Jan. 23, 1945. S. F. LYBARGER 2,367,726

SOUND TRANSMITTER

Filed Jan. 10, 1942

Fig. 1.

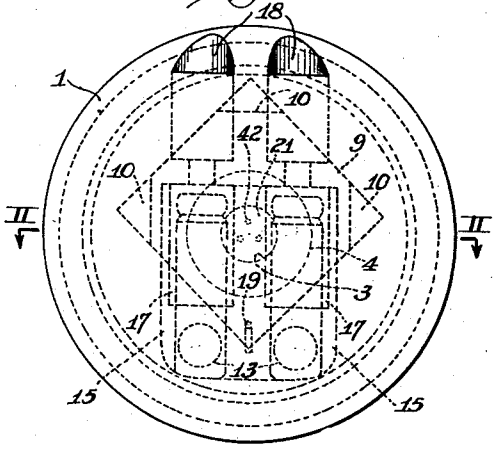


Fig. 4.

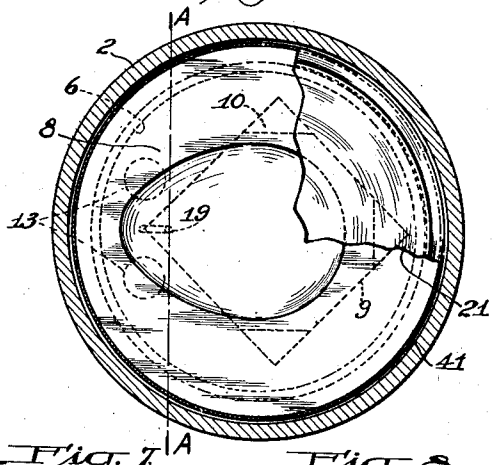


Fig. 2.

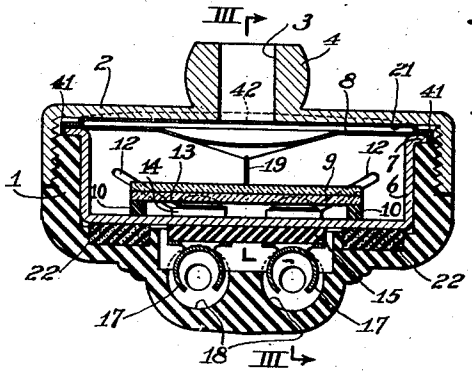


Fig. 7.

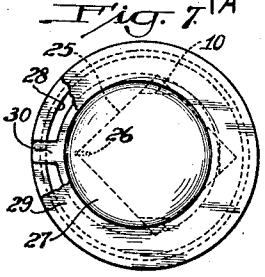


Fig. 8.

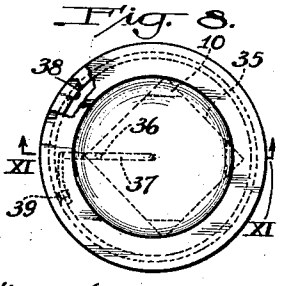


Fig. 6.

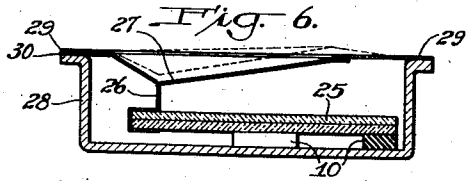


Fig. 10.

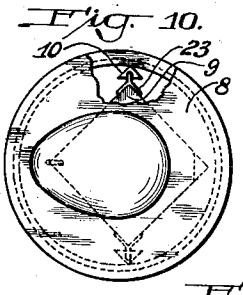


Fig. 11.

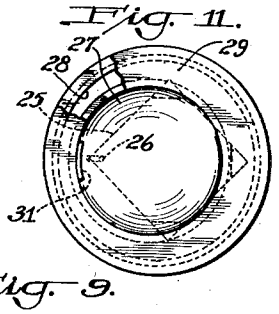


Fig. 3.

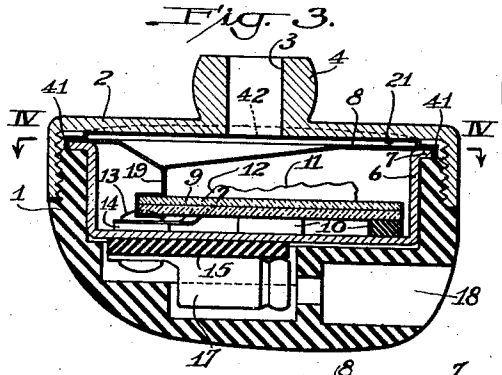
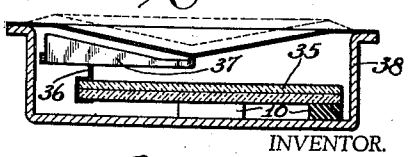


Fig. 9.



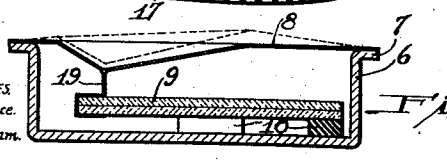


Fig. 5.

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Patented Jan. 23, 1945 2,367,726

UNITED STATES PATENT OFFICE

2,367,726

SOUND TRANSMITTER

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Application January 10, 1942, Serial No. 426,343

6 Claims. (Cl. 181—32)

This invention relates to sound transmitters, such as microphones and receivers, and more particularly to very small telephone receivers of the type generally used for hearing aids or audiphones and which utilizes Rochelle salts or similar electrically responsive crystals for converting the electric power supplied to them into acoustic energy which is delivered to the ear of the wearer.

Most hearing aid crystal receivers employ a long narrow crystal which extends nearly across the receiver case and has its opposite ends anchored and its central portion connected to the diaphragm and free to vibrate in response to the electric power supplied to it. Such a crystal has a length nearly as great as the width of the case. While a "bender" crystal of the type commonly used gives a relatively high efficiency up to about 3500 cycles, the number of failures of such crystals in service has been so high that they can not be considered satisfactory. Besides, the frequency curve of such a crystal shows non-uniformities which are not desirable and does not extend to a sufficiently high frequency with good efficiency. Moreover, such a "bender" crystal has to be extremely thin and comparatively long in relation to its width in order to attain sufficient flexibility to give the desired frequency response characteristics. The actual crystal thickness is generally .020 inch, which means that each section of the crystal is only .010 inch thick. The mechanical difficulties involved in handling such long thin slabs of Rochelle salts are considerable. They are subject to mechanical breakage because of their relatively long length, and are also affected by humidity very much more than the more compact square type that will be referred to presently. Another disadvantage of a long narrow crystal is that it is supported in the case at only two widely spaced points.

A more practical type of crystal is a square one so constructed that when three of its corners are more or less anchored the electric voltage supplied to the crystal will cause it to tend to twist and thereby cause its free corner to vibrate. This type of crystal is quite sensitive and the amount of motion secured is relatively large in comparison with many other arrangements. However, the principal objection to "twister" crystals has been that in order to use such a crystal of a practical size the case must be relatively large because the free corner of the crystal is located at substantially the center of the case below or behind the center of the diaphragm. An attempt has been made to use a smaller case, without reducing the size of the crystal, by providing the smaller case with an offset in which a portion of the crystal is housed. With such an arrangement a crystal may be employed whose edge is nearly one-half the length of the inside diameter of the case. Nevertheless, there is a definite objection to the increase in size of the receiver necessitated by the offset, and the amplitude of vibration of the diaphragm can not exceed that of the free corner of the crystal.

A problem that arises with all crystal receivers is that of service and repair. They are so difficult to repair that the practice is to discard the entire receiver and replace it with a new one.

It is among the objects of this invention to provide a crystal receiver which has greatly improved efficiency for its size, which has more uniform and wider frequency response characteristics than heretofore, which is rugged in construction, which utilizes a type of crystal that is mechanically strong and affected by humidity to the least possible degree, which is simple in construction and easy to assemble, in which a much larger proportion of the available space inside of the receiver case is occupied by the crystal to thereby permit the use of a larger crystal giving greater sensitivity, in which the sound reproducing unit is a separate element which can be easily replaced by a dealer or user without replacing the entire receiver case, in which means may be provided for damping the vibration of the reproducing unit so that practically all of the vibration is that of the diaphragm whereby back radiation from the receiver case is reduced to the point where it does not feed back to the microphone of the audiphone, and in which a definite lever action is present so that the relatively high mechanical impedance of the crystal itself is efficiently matched to the considerably lower impedance of the diaphragm and air column beyond.

The invention is illustrated in the accompanying drawing in which Fig. 1 is a greatly enlarged bottom plan view of my receiver as shown herein; Fig. 2 is a transverse section taken on the line II—II of Fig. 1; Fig. 3 is a transverse section taken on the line III—III of Fig. 2; Fig. 4 is a horizontal section taken on the line IV—IV of Fig. 3; Fig. 5 is a somewhat diagrammatic section of the reproducing unit illustrating in an exaggerated manner the vibration of the diaphragm; Fig. 6 is a view similar to Fig. 5 of a modification of this invention; Fig. 7 is a reduced plan view of Fig. 6 broken away in part; Fig. 8 is a plan view similar to Fig. 7 of a further modification of this invention; Fig. 9 is a sectional view similar to Figs. 5 and 6 of the modification shown in

Fig. 8; and Figs. 10 and 11 are fragmentary plan views of additional modifications of my invention.

Referring to Figs. 1 to 4 of the drawing, an audiphone receiver case is formed from a cup-like base member 1 of Bakelite or the like and a metal cover 2 screwed on the base. The cover is provided with a central opening 3 encircled by an integral boss 4 adapted to receive an ear tip (not shown) for holding the receiver in the ear of a person who is hard of hearing.

In accordancce with this invention the reproducing elements of the receiver are not connected directly to the case as has been the practice heretofore, but they are mounted in a metal cup 6 that is removably mounted in the case and held therein only by the cover so that if any repairs are required the reproducing elements can be readily removed as a unit and a new unit quickly inserted in their place. The cup preferably is cylindrical with a flat bottom and with an open top encircled by an integral flange 7 on which rests the marginal portion of a diaphragm 8 of metal or other suitable material.

Disposed within the cup below the diaphragm is a square piezo-electric crystal 9 having three corners secured to slightly resilient triangular pads 10 affixed to the bottom of the cup close to its side wall. The fourth corner is therefore left free to vibrate when the crystal is supplied with varying electric voltage through wires 11 connected to a pair of metal terminals 12 attached to rivets 13 extending through the bottom of the cup on opposite sides of the free corner of the crystal. The rivets are insulated from the cup by encircling insulating headed sleeves 14 and by an insulating block 15 held against the outer surface of the cup's bottom by the rivets, as shown in Fig. 3. These rivets clamp against the insulating block a pair of tubular spring clips 17 for receiving and gripping the tips of wires (not shown) from the microphone with which the receiver is used. The bottom of the case has a thick central portion provided with a pair of parallel passages 18 through which the microphone wires are led to the clips. When varying electric voltage is supplied to the crystal from the microphone, the tendency of the crystal to twist causes its free corner to vibrate and this vibration is transmitted to the diaphragm through a driving pin 19 secured thereto and hooked around the free corner of the crystal to which it is cemented.

The cup 6 is clamped in the case by the cover 2 from which the diaphragm is spaced by a disc-like cap 21 provided with a marginal portion resting on the marginal portion of the diaphragm as shown in Figs. 2 and 3. The cap is encircled by a flange 41 that overlaps flange 7 of the base member to center the cap. The major portion of the cap is pressed outwardly toward cover 2 so that none of the diaphragm that does not touch flange 7 is touched by the cap either. The cap preferably is slightly convex so that when the cover is screwed onto the base member it first engages the center of the cap and then presses it inwardly, thereby insuring tight engagement between cap and cover to prevent the cap from vibrating. The center of the cap is provided with a few small holes 42 in line with opening 3 in the cover. The cap is cemented or otherwise attached to the cup 6 and thus prevents the delicate diaphragm from being injured when the cup is handled outside of the case, and also minimizes the chance of foreign objects inserted in opening 3 reaching the diaphragm. To prevent vibration of the bottom of the cup from vibrating the bottom of base 1 and thereby feeding sound back to the microphone, the bottom of the cup is spaced from base 1, and its vibrations may be damped by resilient pads 22 of felt, sponge rubber or the like mounted in the base in engagement with the bottom of the cup, as shown in Fig. 2. The side wall of the case is the point of least vibration of the case and it is to that point that the cup is clamped by its flange 7. This feature also helps prevent the cup from vibrating the case. When the receiver requires repair work it is a simple matter to merely unscrew cover 2, remove cup 6, insert a new cup in its place, and replace the cover without discarding the entire receiver.

Another feature of this invention is that the crystal is connected to the diaphragm in such a manner that a much larger square crystal can be used than heretofore for the same size case. This results in a stronger crystal than the customary oblong bender crystal, one easier to handle, and a crystal that is affected less by humidity. These advantages are obtained by using a substantially square crystal which is nearly as far across diagonally as the inside of the case, whereby the free corner of the crystal is disposed laterally of the center or axis of the diaphragm, and by connecting that corner of the crystal to the diaphragm off center of the latter, or to its center through the medium of a lever. When driven off center, the diaphragm preferably has a substantially stiff central portion to which the driving pin is connected. Most suitably, as shown in Figs. 2, 3 and 4, the central portion of the diaphragm is made stiff by providing it with a depression, preferably conical with the base of the cone either circular or elliptical (Fig. 4) and with the apex off center and nearly above the free corner of the crystal to which it is connected by pin 19. The stiff cone carries the vibrations of the crystal throughout the area of the diaphragm. If the stiff portion of the diaphragm is anything but round, it is preferred that its long axis extend in the direction of the crystal diagonal that passes through the driving corner. The driving pin preferably is flexible laterally so that it can yield and not cause the far side of the diaphragm cone to tilt down into the cup when the free corner of the crystal swings upwardly.

The amplitude of vibration of the free corner of the crystal can be increased by using a diamond-shape crystal so that its two opposite anchored corners can be located closer to the side of the case, or, as shown in Fig. 10, by attaching rigid metal extensions 23 to those two corners of the crystal and mounting their outer ends on pads 10 at the side of the case. This, in effect, increases the length of one diagonal of the crystal so that its center can vibrate through a longer path for the same amount of bending.

A further important feature of this invention is that the amplitude of vibration of the major portion of the diaphragm can be increased over that of the vibrating free corner of the crystal. This may be accomplished in several ways, all of which make use of leverage. Thus, the flat area of the diaphragm surrounding the cone may be made with varying degrees of stiffness or resiliency, the resiliency being least in the area between the periphery of the diaphragm and the cone edge closest to it, which is at the left of the driving pin as seen in Figs. 3, 4 and 5. In such a case the resiliency or stiffness is so controlled that the total effective stiffness of the

flat area of the diaphragm lying between a line A—A, shown in Fig. 4 extending across the diaphragm directly above the driving pin and perpendicular to the major axis of the cone's base, and the adjacent side of the cup is greater than the total effective stiffness of the remaining flat area of the diaphragm. It is important that the total stiffness of the diaphragm presented to the vibrating corner of the crystal be kept relatively low in order to prevent loss of amplitude at low frequencies. Due to the stiffness control, as shown in Fig. 5, the amplitude of vibration of the flat area at the left of the driving pin is constrained relative to the remaining flat area of the diaphragm to such an extent that it serves as a fulcrum for the adjacent end of the rigid conical portion which thereby acts as a lever and causes the major portion of the diaphragm to vibrate with a greater amplitude than the apex of its conical portion. As driving pin 19 will yield laterally, it does not interfere with this canting movement of the diaphragm. Or the yielding of the apex of the cone will serve the same purpose.

In the modification of the invention illustrated by Figs. 6 and 7 the same large "twister" type of crystal 25 is used as in the first embodiment, and its free or vibrating corner is connected by a resilient driving pin 26 to the diaphragm 27 near the side of the metal cup 28 in which these elements are housed. However, the cone that makes the central portion of the diaphragm stiff may have a circular base nearly as large as the diaphragm, but preferably eccentric therewith. The major portion of the periphery of the diaphragm is spaced from the side wall of cup 28, but is connected thereto by a very flexible ring 29 of oiled silk or other impervious material. The inner edge of the ring is cemented to the narrow flat marginal area of the diaphragm, and its outer edge rests on top of the metal cup. When the diaphragm is vibrated by the crystal it vibrates substantially as a rigid unit, the vibration being permitted by the encircling resilient ring 29.

Although the desired lever action that increases the amplitude of vibration of the diaphragm over that of the crystal is obtained to some extent if the diaphragm is entirely free of the cup, the diaphragm can be provided in the area closest to the driving pin with a laterally projecting integral tab or ear 30 the outer end of which rests on top of the cup. This tab, being made of the thin material of the diaphragm, has some resiliency, but much less than the silk ring. Consequently, the tab tends to restrain vibration of the adjoining side of the diaphragm and thus serves as a fulcrum or hinge on which the rest of the diaphragm swings. The result is that the major portion of the diaphragm swings or vibrates with a greater amplitude than the apex of its cone which is connected to the driving pin 26.

If ear 30 is not used, a tiny weight 31 can be mounted on the edge portion of the diaphragm at the same point, as shown in Fig. 11. The inertia of this weight constrains vibration of the adjoining area of the diaphragm and thereby causes the opposite side of the diaphragm to vibrate in a greater arc. The weight therefore serves, in effect, as a fulcrum for the diaphragm.

In the modification shown in Figs. 8 and 9 the large "twister" crystal 35 has its vibrating corner near the side wall of the cup as previously explained, but the driving pin 36, instead of being connected directly to the diaphragm off center, is connected to the center of the diaphragm through the medium of a lever 37. The central portion of the diaphragm is made substantially rigid by providing it with a conical depression having a circular base concentric with the diaphragm and having its apex at the center of the diaphragm. The flat area of the diaphragm encircling its cone flexes when the diaphragm is vibrated, as shown in Fig. 9. The lever by which the driving pin is connected to the center of the diaphragm may take various forms. The one illustrated in Figs. 8 and 9 is in the form of a tiny stiff bar the outer end of which is bent at substantially a right angle and rigidly connected to the side of the cup 38 by a fastener 39. The portion of the lever between the case and its radially extending portion will twist sufficiently to permit the inner end of the lever to vibrate axially of the case. The inner end of the lever is cemented to the apex of the diaphragm's cone, and driving pin 36 is attached to the lever between its ends. When the free corner of the crystal vibrates, the driving pin causes the lever to vibrate which in turn vibrates the diaphragm. It will be seen that, due to the crystal being connected to the lever between its ends, the inner end of the lever will vibrate in a longer arc than the free corner of the crystal, and therefore the amplitude of vibration of the diaphragm is greater than that of the crystal. Although this invention has been described in connection with a receiver, it will be understood that the same general principles can be used in a microphone to advantage.

To permit a better understanding of the invention I shall now give some of the approximate dimensions of a receiver constructed in accordance with this invention and which has proved to be very satisfactory. Of course, these dimensions are not the only ones that might be used, but are given merely by way of example and are approximate only.

The overall diameter of the cup 6 is ¾ inch and its inside diameter 41/64 inch. The diaphragm is made from aluminum foil .001 inch thick, and the apex of its conical portion is 3/64 inch below the top of the diaphragm. The conical portion has an elliptical base and an eccentric apex formed by pressing the diaphragm with a die made by cutting off at an oblique angle a tool having the shape of a right cone. The major and minor axes of the elliptical base of the conical portion are 7/16 and ⅜ inch, respectively. The shortest distance between the apex and a line passing through the edge of the base of the conical portion of the diaphragm is 3/32 inch, while the longest distance is 11/32 inch. The narrowest width of the flat portion of the diaphragm surrounding the conical portion is ⅛ inch, and the greatest width is 5/16 inch.

According to the provisions of the patent statutes, I have explained the principle and construction of my invention and have illustrated and described what I now consider to represent its best embodiment. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. A sound transmitting vibratable integral diaphragm of substantially uniform thickness throughout its area for use in a case containing a piezo-electric crystal, said diaphragm having an eccentrically positioned depression the wall

of which tapers toward a driving point, said wall forming a stiffening portion in the diaphragm surrounded by a flexible substantially flat area, said driving point being located between the center of the diaphragm and the narrow part of said flexible area and adapted to be operatively connected to a piezo-electric crystal, and the outer edge of said flexible area being adapted to be held substantially stationary when the rest of the diaphragm vibrates, whereby during vibration of the diaphragm the wide part of said flexible area opposite said narrow part has a greater amplitude of vibration than said narrow part.

2. A sound transmitting vibratable diaphragm for use in a case containing a piezo-electric crystal, said diaphragm having an eccentrically positioned stiffened portion provided with a wall of substantially uniform thickness and surrounded by a flexible substantially flat area the outer edge of which is adapted to be held substantially stationary while the rest of the diaphragm vibrates, and said stiffened portion having a driving point located between the center of the diaphragm and the narrow part of said flexible area and adapted to be operatively connected to a piezo-electric crystal, whereby during vibration of the diaphragm the wide part of said flexible area opposite said narrow part has a greater amplitude of vibration than said narrow part.

3. A sound transmitting vibratable diaphragm for use in a case containing a piezo-electric crystal, said diaphragm comprising a relatively stiff member, a resilient tab projecting laterally therefrom, and a flexible sealing member surrounding said stiff member and secured thereto, the outer edge of said sealing member and the outer end of said tab being adapted to be held substantially stationary while the rest of the diaphragm vibrates, and said stiff member having a driving point located between the center of the diaphragm and said tab and adapted to be operatively connected to a piezo-electric crystal, whereby during vibration of the diaphragm the part of said sealing member opposite said tab has a greater amplitude of vibration than said tab.

4. A sound transmitting vibratable diaphragm for use in a case containing a piezo-electric crystal, said diaphragm comprising a relatively stiff member, a flexible sealing member surrounding said stiff member and secured to the edge thereof, the outer edge of said sealing member being adapted to be held substantially stationary while the rest of the diaphragm vibrates, and a weight attached to one of said members adjacent their adjoining edges, said stiff member having a driving point located between the center of the diaphragm and said weight and adapted to be connected to a piezo-electric crystal, whereby during vibration of the diaphragm the part of said sealing member at the side of the diaphragm opposite said weight has a greater amplitude of vibration than said weight.

5. A sound transmitting substantially circular vibratable diaphragm for use in a case containing a piezo-electric crystal, said diaphragm comprising a relatively stiff conical member positioned eccentrically of the diaphragm, a resilient tab projecting laterally therefrom, and a flexible sealing member surrounding said conical member and secured thereto, the apex of said conical member being located between the center of the diaphragm and said tab and being adapted to be operatively connected to a piezo-electric crystal, and the outer edge of said sealing member and the outer end of said tab being adapted to be restrained from vibrating when the rest of the diaphragm vibrates, whereby during vibration of the diaphragm the wide part of said sealing member farthest from said tab has a greater amplitude of vibration than said tab and the adjacent narrow part of the sealing member.

6. A sound transmitting substantially circular vibratable diaphragm for use in a case containing a piezo-electric crystal, said diaphragm comprising a relatively stiff conical member positioned eccentrically of the diaphragm, a flexible sealing member surrounding said conical member and secured to the edge thereof, the outer edge of said sealing member being adapted to be restrained from vibrating when the rest of the diaphragm vibrates, and a weight attached to said conical member adjacent its edge, the apex of said conical member being located between the center of the diaphragm and said weight and being adapted to be operatively connected to a piezo-electric crystal, whereby during vibration of the diaphragm the wide part of said sealing member farthest from said weight has a greater amplitude of vibration than said weight and the adjacent narrow part of the sealing member.

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