April 28, 1931. C. B. SAWYER ET AL 1,802,781

PIEZO-ELECTRIC DEVICE

Filed May 6, 1927

FIG. 1.

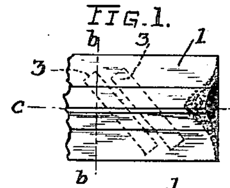


FIG. 2.

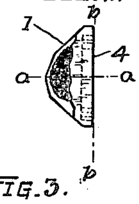


FIG. 3.

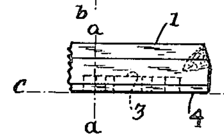


FIG. 4.

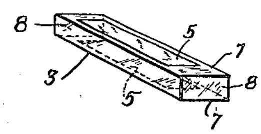


FIG. 5.

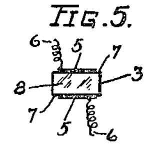


FIG. 6.

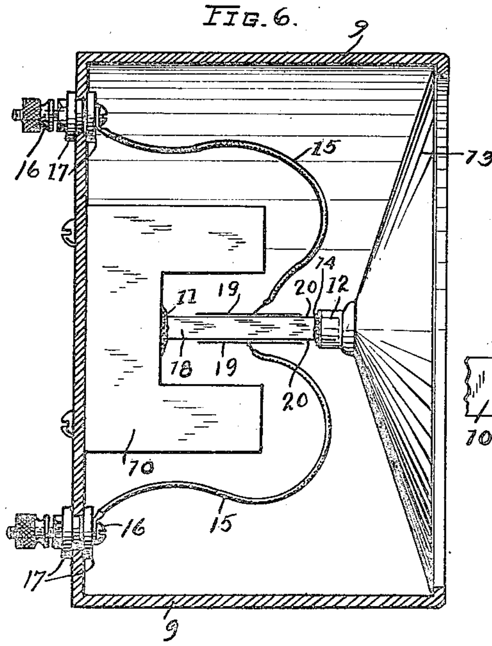


FIG. 7.

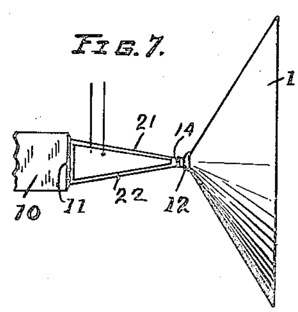


FIG. 8.

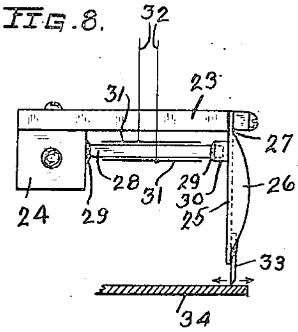
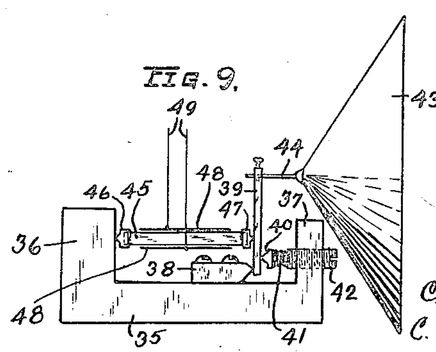


FIG. 9.



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1,802,781

UNITED STATES PATENT OFFICE

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PIEZO-ELECTRIC DEVICE

Application filed May 6, 1927. Serial No. 189,442.

This invention relates to piezo-electric•devices, and more particularly to an improved method of and means for utilizing the piezo effect of piezo-electric material.

Piezo-electric crystals, such as, for example, Rochelle salt crystals, have been used in various devices, such as loud speakers, transmitters and the like for transforming sound pulsations into electric vibrations, and vice versa. In general, an entire crystal has been employed and a twisting motion or longitudinal expansion of the crystal obtained when an electric field has been applied thereto. The crystals so employed have been either of the clear type or of the composite type. The former type comprises a clear crystalline structure, whereas the latter type is characterized by porous or composite portions at the ends, frequently known as hourglass regions. With either type of crystal the mechanical deflection obtained is small unless a relatively large crystal is employed, in which case the tone quality obtained is apt to suffer, since with such large crystals the natural period of the crystal, which is a function of the size, is frequently brought down into the audible range. Thus when the frequency of the applied excitation is substantially the same as the natural period, the response is much greater for this frequency than for the other applied frequencies, whereby blasts or distortions result.

In employing complete crystals, furthermore, since such crystals are ordinarily of non-uniform cross-section, the length of path of the electrostatic field varies. Such variation in the path of the electrostatic field necessarily results in a non-uniform potential gradient and therefore non-uniform piezo-electric effect in various portions of the crystal. Furthermore, the thinner sections of the crystal may therefore be near the breakdown point due to the applied voltage when the thicker sections of the crystal are still capable of withstanding considerably higher voltages.

It will also be noted that piezo-electric crystals, for example, Rochelle salt crystals, as previously used have been of non-uniform character, with attendant disadvantages. Moreover, when Rochelle salt crystals of the composite type have been employed such crystals have been subject to changes in characteristics, due to loss of, or increase of, moisture content in the porous end regions.

Furthermore, large and relatively perfect crystals are required when used for frequencies within the audible range, in some cases weighing one or two pounds apiece with the attendant difficulties of growing and expense of production.

An object of our invention is to provide a piezo-electric acoustic device of improved operating characteristics.

A further object of this invention is to provide a piezo-electric acoustic device of greater efficiency.

Another object of the invention is to provide piezo-electric acoustic devices of uniform quality and characteristics.

A further object of this invention is the more efficient utilization of a piezo-crystalline material of the Rochelle salt type.

Another object of our invention is to provide piezo-electric crystalline material of improved character for use in acoustic devices.

A further object of the invention is to provide a piezo-electric acoustic device which will reproduce electrical impulses, faithfully corresponding to mechanical vibrations supplied to the device, and vice versa.

Other objects of the invention will be apparent to those skilled in the art from the following description and annexed drawings, in which

Figures 1, 2 and 3 are respectively a top plan view, end elevation, and front elevation of a portion of a Rochelle salt crystal of the composite type, the dotted lines in said figures illustrating one manner in which bars according to our invention may be obtained from this form of crystal;

Figs. 4 and 5 are respectively a perspective view and an end elevation of a piezo-electric bar according to our invention, electrodes being shown associated with the opposed longitudinal faces of said bar;

Fig. 6 is a sectional view showing a microphone constructed in accordance with this invention;

Fig. 7 illustrates a modified form of acoustic device according to this invention embodying a piezo-electric bar having opposed longitudinal faces of substantially trapezoidal shape;

Fig. 8 is an elevational view showing an acoustic device according to this invention for cutting phonograph records; and

Fig. 9 is an elevational view illustrating a loud speaker constructed in accordance with our invention.

In our present invention we cut or otherwise obtain from a piezo-electric crystal or portion thereof, preferably though not necessarily Rochelle salt, a bar which is preferably though not necessarily of materially greater length than the cross-sectional dimensions thereof and which may be of substantially rectangular cross-section. The longitudinal faces of the bar may also be of rectangular shape, although it is frequently desirable that the said faces be of trapezoidal or of other suitable shape.

In the case of bars of piezo-electric material of the Rochelle salt type, for example, double tartrates, such as of the alkali metals, obtained from such a piezo-electric crystal or portion thereof, a pair of opposed longitudinal faces thereof are preferably substantially parallel to the plane of the major longitudinal and major transverse crystalline axes, as hereinafter defined. Moreover, such a bar is preferably so cut that its greatest dimension is at an angle of substantially 45 degrees to a major crystalline axis, although it will be understood that certain of the advantages of this invention may be realized if said bars are cut at other angles. In general it may be stated that the bar is preferably so cut from a piezo-electrical material that when an electrostatic field is applied to said bar perpendicular to the said opposed longitudinal faces thereof, the bar will tend to expand or contract in the direction of its greatest longitudinal dimension or, in other words, of what may be termed its longitudinal axis.

We may provide an improved acoustic device according to this invention by suitably mounting a piezo-electric bar of the type above described. Thus, the bar may be secured at one end thereof to a support and an acoustic member such as a loud speaker cone or record-cutting jewel secured to the opposed or free end of said bar. Suitable electrodes may then be disposed on opposed longitudinal faces of said bar whereby an electrostatic field may be applied therethrough perpendicular to the longitudinal axis thereof, whereby the free end of said bar will move in a direction perpendicular to the electrostatic field to actuate said acoustic member.

In Figs. 1, 2 and 3 is shown a portion 1 of a Rochelle salt crystal of the composite type having the hourglass or porous end region 2. The crystal portion 1 is shown as having the major longitudinal axis *c—c*, the major transverse axis *b—b* and the minor axis *a—a*, said axes being mutually perpendicular. There is indicated in the dotted lines in Figs. 1, 2 and 3 one manner in which a bar according to our present invention may be obtained from the crystal portion 1. Each bar 3 is preferably so cut from the crystal portion 1 that a pair of opposed faces are substantially parallel to the bottom face 4 of the crystal portion 1 and to the major crystalline axes *c—c* and *b—b*. Where the bottom face 4 is relatively smooth, such face may form one of the faces of each bar to be cut therefrom. Moreover, the bars 3 are preferably so cut from a crystal portion 1 that the direction of major dimension of the bar or, as may be stated, the longitudinal axis of the bar, is at substantially 45 degrees to each of the major crystalline axes since bars so cut exhibit the greatest amount of longitudinal movement for a given electrostatic field. In other words, the longitudinal axis of the bar represents the direction of movement of the bar when subjected to an electrostatic field. It will be understood, of course, that one or more bars may be obtained from one crystal portion, depending upon the size of the crystal or crystal portion and the size of bar desired.

In Figs. 4 and 5 are shown a piezo-electric bar 3 of our invention having associated therewith suitable electrodes 5 to which may be connected suitable wires 6. The bar 3 is shown as being of materially greater length than the cross-sectional dimensions thereof, the bar being shown as having a substantially rectangular cross-section. The bar 3 is shown as having the ends 8 and the substantially parallel longitudinal faces 7. The dimensions of the bar 3 are dependent upon the particular conditions to which the bar is to be subjected. Frequently, however, it is found advantageous to have the distance between the opposed faces 7 relatively small since in such case the desired mechanical movement of the bar due to the piezo-electrical effect may be obtained from relatively small applied voltages since it is well understood that the mechanical movement of the crystal is dependent upon the volts per inch, or in other words, the potential gradient through the crystal. Conversely, mechanical movement of relatively small magnitude will produce voltages of appreciable magnitude.

When the bar shown in Figs. 4 and 5 is subjected to an electrostatic field perpendicular to its faces 7, as through the electrodes 5, the bar 3 expands or contracts along its longitudinal dimension or longitudinal axis dependent upon the direction of said electrostatic field since the bar is so oriented that its longitudinal dimension is at an angle of substantially 45 degrees to the major crystalline axes. It will thus be evident that the longitudinal dimensions of the bar is frequently preferably of materially greater magnitude than the cross-sectional dimensions. The bar 3 however may be of various shapes and cross-sectional dimensions dependent upon the particular use to which the bar is to be put.

In Fig. 6 I have shown a microphone embodying my invention. Thus, to the casing 9 is secured a relatively heavy support 10 which may be of lead or other suitable material which will remain stationary and not be affected by vibrations of relatively high frequency. The support 10 is shown as being substantially U-shaped. The piezo-electric bar 18 may be secured at one end thereof to the support 10 by suitable adhesive material 11, such as shellac, Canada balsam or the like. To the outer or actuating end of the bar 18 may be secured a socket member 12 which in turn carries a suitable acoustic diaphragm, such as the cone 13. Shellac or other suitable adhesive material 14 may also be employed to secure the socket member 12 to the outer or actuating end of the bar 18. Electrodes 19, such as of tin foil, may be disposed adjacent or secured to the opposed longitudinal faces 20 of the bar 18. Suitable wires 15 may be connected to the electrodes 19 and to binding posts 16 insulated as by the insulative washers 17 from the casing 9.

When sound waves impinge upon the cone 13, the bar 18 is stressed along its longitudinal axis whereby, due to the piezo-electric effect, an electromotive force is generated between the electrodes 19. By connecting suitable apparatus to the binder posts 16, therefore, such varying voltage may be transmitted to suitable apparatus such as broadcasting apparatus, sound reproducing apparatus or the like.

The apparatus shown in Fig. 6 may also be employed as a loud speaker by applying suitable voltage to the electrodes whereby varying electrostatic field is applied to the bar 18. Due to the piezo-electric effect and the position of the longitudinal axis of the bar with respect to the crystalline axes, such varying electrostatic field causes the bar 18 to contract or expand along its longitudinal axis, thus actuating the cone to reproduce sounds corresponding to the electric vibrations transmitted to the bar.

The longitudinal faces 20 of the bar shown in Fig. 6 may be of rectangular shape as shown in Fig. 4 or of substantially trapezoidal shape as indicated by the faces 21 of the bar 22 shown in Fig. 7, or of any suitable shape. The natural period of a bar when expanding and contracting longitudinally is proportional to its length. A bar of the shape shown in Fig. 7 therefore may be considered as made up of an infinite number of bars of unequal length therefore tending to respond to an infinite number of natural periods. Experience has shown that when a bar of this shape is used for a microphone or loud speaker, very desirable acoustic characteristics are obtained.

Referring again to the structure shown in Fig. 6, the equivalent electrostatic capacity of the microphone may, of course, be increased as by decreasing the distance between the electrodes by making the bar thinner, or by increasing the area of the electrodes by increasing the area of the longitudinal faces of the bar, as is the case in any dielectric material, or vice versa, so that the impedance may be given the value most suitable for any thermionic or other electrical device with which the microphone may be used. If the longitudinal dimensions of the bar are reasonably small the natural period or periods of the bar 18 will be well above the audible range and disagreeable resonances or blasts prevented.

In carrying out our invention, instead of securing a piezo-electric bar at one end thereof to a relatively heavy support and at the other end thereof to an acoustic member, as in Fig. 6, we may secure acoustic members to each end of said bar. Thus, acoustic diaphragms, such as cones, may be secured to the ends of a bar to form, for example, a loud speaker. In such case the bar may be supported or suspended as by resilient material cooperating with the central portion thereof.

In Figs. 8 and 9 we have shown devices embodying our invention in which the longitudinal movement of a bar under the influence of an electrostatic field is mechanically magnified. Thus in Fig. 8 is shown a device for cutting phonograph records. To the arm 23 is secured a support 24 preferably of lead or other suitable material. At the outer end of the arm 23 is secured a lever 25 which may be of channel formation as shown at 26 to provide stiffness. The lever 23 may thus pivot at 27 adjacent the arm 23. A piezo-electric bar 28 according to our invention is shown disposed intermediate the support 24 and the lever 25, one end of the said bar being secured to said support by adhesive material such as shellac 29, the outer or actuating end of the bar being secured by suitable adhesive material 29 such as shellac to a socket member 30 which is in turn disposed adjacent and secured to the lever 25. Electrodes 31 of tin foil or the like may be disposed adjacent or secured to opposed longitudinal faces of the bar 28 to which electrodes may be secured the wires 32. To the lower end of the lever 25 is shown secured a cutting jewel or member 33 arranged to cut a suitable groove in a record blank 34.

When the bar 28 is subjected to a varying voltage by means of the wires 32 a varying electrostatic field will be set up in the bar 28 causing the bar 28 to contract and expand longitudinally or in the direction of its greatest dimension. Such longitudinal movement will be transmitted to the lever 25 giving the cutting jewel 33 a magnified motion in the directions indicated by the arrows in Fig. 8. In this manner a suitable spiral groove may be cut in the record blank 34. It will be understood that during the process of cutting the record the blank 34 will be rotated and simultaneously moved bodily in a direction toward the right, referring to Fig. 8, whereby a spiral groove may be cut in the blank.

In Fig. 9 we have illustrated a loud speaker device embodying our invention. The relatively heavy frame portion 35 having the upstanding portions 36 and 37 may be composed of lead or other suitable material. To the frame 35 is firmly secured a fixed fulcrum member 38, cooperable with the lever 39. A yieldable fulcrum member 40 cooperates with the opposed side of the lever and is supported by a relatively heavy or stiff spring 41, the tension of which may be regulated by the screw 42 carried by the frame portion 37. A cone 43 mounted on a shaft 44 is secured to the lever 39. Disposed between the frame member 36 and the lever 39 is a piezo-electric bar 45 to each of the ends of which are secured, by suitable cement, the end pieces 46 and 47 arranged to cooperate with the frame portion 36 and lever 39 respectively, which end pieces 46 and 47 may be omitted if desired. On opposed longitudinal faces of the bar are disposed electrodes 48 such as of tin foil, to which electrodes are secured the wires 49. When the bar 45 is subjected to an electrostatic field by means of the wires 49 and electrodes 48, the bar 45 will expand longitudinally and move the lever 39 and cone 43 forwardly, toward the right in Fig. 9. If the electrostatic field is reversed the bar will contract, and the lever 39 and cone 43 will be moved rearwardly by the fulcrum member 40. Due to the leverage means shown the cone 43 is given a magnified vibratory motion corresponding to the electrical impulses applied between the electrodes 48.

It will thus be seen that we have provided a piezo-electric bar and acoustic devices embodying the same of advantageous operating characteristics.

It will furthermore be noted that we have provided piezo-electric bars of economical characteristics in that a plurality of bars may be obtained from a single piezo-electric crystal or portion thereof. Our improved bars may moreover be obtained from imperfect crystals or portions thereof.

It will furthermore be seen that we have provided piezo-electric bars which may be given uniform and constant piezo-electric characteristics since porous and imperfect crystalline structures may be avoided in cutting said bars.

It will also be noted that by means of our invention we may provide piezo-electric bars and devices embodying the same of uniform dimensions and operating characteristics.

It will further be seen that we have provided piezo-electric bars and devices embodying the same whose operating characteristics may be varied to suit the voltages available or to bring the impedance of said bars closer to a desired impedance, as when said devices are used as loud speakers or record-cutting devices.

It will moreover be noted that we have provided piezo-electric bars whose dimensions may be varied to bring the natural period thereof to any desired value.

It will also be seen that by our invention we may provide a piezo-electric bar responding to an infinite number of natural periods whereby when such bar is embodied in an acoustic device good reproduction throughout the musical range is effected and undesirable resonances and blasts prevented.

It will moreover be understood that our invention is not limited to bars formed from Rochelle salts but that any suitable piezo-electric material may be utilized in the construction thereof.

To those skilled in the art many modifications of and widely differing embodiments and applications of our invention will suggest themselves without departing from the spirit and scope thereof. Our disclosures and the descriptions herein are purely illustrative and are not intended to be in any sense limiting.

What we claim is:

1. In an acoustic device of the class described, in combination, a support not appreciably affected by electrical or mechanical vibrations of audible frequency, a bar of piezo-electric material of the Rochelle salt type secured at one end thereof to said support, said bar being of substantially rectangular cross-section and of materially greater length than the cross-sectional dimensions thereof, said bar having a pair of opposed longitudinal faces parallel to the plane of the major longitudinal and major transverse crystalline axes, the longitudinal axis of said bar being disposed at substantially 45 degrees to said major crystalline axes, an acoustic member secured to the opposed or free end

of said bar and arranged to function acoustically when moved in alignment with the longitudinal axis of said bar, electrodes secured to said opposed longitudinal bar faces whereby, when an electrostatic field is applied to said bar through said electrodes, said acoustic member will move in alignment with the longitudinal axis of said bar, and vice versa.

2. In an acoustic device of the class described, in combination, a support of sufficient mass as to be substantially unaffected by vibrations of audible frequency, a bar of piezo-electric material of the Rochelle salt type cemented at one end to said support, said bar being of materially greater length than the cross-sectional dimension and having its longitudinal axis disposed at substantially 45 degrees to one of the major crystalline axes, electrodes disposed on opposite faces of the bar, means for producing an electrostatic field, and an acoustic member secured directly to the unsupported end of said bar.

3. In an acoustic device for receiving or radiating sound waves, in combination, a support of sufficient mass as to be substantially unaffected by vibrations of audible frequency, a bar of piezo-electric material of the Rochelle salt type cemented at one end to said support, said bar being of materially greater length than the cross-sectional dimension and having its longitudinal axis disposed at substantially 45 degrees to one of the major crystalline axes, electrodes disposed on opposite faces of the bar, means for producing an electrostatic field, and an acoustic diaphragm for receiving or radiating sound waves secured directly to the unsupported end of said bar.

4. In an acoustic device for receiving or radiating sound waves, in combination, a support of sufficient mass as to be substantially unaffected by vibrations of audible frequency, a bar of piezo-electric material cemented at one end to said support, said bar being of materially greater length than the cross-sectional dimension and having its longitudinal axis disposed at substantially 45 degrees to one of the major crystalline axes, the cross section of said bar decreasing from the supported end to the unsupported end, electrodes disposed on opposite faces of the bar, means for producing an electrostatic field, and an acoustic diaphragm for receiving or radiating sound waves secured to the unsupported end of said bar.

5. In a sound reproducing device in combination, a support of sufficient mass as to be substantially unaffected by vibrations of audible frequency, a bar of piezo-electric material of the Rochelle salt type rigidly secured at one end to said support, said bar being of materially greater length than the cross-sectional dimension and having its longitudinal axis disposed at substantially 45 degrees to one of the major crystalline axes of the piezo-electric material, electrodes disposed on opposite faces of the bar substantially parallel to the plane determined by the major crystalline axes, a sound radiating diaphragm rigidly secured directly to the unsupported end of the bar, whereby upon the production of a variable electrostatic field between the electrodes said bar and the sound radiating diaphragm will be caused to vibrate.

In testimony whereof we affix our signatures.

CHARLES B. SAWYER.
CHARLES F. BRUSH, Jr.