub-assembly, a housing having an open side secured to said frame with the crystal within the housing and together with the sub-assembly forming a substantially air-tight enclosure to protect said crystal against moisture.

5. A mounting chassis for a four cornered piezoelectric crystal unit having a drive pin connected to one corner thereof and having a diaphragm with an apex comprising; a frame having a rounded first end portion, a rounded second end portion and two side portions connecting said first and second end portions; said frame having a plurality of notched-out portions in the said rounded first end portion for receiving three corners of the crystal unit to position the crystal unit within the frame and for positioning the fourth corner of the crystal unit and the connected drive pin with respect to the frame; and said frame having shoulder means for positioning the diaphragm with respect to the frame to cause said drive pin to align with the apex of the said diaphragm.

6. A mounting chassis for a four cornered piezoelectric crystal unit having a drive pin connected to one corner thereof and having a diaphragm with an apex comprising; a frame having a rounded first end portion, a rounded second end portion and two side portions connecting said first and second end portions; said frame defining an opening and having a plurality of notched-out portions in the said rounded first end portion for receiving three corners of the piezoelectric crystal unit to position the crystal unit within the frame and for positioning the fourth corner of the crystal unit and the connected drive pin with respect to the frame; and means on said frame for positioning said diaphragm with respect to said frame to cause said drive pin to align with the apex of the said diaphragm.

7. An earphone adapted to be placed in a person's outer ear comprising in combination, a first case portion adapted to engage the wearer's ear to help hold the earphone in place, a second

case portion adapted to engage the wearer's ear to help hold the earphone in place, an annular frame, a diaphragm connected directly to the frame, a piezoelectric unit connected directly to the frame, a drive pin connecting the crystal unit to the diaphragm; said frame, said diaphragm, and said piezoelectric unit establishing an operable subassembly independent of said first and second case portions, and means for connecting said operable subassembly to said first and said second case portions.

8. An operative subassembly for an insert type earphone adapted to be connected in an electrical circuit comprising, in combination, a flexing type piezoelectric crystal unit including two lead means for connecting said subassembly in said circuit, a loop of material around said crystal unit and in engagement therewith at three spaced points to hold three corners of said crystal unit against movement; diaphragm means connected to said loop of material and connected to a fourth corner of said crystal unit which is adapted to move, said loop of material including an integral cross bar having two notched-out portions, each of said two lead means being adapted to be wrapped about said cross bar at one of said notches and connected to a wire comprising one side of said electrical circuit, said notches serving to prevent the said leads from sliding on said cross bar, and said cross bar serving to prevent a tension on said wires from being transmitted to said leads.

9. An operative subassembly for an insert type earphone comprising, in combination, an annular frame having a plurality of notched-out portions in one face thereof and having shoulder means in the other face thereof, a rectangular piezoelectric crystal unit secured directly to said frame with some but not all of its corners positioned in the notches for accurately locating said crystal unit with respect to said frame, a diaphragm secured directly to said frame and engaging said shoulder means for accurately locating said diaphragm with respect to said frame, and a drive pin secured to one free corner of said crystal unit which is not in a notch in said frame and connected to said diaphragm.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,947,362	Schoenhut	Feb. 13, 1934
2,145,449	Lockhart	Jan. 31, 1939
2,248,837	Walters	July 8, 1941
2,284,063	Modine	May 26, 1942
2,325,590	Carlisle et al.	Aug. 3, 1943
2,353,089	Shapiro	July 4, 1944
2,367,726	Lybarger	Jan. 23, 1945
2,391,924	Rutter et al.	Jan. 1, 1946
2,399,513	Shapiro	Apr. 30, 1946