

May 20, 1941.

F. F. ROMANOW
PIEZOELECTRIC DEVICE

2,242,757

Filed Feb. 11, 1939

2 Sheets-Sheet 1

FIG. 1

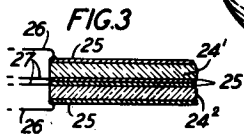
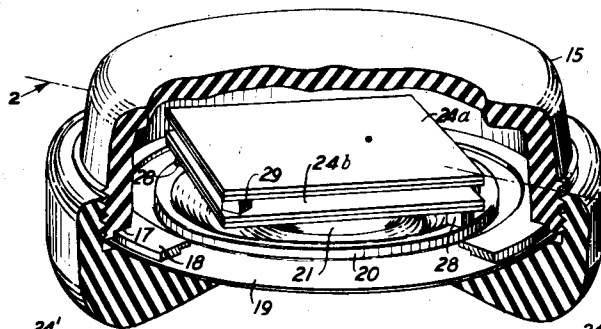


FIG. 2

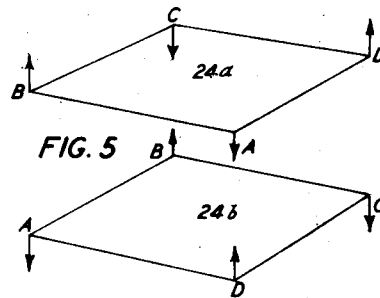
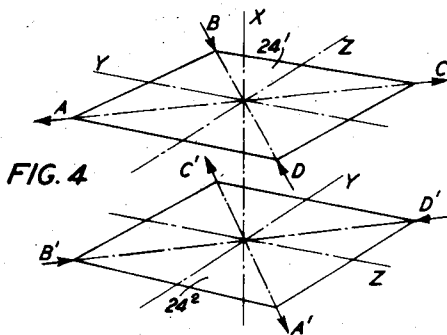
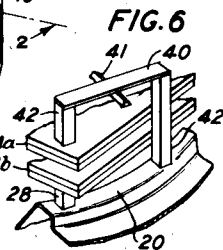
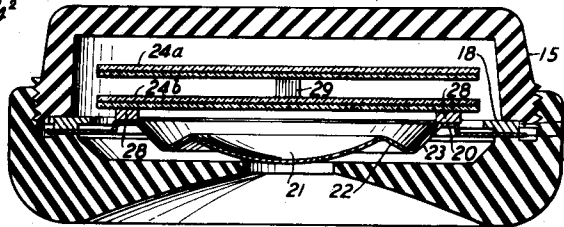
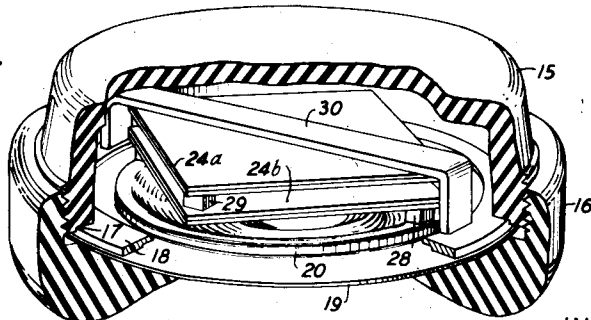


FIG. 7



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FIG. 8

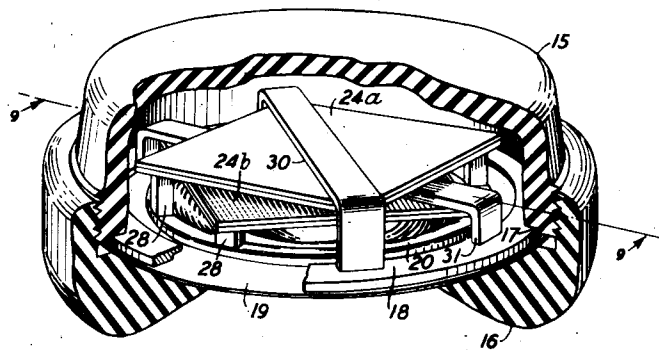


FIG. 9

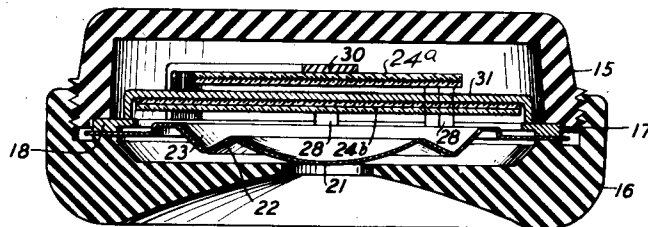
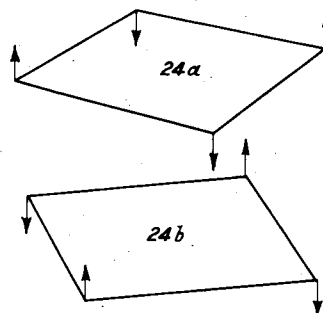


FIG. 10



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2,242,757

PIEZOELECTRIC DEVICE

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Application February 11, 1939, Serial No. 255,826

13 Claims. (Cl. 179-110)

This invention relates to piezoelectric devices and more particularly to acoustic devices of the type disclosed in the application Serial No. 255,817, filed February 11, 1939, of Thomas J. Pope, and comprising a diaphragm and a piezo-electric element in energy transferring relation with the diaphragm.

One object of this invention is to obtain a uniform response and a high response level for piezoelectric acoustic devices.

Another object of this invention is to distribute the load upon the crystal element in piezoelectric devices.

A further object of this invention is to obtain a relatively simple mode of vibration of composite piezoelectric elements.

Still another object of this invention is to improve the character of vibration of the diaphragm in a piezoelectric acoustic device.

In one illustrative embodiment of this invention, a telephone receiver comprises a diaphragm and piezoelectric means for actuating the diaphragm.

In accordance with one feature of this invention, the actuating means comprises a pair of spaced, similar, composite elements. Each piezoelectric element may include a pair of rectangular, for example, square, crystal plates or slabs secured together in face-to-face relation and so oriented that diagonally opposite corners of the element deflect in the same direction in response to electrostatic stresses. One pair of diagonally opposite corners of one composite element is connected to the diaphragm.

In accordance with another feature of this invention, the two composite piezoelectric elements are oriented so that the axes of similar deflection of one are at an angle to the corresponding axis of the other.

In one specific embodiment, these axes of one element are at right angles to the corresponding axis of the other, and two diagonally opposite corners of one element are connected to two corners of the other. The other two corners of one element are connected to the diaphragm. The other two corners of the other element may be unrestrained or may be fixed against displacement.

In another specific embodiment, the two composite elements have their axes of similar deflection at substantially 45 degrees to one another. Two diagonally opposite corners of each element are fixed and the other corners are connected to the diaphragm, the orientation being such that the corners connected to the diaphragm deflect in the same directions in response to electrostatic stresses.

The invention and the foregoing and other features thereof will be understood more clearly and fully from the following detailed description with

reference to the accompanying drawings wherein:

Fig. 1 is a perspective view of a telephone receiver illustrative of one embodiment of this invention, a portion of the casing being broken away to show the internal structure;

Fig. 2 is a view in section along line 2-2 of Fig. 1;

Fig. 3 is a fragmentary view in section of one of the composite piezoelectric elements, showing the construction thereof;

Fig. 4 is a diagrammatic exploded view of one of the composite piezoelectric elements, showing the characteristic axes thereof;

Fig. 5 is a diagrammatic view illustrating the relative directions of deflection of the corners of the two composite piezoelectric elements;

Fig. 6 is a fragmentary view illustrating a modification of the device shown in Fig. 1;

Fig. 7 is a perspective view of another modification of the construction illustrated in Figs. 1 and 2;

Fig. 8 is a perspective view of a telephone receiver illustrative of another embodiment of this invention, a portion of the casing being broken away to show the internal structure;

Fig. 9 is a view in section along line 9-9 of Fig. 7; and

Fig. 10 is a diagrammatic view illustrating relatively the direction of deflection of the corners of the composite piezoelectric elements in the receiver shown in Figs. 7 and 8.

Referring now to the drawings, the telephone receiver shown in Figs. 1 and 2 comprises a casing 10, for example, of molded insulating material, and a centrally apertured cap or ear-piece 11 threaded to the casing 10. The casing is provided with an internal shoulder 17 on which there is seated an annular spacer 18.

Seated in turn upon the spacer 18 and held thereagainst by the cap or ear-piece 11 is a diaphragm having a flexible, flat supporting portion 19, a bodily vibratile central portion and an intermediate annular portion 20, L-shaped in section. The bodily vibratile portion includes a central concavo-convex section 21, and a pair of frusto-conical sections 22 and 23. The diaphragm may be formed in a single piece and preferably is of a lightweight metal such as duralumin.

Mounted within the casing 10 is a pair of rectangular, for example, square, composite piezoelectric elements 24a and 24b. Each of these elements, as shown more clearly in Fig. 3, comprises a pair of piezoelectric crystal, for example, Rochelle salt, plates or slabs 24¹ and 24² and electrodes 25 upon each face of the plates or slabs. The electrodes 25 may be of a metal, such as gold, or of graphite, deposited upon the plates or slabs. The two plates or slabs are secured together in face-to-face relation as by a suitable cement.

Electrical connection to the electrodes 25 may be established through conductors 26 and 27, such as platinum-rhodium ribbons, cemented or attached in some other way to the electrodes. The outer conductors 26 may be connected together and the inner conductors 27 also connected together as described hereinafter.

The crystal plates or slabs 24¹ and 24² may be cut from a mother crystal, as described in the aforementioned application of Thomas J. Pope, so that the sides thereof are parallel to the Y and Z axes and the faces are normal to the X or electrical axis, as illustrated in Fig. 4. When a potential is impressed between the electrodes on opposite faces of such a crystal plate or slab, the plate or slab will tend to expand along one diagonal, for example, along the diagonal AC in Fig. 4, and to contract along the other diagonal, for example, along BD in Fig. 4. The two crystal plates or slabs are oriented so that corresponding axes of expansion and contraction thereof are at right angles to one another. For example, as shown in Fig. 4, they may be related so that the Y and Z axes of one are at right angles to the corresponding axis of the other, whereby when the crystal 24¹ tends to expand along AC and to contract along BD, the crystal 24² will tend to contract along B'D', which is in line with AC, and to expand along A'C', which is in line with BD. Consequently, because the two plates or slabs 24¹ and 24² are secured together in face-to-face relation, the diagonal forces will result in deflection of the corners of the composite element, substantially normal to the faces thereof. Thus, if the polarity of the impressed potential is such as to produce diagonal stresses of the direction shown in Fig. 4, as illustrated on the composite element 24b in Fig. 5 two diagonally opposite corners (BC' and A'D') will deflect upwardly and the other two diagonally opposite corners (AB' and CD') will deflect downwardly.

If the two plates or slabs 24 have their Y and Z axes related as shown in Fig. 4, the indicated directions of expansion and contraction will obtain if the potentials applied are such that corresponding surfaces of the two plates or slabs are at the same polarity. In this case, the upper surface of the slab 24² is opposite in polarity to the lower face of the slab 24¹ and electrically insulated therefrom by a suitable medium.

It will be understood that the relative directions of expansion and contraction indicated in Fig. 4 may be obtained if the Y and Z axes of each plate or slab are parallel to those of the other and the potentials applied are such that corresponding surfaces of the two faces are opposite in polarity. In this case, the upper face of the slab 24² is at the same polarity as the lower face of the slab 24¹ and hence, need not be insulated therefrom. For this case, the conductors 26 may be connected together and the conductors 27 also connected together as noted heretofore.

As illustrated by the arrows in Fig. 5, the two composite elements 24a and 24b are oriented so that for the potential at any particular instant aligned corners of the two deflect in opposite directions. The desired orientation, it will be understood may be obtained by proper correlation of the polarity of the potentials applied to the electrodes of the plates or slabs and by proper orientation of the axes of contraction and expansion of the two crystals. That is to say, the two composite elements may have their diagonals in the relation indicated by the letters in

Fig. 5 and potentials of like polarity applied to corresponding surfaces. Alternatively, the two elements may have their corresponding diagonals in alignment in which case the potentials applied to corresponding surfaces thereof would be opposite in polarity.

It will be understood, of course, that in Figs. 4 and 5 the arrows indicate the direction of stresses and deflection for potentials of one polarity. When the polarity of potential is reversed, the direction of stresses and deflection also will be reversed. Hence, if the potential applied is variable, for example, corresponding to speech and music frequencies, the corners of the composite elements will vibrate at corresponding frequencies, the amplitude of deflection being proportional to the magnitude of the potential.

As shown in Figs. 1 and 2, two diagonally opposite corners of the composite element 24b are connected to diametrically opposite points on the annular portion 20 of the diaphragm, as by balsa wood blocks 28 cemented thereto. The other two corners of the composite element 24b are connected to the juxtaposed corners of the composite element 24a, as by balsa wood blocks 29 cemented thereto, only one of which is shown in each of Figs. 1 and 2. Hence, the composite element 24a provides a load upon the composite element 24b which, it has been found, results in an increase in the response at low frequencies. This in turn enables the attainment of a high average response level throughout a wide range of frequencies.

The composite element 24a may be unrestrained except for its connection to the element 24b, as illustrated in Figs. 1 and 2, or, as shown in Fig. 7, it may be fixed along one diagonal as by a rigid bracket or bridge member 30 carried by the ring member 18 and affixed, as by cementing, to the element 24a. In Fig. 7, the construction of the other parts and the orientation of the composite elements is the same as in the construction shown in Figs. 1 and 2.

If desired, the upper crystal element 24a in Fig. 1 may be utilized also to apply driving forces to the diaphragm. Thus, the two free corners of this element in Fig. 1 may be connected to points on the diaphragm adjacent the blocks 28 through a direction reversing mechanism, such as a lever, so that the forces applied thereby to the diaphragm are directionally in phase with those applied by the element 24b through the blocks 28. Such construction is illustrated in Fig. 6 wherein 40 is a lever having a fulcrum 41, the ends of the lever being connected to the portion 20 of the diaphragm and the element 24a by balsa wood blocks 42.

In the embodiment of this invention illustrated in Figs. 8, 9 and 10, the casing, diaphragm and composite piezoelectric elements likewise are the same as in the device shown in Figs. 1 and 2. However, the composite elements are oriented and supported differently so that each element has two corners connected to the diaphragm and these corners move or deflect in the same direction at any instant. The composite element 24a is affixed along one diagonal thereof to the bracket or bridge member 30. The composite element 24b also is affixed along one diagonal thereof to a second bracket or bridge member 31 carried by the ring spacer 18. The two elements 24a and 24b have their corresponding diagonals at substantially 45 degrees to one another and are oriented so that, as indicated in Fig. 10, all the unfixed corners of the two elements deflect

in the same direction in response to electrostatic forces. These corners are connected to equally spaced points on the annular intermediate portion 20 of the diaphragm by the balsa wood blocks 28. The diaphragm, therefore, has spaced equal forces applied thereto so that the rigid control portion 21, 22, 23 vibrates bodily analogous to a piston.

Although the invention has been described with particular reference to telephone receivers, it will be apparent that it is applicable as well to transmitters. It will be understood, of course, that although several specific embodiments of this invention have been shown and described, various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An acoustic device comprising a diaphragm, and means for actuating said diaphragm including a pair of similar rectangular piezoelectric elements spaced from one another in face-to-face relation, each of said elements including a pair of crystal plates secured together in face-to-face relation and having diagonal axes of expansion and contraction, and said elements being oriented so that the axes of similar deflection of one are at an angle to the corresponding axis of the other.

2. A piezoelectric device comprising a vibratory member, a rectangular piezoelectric element having diagonal axes of deflection, means connecting two diagonally opposite corners of said element to said vibratory member, a second rectangular piezoelectric element spaced from said first element and having diagonal axes of deflection, and means connecting two diagonally opposite corners of said second element to the other two corners of said first element, said elements being oriented so that each two corners thereof connected by said second means tend to deflect in opposite directions in response to electrostatic stresses in said elements.

3. A piezoelectric device in accordance with claim 2 wherein said first piezoelectric element is supported solely by said vibratory member.

4. A piezoelectric device in accordance with claim 2 wherein said second piezoelectric element is supported solely by said first piezoelectric element.

5. A piezoelectric device in accordance with claim 2 wherein said first piezoelectric element is supported solely by said vibratory member and said second element is supported solely by said first element.

6. A piezoelectric device in accordance with claim 2 comprising means fixing the other two corners of said second piezoelectric element against movement.

7. A piezoelectric device in accordance with claim 2 comprising a bridge member secured to said second piezoelectric element along the diagonal extending between the other two corners thereof, and means supporting said bridge member.

8. An arcuate device comprising a pair of superposed piezoelectric elements of similar rectangular configuration, said elements having diagonal axes of similar deflection and their corresponding axes of similar deflection at an angle to one another, a diaphragm, means connecting two diagonally opposite extremities of one of said elements to said diaphragm, and means

fixing the other diagonally opposite extremities of said one element to two diagonally opposite extremities of the other of said elements.

9. An acoustic device comprising a pair of superposed rectangular piezoelectric plates each having diagonally opposite corners deflective in the same direction in response to electrostatic forces produced in said plates, the axes of similar deflection of one of said plates being at angles to the corresponding axis of the other of said plates, a diaphragm having spaced points connected to one pair of diametrically opposite points of one of said plates, and means connecting the other diagonally opposite points of said one plate in fixed relation to one pair of diagonally opposite points of the other of said plates.

10. An acoustic device comprising a pair of substantially square piezoelectric elements arranged one above the other and having diagonal axes of deflection and their corresponding axes of deflection at equal angles to one another, means fixing one pair of diagonally opposite corners of one of said plates, means fixing the corresponding pair of diagonally opposite corners of the other of said plates, and a vibratory member connected to the other corners of both of said plates.

11. A telephone receiver comprising a diaphragm, and means for actuating said diaphragm comprising a pair of substantially square piezoelectric elements having diagonal axes of deflection, said elements being arranged one above the other and with corresponding deflectional axes thereof at substantially 45 degrees to one another, a rigid member fixedly supporting one pair of diagonally opposite corners of one of said plates, a second rigid member fixedly supporting the corresponding pair of diagonally opposite corners of the other of said plates, and means connecting the other corners of both of said plates to said diaphragm.

12. A piezoelectric device comprising a rectangular composite piezoelectric element including a pair of crystal slabs the faces of which are parallel to the Y and Z axes thereof, said slabs being secured together in face-to-face relation and oriented so that the axes of deflection of said element are along the diagonals thereof, a second rectangular composite piezoelectric element similar to said first element, in face-to-face relation therewith and spaced therefrom, said elements being oriented so that each of the diagonals of one is at right angles to the corresponding diagonal of the other whereby, in response to electrostatic stresses in said elements, juxtaposed corners of the two tend to deflect in opposite directions, vibrating means connected to two diagonally opposite corners of one of said elements, and means connecting the other two corners of said one element to the corners of the other element in juxtaposition thereto.

13. A piezoelectric device comprising a pair of composite rectangular piezoelectric plates having corresponding diagonal axes of similar deflection, said plates being mounted in face-to-face relation and spaced from one another with corresponding axes thereof at equal angles to each other, a vibratory member, and means connecting two diagonally opposite corners of each of said plates to said vibratory member.

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