April 28, 1931. C. B. SAW... 1,802,780

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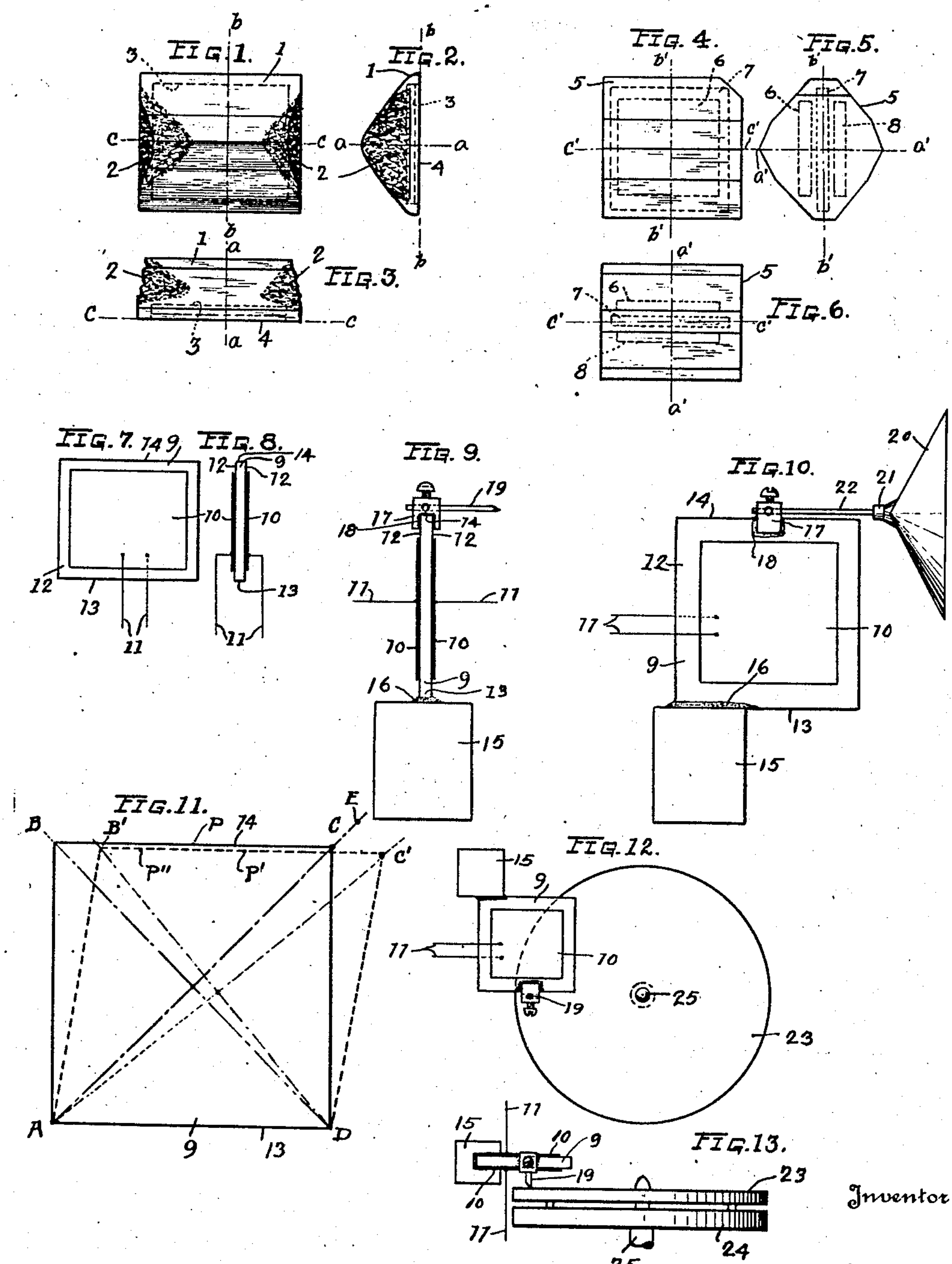
Filed May 6, 1927



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Patented Apr. 28, 1931 1,802,780

UNITED STATES PATENT OFFICE

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PIEZO-ELECTRIC DEVICE

Application filed May 6, 1927. Serial No. 189,441.

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 hour-glass 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. Thus 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 and 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 variations 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, and in inefficient use of the piezo-electric material, since the thinner sections of the crystal may 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.

Moreover, when relatively small crystals are used, mechanical levers are frequently necessarily employed therewith to mechanically magnify the movement of the crystal. In such cases, the natural period of the entire device, or of the lever itself, usually falls within the audible range, resulting also in distortions or discordant blasts or resonances.

Furthermore, 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.

An object of my 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 this invention is to provide a piezo-electric acoustic device in which the expansion of a piezo-crystalline material by an electric field may be mechanically magnified without the use of levers.

Another object of my invention is to provide Rochelle salt piezo-electric portions of uniform and improved quality and characteristics.

A further object of this invention is to provide piezo-electric crystalline portions of improved character for use in acoustic devices.

Another object of the invention is to provide a slab of piezo-electric material of such characteristics that when suitably mounted and subjected to an electrostatic field, a point on said slab will have a greater mechanical movement than the expansion of said slab in any direction.

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 Rochelle salt crystal of the composite type, the dotted lines in said figures illustrating one manner in which a slab according to my invention may be obtained from this form of crystal;

Figs. 4, 5 and 6 are respectively a top plan view, end elevation, and front elevation of a slightly imperfect Rochelle salt crystal of the clear complete type, the dotted lines in said figures illustrating one manner in which slabs according to this invention may be obtained from this form of crystal;

Figs. 7 and 8 are respectively a front elevation, and end elevation of a piezo-electric slab according to my invention, electrodes being shown associated with the faces of said slab;

Figs. 9 and 10 are respectively an end elevation, and front elevation of a piezo-electric device according to my invention, the device shown in Fig. 9 being arranged to actuate a cutting jewel, the device shown in Fig. 10 being arranged to actuate a loud speaker cone;

Fig. 11 is a diagrammatic view of a piezo-electric slab illustrating the operation of said slab when mounted as shown in Figs. 9 and 10; and

Figs. 12 and 13 are respectively a top plan view, and front elevation of a piezo-electric acoustic device similar to that shown in Fig. 9, arranged for the cutting of phonograph records.

In my present invention I cut or otherwise obtain from a piezo-electric crystal or portion thereof, preferably though not necessarily of Rochelle salt, a slab, which is preferably relatively thin, and whose faces are preferably parallel, and whose opposed edges may also be parallel, as in the case of a rectangular or square slab. While the slab is preferably rectangular, it will be understood that other shapes may also be employed.

In the case of the slab of square shape, the said slab is preferably so cut that the faces thereof are substantially parallel to the plane of major longitudinal and major transverse crystalline axes as hereinafter defined, although certain of the advantages of my invention may be realized when said faces are not so disposed. Moreover, the slab is preferably so cut that when an electrostatic field is applied through the slab substantially perpendicular to the faces thereof, said slab will tend to expand along one of its diagonals, or stating the proposition more generally, so that the slab will tend to expand in a direction at substantially 45 degrees to a major crystalline axis.

I may provide an improved acoustic device according to the invention by suitably mounting a piezo-electric slab of the type above described. Thus, a square slab may be fixed to a suitable support at one edge, or a portion thereof. Suitable electrodes may then be disposed on the faces of the slab whereby an electrostatic field may be applied through the slab perpendicular to the faces thereof. When such electrostatic field is applied, the slab, if square, will tend to expand and contract along its diagonals, as will be more fully described hereinafter. By securing a suitable acoustic member such as a loud speaker cone, phonograph record cutting jewel, or other member to the edge of the slab opposite to the fixed edge, said cone or other member may be caused to have a mechanical movement greater than the expansion of said slab in any direction, thereby effecting a mechanical magnification of the slab expansion without the use of levers.

In Figs. 1, 2 and 3 is shown a Rochelle salt crystal 1 of the composite type having hourglass or porous end regions 2. The crystal 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 slab according to my invention may be obtained from the crystal 1. The slab 3 is preferably so cut from the crystal 1 that its faces are substantially parallel to the bottom face 4 of the crystal 1 and to the major crystalline axes. Where the bottom face 4 is relatively smooth, such face may form one of the faces of the slab to be cut therefrom. It will be understood, of course, that one or more slabs may be obtained from one crystal depending upon the size of the crystal and of the slabs desired.

In Figs. 4, 5 and 6 is shown a slightly imperfect Rochelle salt crystal of the clear complete type, the crystal 5 having the major longitudinal axis $c'—c'$, the major transverse axis $b'—b'$ and the minor axis $a'—a'$, said axes being mutually perpendicular. In the dotted lines at 6, 7 and 8 are indicated slabs which may be obtained or cut from the crystal 5. The faces of the slabs 6, 7 and 8 are preferably substantially parallel to the major crystalline axes $c'—c'$ and $b'—b'$. It will be understood, of course, that the dimensions of the slabs cut from the crystal 5 and the number of slabs obtained therefrom will be dependent on the number and size of slabs desired and upon the size and quality of the crystal 5.

In Figs. 7 and 8 are shown a piezo-electric slab 9 of my invention having associated therewith suitable electrodes 10 to which are connected suitable wires 11. The slab 9 is shown as being substantially square and as having the substantially parallel faces 12 and the opposed edges 13 and 14. The thickness of the slab 9 will depend upon the particular conditions to which the slab is to be subjected. Frequently, however, it is found advantageous to have the slab 9 relatively thin since in such case the mechanical movement of the slab 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. While the slab 9 may perferably be of square or rectangular shape, it should be noted that advantageous results may be obtained with slabs of various regular and irregular shapes, the shape of the slab being dependent upon the particular use to which it is put.

With the square slab 9 shown in Figs. 7 and 8 and cut or obtained from a crystal as hereinbefore disclosed, the expansion of the crystal upon application of an electrostatic field will take place along a diagonal AC or BD (Fig. 11) or, in other words, in a direction at substantially 45 degress to a major crystalline axis. While certain advantages may be obtained when the expansion of the crystal is at angles appreciably greater or less than 45 degrees to said major crystalline axes, I have found that in general the greatest effect is obtained when the crystal expands in the above described manner. The above-mentioned action of the slab 9 under an electrostatic field I have substantiated by numerous observations under a microscope.

In Figs. 9 and 10 I have shown a slab 9 suitably mounted to form an acoustic device of advantageous character whereby mechanical movement of an acoustic member greater than the mechanical movement or expansion of the slab 9 in any direction may be obtained without the use of levers or equivalent means. Thus the slab 9 is secured at a lower edge 13 to the base or support 15 by suitable adhesive material 16 such as shellac, Canada balsam, or the like. The slab 9 may be secured to said support 15 along the entire edge 13 or portion thereof. The base or support 15 is preferably of lead or similar heavy material which will remain stationary and not be affected by vibrations of relatively high frequency. To the faces 12 of the slab 9 are secured the electrodes 10 such as of tin foil, said electrides covering preferably a relatively large portion of the said faces. Suitable wires 11 are secured to the electrodes 10 whereby the slab 9 may be subjected to a varying electrostatic field. To the upper edge 14 of the slab 9 is secured a clamp 17 by suitable adhesive material 18. In Fig. 9 a phonograph record cutting jewel 19 is shown associated with the clamp 17, the axis of the jewel 19 being shown as perpendicular to the faces 12, whereas in Fig. 10 is shown an acoustic diaphragm 20, such as a cone, secured to a socket member 21 in turn carried by a shaft 22. The shaft 22 which is shown as parallel to the faces 12 is carried by the clamp 17.

When a variable voltage is applied through the wires 11 to the devices shown in Figs. 9 and 10, the jewel 19 in Fig. 9 will vibrate in a direction parallel to the faces 12, while the cone 20 will vibrate in a direction longitudinally of the shaft 22.

In Fig. 11 I have illustrated diagrammatically the action of the slag 9 shown in Figs. 9 and 10 when subjected to a varying electrostatic field by means of the electrodes 10. The slab 9 in normal position when not subjected to an electrostatic field, is shown in the full lines ABCD, the lower edge AD (13) being fixed in position as in the manner indicated in Figs. 9 and 10. When an electrostatic field is applied to the slab 9 in one direction through the electrodes 10, the slab 9, if the lower edge were not fixed or restrained, would tend to elongate along the diagonal AC to the position indicated by AE, the expansion CE being proportional to the strength of the electrostatic field. At the same time, if the lower edge AD were unrestrained, the slab 9 would tend to contract along the diagonal BD. Since, however, the lower edge AD is restrained or fixed in position, the diagonal AC assumes the position AC′ instead of the position AE. At the same time the diagonal BD which tends to contract, assumes the position B′D, the slab 9 assuming the position AB′C′D shown in dotted lines, the edges AB and DC remaining parallel in the distorted position AB′ and DC′. Upon the reversal of the direction of the electrostatic field, the slab would tend to expand along the diagonal BD and contract along the diagonal AC, the slab 9 assuming a position the reverse of that indicated in dotted lines in Fig. 11.

Assuming a point P on the upper edge BC (14) of the slab 9, at which point a clamp such as the clamp 17 in Figs. 9 and 10 may be secured, it will be noted that said point P moves to a point P′ when the slab 9 moves to the position AB′C′D. The point P moreover would move to the point P″ if the electrostatic field were reversed. The distance traversed by the point P, namely PP′ and PP″, when the slab is subjected to the aforementioned electrostatic field, are each greater than the expansion of the diagonal AC which is equivalent to the distance CE or the difference in length between AC′ and AC. In effect, therefore, the point P, when the slab 9 is subjected to a varying electrostatic field, moves a greater distance than the expansion of the slab in any direction. It may be said, therefore, that a magnification is given to the movement of an acoustic member secured to the upper edge 14 of the slab 9 without the use of any levers or the like.

In Figs. 12 and 13 I have shown the application of a device such as shown in Fig. 9 to the cutting of phonograph master records from a wax blank 23. Thus the turn table 24 may be rotated about the spindle 25 and the wax blank 23 disposed over the upper end of the spindle 25 on said turn table 24. In operation, the slab support 15 may be disposed in fixed position and the turn table 24 and record blank 23 rotated. The turn table moreover normally moves toward the cutting jewel 19 in order that a spiral groove may be cut in the blank 23. When a varying electrostatic field is applied to the electrodes 10 it will be understood from the previous description that the cutting jewel 19 will vibrate in such manner to cut a wavy spiral groove in the master blank 23, whereby to record the sound equivalents of the alternating electromotive force applied to the wires 11.

It will thus be seen that I have provided a piezo-electric slab of advantageous characteristics, and that an acoustic member secured to said slab will be given a magnified movement without the use of levers or the like.

It will furthermore be noted that I have provided piezo-electric slabs of economical characteristics in that a plurality of slabs may be obtained from a single piezo-electric crystal or portion thereof.

Furthermore, my improved piezo-electric slabs may be obtained from imperfect crystals or portions thereof thereby effecting great economy in the production of said slabs.

It will also be noted that by means of my invention I may provide piezo-electric slabs and devices embodying the same of uniform dimensions and operative characteristics.

It will furthermore be seen that I have provided piezo-electric slabs of uniform and constant electric characteristics, since no porous Rochelle salt crystal end regions need be included in said slabs.

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

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

It will moreover be understood that my invention is not limited to slabs formed Rochelle salts, but 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 my invention will suggest themselves without departing from the spirit and scope thereof. My disclosures and the descriptions herein are purely illustrative and are not intended to be in any sense limiting.

What I claim is:

1. In an acoustic device of the class described, in combination, a support, a slab of Rochelle salt rigidly secured at one portion thereof to said support, an acoustic member attached to a portion of said slab opposed to said fixed portion, said slab being arranged to expand or contract in a direction substantially 45 degrees to the direction of movement of the acoustic member when said slab is acted on by an electrostatic field, whereby a motion greater than the actual expansion or contraction of the slab in any direction is imparted to the acoustic member.

2. In an acoustic device of the class described, in combination, a support, a substantially rectangular slab of piezo-electric material, said slab being so oriented with respect to the crystalline axes that the slab tends to expand and contract in a direction substantially parallel to the diagonals of the slab, a portion of one edge of said slab being secured to said support, an acoustic member attached to said slab adjacent an edge opposed to said fixed edge whereby when said slab is subjected to an electrostatic field said acoustic member is given a greater mechanical motion than the expansion or contraction of said slab in any direction.

3. In an acoustic device of the class described, in combination, a support, a slab of piezo-electric material, said slab being rigidly secured at one edge thereof to said support, an acoustic member secured to an edge of said slab opposed to said fixed edge, said slab being so oriented that when subjected to an electrostatic field said acoustic member will be actuated in a direction substantially parallel to the plane of one face of said slab and at right angles to a perpendicular from said support through said slab, and vice versa.

4. In an acoustic device of the class described, in combination, a support not appreciably affected by electrical or mechanical vibrations of audible frequency, a slab of piezo-electric material of the Rochelle salt type secured at one edge thereof to said support, said slab having faces of substantially rectangular shape, said faces being substantially parallel to each other and to the major crystalline axes, said fixed edge and opposed edge being substantially parallel to one of said major crystalline axes, an acoustic member secured to said opposed edge of said plate and arranged to function acoustically when moved in a direction parallel to the faces of said slab, electrodes secured to the faces of said slab whereby when an electrostatic field is applied to said slab through said electrodes said acoustic member will have a greater movement than that of any elements of the slab in the direction of expansion or contraction.

5. In an acoustic device of the class described, a support, a piezo-electric slab of the Rochelle salt type rigidly secured at one portion thereof to said support, an acoustic mem-

ber attached to one portion of the slab opposed to said secured portion, said slab being arranged to expand or contract in a direction substantially 45 degrees to the direction of movement of the acoustic member, whereby the portion of the slab to which the acoustic member is attached has a motion greater than the actual expansion or contraction of the slab in any direction.

6. In an acoustic device of the class described, a support, a piezo-electric slab of the Rochelle salt type of substantially rectangular shape having faces substantially parallel to each other and to the major crystalline axes, means for supporting said slab at one portion thereof, and an acoustic member disposed at an opposed portion thereof, whereby the acoustic member will have a greater movement than the linear expansion or contraction of any element of the slab.

7. In a piezo-electric device of the class described, in combination, a support, a slab of piezo-electric material of the Rochelle salt type having faces substantially parallel to each other and to the major crystalline axis of the Rochelle salt crystal, said slab being secured along one of its edges to said support so that expansion and contraction of the slab upon the application of a electrostatic field takes place in a direction at an angle substantially less than 90 degrees to the supported edge, whereby a point on the opposite edge of the slab will have a movement greater than that of the slab in the direction of expansion or contraction.

8. In a piezo-electric device of the class described, in combination, a support, a slab of piezo-electric material of the Rochelle salt type having faces substantially parallel to each other and to the major crystalline axis of the Rochelle salt crystal, said slab being of substantially rectangular shape and having the longitudinal axis of the crystal substantially normal to two of its edges, said slab being supported on one of said edges whereby a motion greater than the expansion or contraction of the slab in any direction is imparted to a point on the unsupported edge.

9. In a piezo-electric device of the class described, a support, a slab of Rochelle salt having the faces substantially parallel to each other and to the major crystalline axes and having an edge extending substantially at right angles to the longitudinal axis of the crystal, said edge being securely mounted to said support whereby a point on the opposed unsupported edge of the slab will have a movement substantially parallel to the supported edge upon the application of an electrostatic field or vice versa.

10. In a piezo-electric device, in combination, a support, a slab of piezo-electric material having faces substantially parallel to each other and perpendicular to the electric axis of the piezo-electric material, said slab being secured along one of its edges to said support, the free edge portion of said slab, when so arranged, having the property of moving parallel to the base a greater linear distance than the movement of the slab in the direction of expansion or contraction, and a device secured to the free edge of the slab for utilizing such magnified motion of the slab or imparting motion to the slab.

In testimony whereof I affix my signature.

CHARLES B. SAWYER.