April 8, 1930. A. McL. NICOLSON 1,753,312

INTERNALLY CLAMPED COMPOSITE PIEZO ELECTRIC ACOUSTIC DEVICE

Filed Jan. 11, 1927

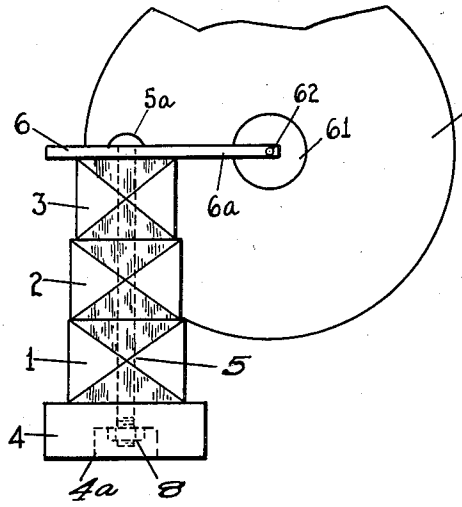


Fig. 1

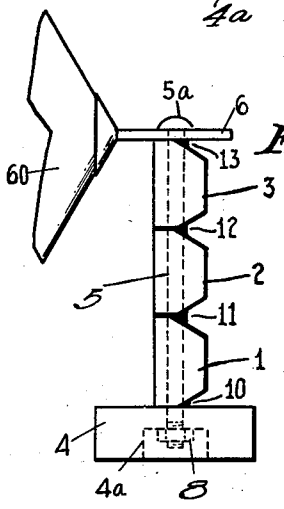


Fig. 2

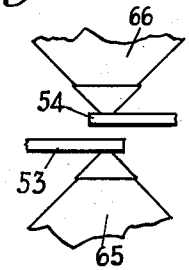


Fig. 6

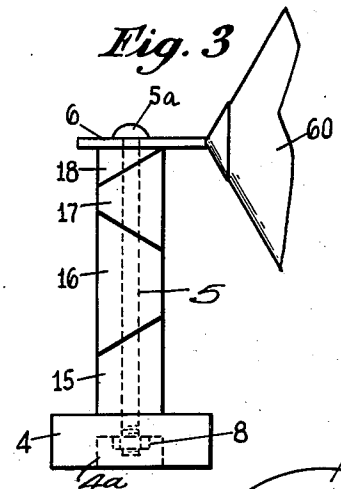


Fig. 3

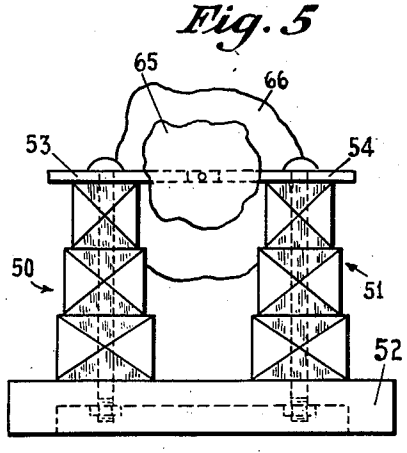


Fig. 5

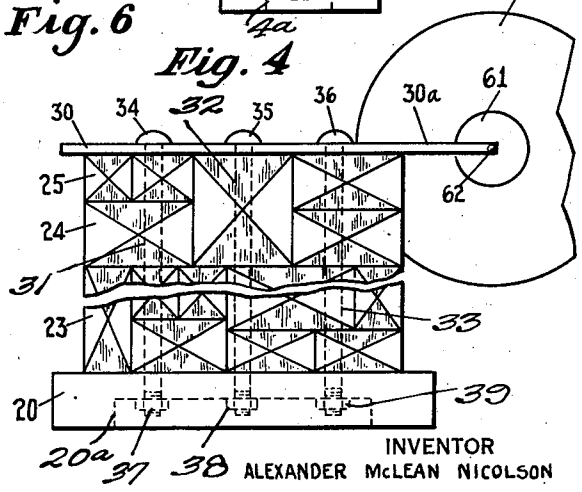


Fig. 4

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UNITED STATES PATENT OFFICE

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INTERNALLY-CLAMPED COMPOSITE PIEZO-ELECTRIC ACOUSTIC DEVICE

Application filed January 11, 1927. Serial No. 160,359.

This invention relates to a piezo-electric device, and more particularly, to an acoustic device, adapted for the conversion of fluctuating electromotive forces into sound waves, and vice versa. It has been known for some time that crystals of certain substances, such as Rochelle salt, quartz, tourmaline, and the like, produce an electromotive force if subjected to physical stress or movement, and conversely, produce physical stresses or movement in response to the impression of an electromotive force upon them.

In my copending application, Serial No. 155,900, entitled "Internally clamped composite piezo-electric torsion device", filed Dec. 20, 1926, I have shown and described a modified form of composite piezo-electric crystal particularly adapted for torsional vibration, comprising a plurality of chemically and optically similar component piezo-electric crystals arranged so that piezo-electric torsional vibrations of the individual component crystals may be integrated, and mechanically clamped into a single entity by means of an elastic and preferably metallic tie rod passing internally through the composite device, and preferably through a plurality of component crystals.

I have discovered that such a composite piezo-electric device as I have described in the said application may be utilized in connection with an acoustic diaphragm to produce an acoustic device such as a loud speaker, or a microphone, and as a matter of fact, when properly constructed and arranged, will produce results never before obtained.

It is an object of this invention to provide an acoustic device of high quality and high sensitivity.

It is still a further object of this invention to provide a piezo-electric acoustic device of high quality and high sensitivity at a relatively low cost.

It is still a further object of this invention to provide a piezo-electric acoustic device of high quality and high sensitivity, characterized by extreme simplicity and reliability, at a relatively low cost.

It is still a further object of this invention to provide such a piezo-electric acoustic device, which may be easily and quickly disassembled to permit of inspection and replacement of any component crystal.

It is still a further object of this invention to provide a generally improved device of the class described. Still other objects will be apparent from the specification.

The features of novelty which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its fundamental principles and as to its practical application, will best be understood by reference to the specification and accompanying drawing, in which:

Fig. 1 is a front elevation of a piezo-electric acoustic device according to my invention.

Fig. 2 is a side elevation thereof.

Fig. 3 is a side elevation of a modified form thereof.

Fig. 4 is a front elevation of a still further modified form thereof.

Fig. 5 is a front elevation of a still further modified form thereof.

Fig. 6 is a plan view of a detail of the arrangement shown in Fig. 5.

In accordance with my invention, I select a multiplicity of piezo-electric crystals to be assembled into a composite device, in the manner shown and described in my copending application referred to above. The selection as therein stated, is preferably made by choosing crystals which are chemically and optically similar. For example. I may select a number of quartz crystals, being careful to separate the crystals of dextro-asymmetry from those of lævo-asymmetry. The composite piezo-electric device may be constructed of either of the components, but it is preferable to use in any one assembly, only crystals of the same asymmetry, as otherwise the mechanical vibrations of the one class will be mechanically 180° out of phase with those of the other class, which will interfere with the proper functioning of the device, and may even cause its destruction.

In the case of other hemihedral crystals which occur only in right-handed or left-handed forms, as the case may be, such for

example, as Rochelle salt, it is not necessary to separate the forms. After the component crystals have been selected, I may then proceed to form an opening through each of the component crystals, parallel to the *c*-axis, and preferably symmetrically disposed within the crystal in any suitable way, as for example, by drilling or by cutting the crystal, fluting it and cementing the parts together again. After the crystals have been selected and provided with openings as described, I may then proceed to build up the composite structure by providing an elastic, preferably metallic, member, adapted to withstand sufficient tension to place the crystals under the desired compression. A base plate will preferably be provided, adapted to receive and secure one end of the elastic member.

The composite device may then be built up by placing the crystals one after another upon the elastic member by passing the same through the hole in the crystal. After a sufficient number of component crystals have been mounted on the elastic member to provide the desired size of composite device, a suitable compression carrying member, such as a metallic plate, may be mounted upon the elastic member bearing against the uppermost crystal and the desired compressive force exerted upon the device by means of a suitable nut which may be formed to engage threads on the elastic member.

The component crystals, when arranged as described, will be lined up in a line parallel to the *c*-axis of the crystals. They may likewise be lined up in line normal thereto, as well, in which case, a suitable compression carrying member resting upon the entire outermost row of crystals will be used so as to distribute the stresses uniformly upon all of the crystals.

It may be found desirable in the case where considerable number of crystals are to be used, to provide a plurality of elastic members spaced at the various points with respect to the composite crystal, whereby a more uniform distribution of the stresses may be effected. It may also be found desirable to provide a plurality of composite devices on the same base, and so arranged as to work each with the other.

Electrodes and leads thereto may be provided, arranged as described in my application above referred to, and the clamping bolt may be used as an internal electrode, if desired.

Also, for the purpose of mechanically reinforcing the crystals at the points of mechanical contact, metallic reinforcing plates may be arranged upon the crystals, which plates may be used as electrodes if desired. As an alternative, the crystal, or salient portions thereof, may be reinforced by the application of "melt" thereto, said "melt" comprising Rochelle salt fused at a temperature controlled according to the amount of water it is desired to retain in the "melt".

A suitable acoustic diaphragm, such for example as a relatively rigid cone will be secured at some non-nodal point with respect to the mechanical vibration of the crystal device, and preferably in such manner that torsional vibration of the crystal causes axial or reciprocal vibration of the diaphragm. More than one diaphragm may be provided if desired; more especially, in the case where a plurality of crystal devices are mounted upon the same base plate, an acoustic diaphragm may be secured to each crystal device and so arranged as to vibrate in such manner as to give rise to compression or rarefaction waves starting in opposite directions simultaneously from the same sound source.

Referring now more particularly to Fig. 1, 1, 2, and 3, designate separate component piezo-electric crystals. A base plate 4 is provided having depression 4^a on the entire side, adapted to permit the mounting of a nut thereon, as will hereinafter be explained. Each of the crystals is provided with an opening extending through the crystal parallel to the *c*-axis and preferably symmetrically disposed with reference to the crystal. This opening may be formed by drilling through the crystal with a drill of the proper size, or it may be formed by sawing through the crystal parallel to the *c* and *b* axes and cutting corresponding grooves in the thus exposed crystal surface, after which the two parts of the crystal are cemented together: for example by means of Rochelle salt "melt".

A corresponding opening is provided through the base plate 4 and a cap or stress distributing member 6 is provided, also having a hole formed therein, and being of a suitable configuration to rest upon the outer surface of the crystal 3 and distribute the stress uniformly over the surface thereof. An elastic securing member or tie rod 5, preferably of metal, having a head 6 formed on one end and having suitable threads on the other end, is provided, of the proper diameter, to pass through the holes of the crystals and base plate.

A suitable acoustic diaphragm 60, which may be in the shape of a cone, of fibrous material such as paper, is mounted upon cap or stress distributing member 6, provided with an extension 6^a. The diaphragm 60 may be secured to the extension 6^a in any desired manner: for example, the arm 6^a may be drilled to receive a link 62, to which is secured a preferably metal carrier plate shaped to receive the center of the cone 60, which may be secured thereon, as for example, by bolting, gluing or shellacking.

The cap or stress distributing member 6 carrying the cone is placed upon the tie rod 5 after which the crystals 3, 2, and 1, are placed thereon; finally the base plate is placed

thereon, and a suitable nut 8 run down in depression 4ª, the cooperation of which with the threads of the tie rods permits placing the desired amount of compression upon the crystals.

Suitable electrodes and leads (not shown) will be provided at the proper poles on each of the individual crystals, for impressing electromotive forces upon the individual crystals, or for drawing therefrom the charges generated by the vibration of the crystal device. As an example of a suitable electrode construction, the tie rod 5 may constitute a common internal electrode, and individual girdle electrodes in the form of a belt of metal foil or gauze may be applied to each crystal around the exterior thereof, all of which girdle electrodes may be connected together. The piezo-electric acoustic device so constituted is ready for use and will function either as a means for converting electrical waves into sound, or as a means for converting sound waves into electrical waves by reason of the torsional vibration of the crystal device: that is to say, if an electromotive force be impressed upon the crystal device, one end of the same will tend to rotate with respect to the other end and will thereby cause substantial reciprocation of the cone 60, or in the case of sound waves impinging upon the cone, these will cause reciprocation of the cone, which, in turn, will cause torsional stress in the crystal device, producing fluctuations of electromotive force corresponding thereto, and in either case the oscillations impressed upon or derived from the crystal device may be amplified, as by thermionic amplifiers, to the extent necessary or desirable.

Referring now to Fig. 2, I have shown the manner of reinforcing the component crystals against mechanical stress. In this instance, 10, 11, 12 and 13 designate solidified coatings of "cement" or "melt", the former comprising Rochelle salt from which about one fourth of the water has been removed, and the latter comprising Rochelle salt heated to a temperature controlled in accordance with the amount of water it is desired to retain in the salt. These coatings may be brushed or otherwise applied to the salient points or planes of the crystals to build up a reinforcing structure, and allowed to harden before the crystals are assembled. If necessary, the crystals may then be ground to remove excess material and leave smoothly fitting cooperating faces.

Also, metallic plates of the proper shape to rest upon a large crystal area may be used, which may form end electrodes for the component crystals.

Referring now to Fig. 3, I have shown a piezo-electric acoustic device assembled in a similar manner, from crystals 15, 16 and 17, of different shape. In this instance, a filler block 18 may be provided under cap 6, for the purpose of distributing the stress uniformly over the upper surface of crystal 17.

Referring now to Fig. 4, I have shown a modification in which a relatively large number of crystals are utilized, arranged in lines parallel to the *c*-axis and also in lines normal thereto, and in which a plurality of tie rods are utilized. In this figure, 20 designates a suitable base plate, provided with a recess 20ª in the under side.

The crystals 23, 24, and 25, etc., are built up and arranged in the manner dictated by the size and shape and number of the various component crystals with the *c*-axes parallel, so as to form a composite device of the size and shape desired. A cap member 30 of the proper size and shape to contact with the top surface of the composite crystal structure is provided, and member 30 as well as the crystal and base plate, are provided with suitable openings, permitting the passage of tie rods 31, 32 and 33 formed on their upper ends with heads 34, 35 and 36, and threaded on their lower ends to accommodate nuts 37, 38 and 39, by means of which the cap may be drawn down upon the composite structure to place the desired compressive force upon the crystals.

The cap 30 will preferably be provided with an extension 30ª, upon which may be secured a diaphragm 60 in a manner previously described.

Referring now to Figs. 5 and 6, I have shown a pair of composite crystal devices 50 and 51, which may be constructed in a manner similar to Figs. 1, 2 or 3, but mounted upon a single base plate 52, and provided with arms 53 and 54 extending toward each other. The arms may be in line with each other, and their adjacent ends slightly spaced from each other, or they may be arranged parallel but laterally offset from each other with their adjacent ends slightly overlapping as shown in Fig. 6, whereby a maximum motion of the two arms may be produced in response to the impression of an electromotive force upon the device, or a maximum charge may be developed by the application of force to the arms.

A suitable diaphragm such as cone 65 may be secured to the arm 53 in a manner already described, and a similar cone 66 secured to the arm 54, with their apexes pointed toward each other.

If the crystals are operated in parallel, that is to say, electrodes provided so that the impressed electromotive force is applied to all of the crystals in the proper sense, each of the crystals will tend to vibrate in the same direction thereby producing relative motion of the diaphragms 65 and 66, 180° out of phase, whereby compression waves may be generated on each side of the device simul-

taneously and similarly for rarefaction waves.

If it is desired to operate the two diaphragms 65 and 66 mechanically in phase, the connection to one of the composite crystal devices may be reversed, which will accomplish the desired result.

While I have shown and described certain preferred embodiments of my invention, it is understood that modifications and changes may be made without departing from the spirit and scope of my invention, as will be understood by those skilled in the art.

I claim:

1. An acoustic device comprising, in combination, a composite piezo-electric device comprising a plurality of chemically and optically similar piezo-electric crystals, means for clamping said crystals in a single entity, said clamping means passing internally through said plurality of crystals, said crystals being so arranged that piezo-electric torsional vibrations of said individual components may be integrated, and an acoustic diaphragm secured to said composite device at a point of maximum piezo-electric response in a manner such that torsional vibration of said device effects vibrations of said diaphragm.

2. An acoustic device comprising in combination, a composite piezo-electric device comprising a plurality of chemically and optically similar piezo-electric crystals of different sizes, metallic clamping means passing internally through said plurality of said crystals, said crystals being so arranged that piezo-electric torsional vibration of said individual components may be integrated, and an acoustic diaphragm secured to said composite device at a non-nodal point thereof in a manner such that torsional vibration of said device effects reciprocatory vibration of said diaphragm.

3. An acoustic device comprising, in combination, a composite piezo-electric device comprising a plurality of chemically and optically similar component piezo-electric crystals of heterogeneous size and shape, an elastic member passing internally through said plurality of crystals, said crystals being so arranged that piezo-electric torsional vibrations of said component crystals may be integrated when electro-motive forces are impressed upon said component crystals, a cap secured to one of said crystals in a manner to be vibrated therewith, and an acoustic diaphragm secured to said cap in such manner that vibration of said cap effects vibration of said diaphragm.

4. An acoustic device comprising, in combination, a composite piezo-electric device comprising a plurality of chemically and optically similar component piezo-electric crystals of heterogeneous size and shape, a plurality of spaced elastic members passing internally through said plurality of crystals, said crystals being so arranged that piezo-electric torsional vibrations of said component crystals may be integrated, when electro-motive forces are impressed upon said component crystals, a cap secured to the outermost layer of crystals in a manner to be vibrated therewith, and an acoustic diaphragm secured to said cap in such manner that vibration of said cap effects vibration of the said diaphragm.

5. An acoustic device comprising, in combination, a base plate, a composite piezo-electric device comprising a plurality of chemically and optically similar component piezo-electric crystals of heterogeneous size and shape, arranged with their *c*-axes parallel and with a plurality of crystals disposed in rows parallel to the *c*-axes thereof, a cap member disposed upon the uppermost layer of crystals, means for physically securing said base plate, said component crystals, and said cap together comprising a plurality of spaced tie rods passing internally through a plurality of said crystals, and an acoustic diaphragm secured to said device at a non-nodal point with respect to torsional vibration thereof, in such manner that torsional vibration of said device effects vibration of said diaphragm.

6. An acoustic device comprising, in combination, a composite piezo-electric device comprising a plurality of chemically and optically similar component piezo-electric crystals arranged with their *c*-axes parallel and with a plurality of crystals in line parallel to the *c*-axes thereof, a cap, means for securing said component crystals and said cap in a single entity, comprising an elastic tie rod passing internally through said composite device, and an acoustic diaphragm secured to said device at a non-nodal point with respect to torsional vibration thereof, in such manner that torsional vibration of said device effects vibrations of said diaphragm for the reproduction of sound.

7. An acoustic device comprising, in combination, a composite piezo-electric device comprising a base plate, a plurality of composite piezo-electric devices mounted on said base plate, each of said devices comprising a plurality of chemically and optically similar component piezo-electric crystals in stacked relation arranged with their *c*-axes parallel, said plurality of stacked crystals being disposed in rows parallel to said axes, a cap, and means for securing said components and said cap in a single entity and to said base plate comprising an elastic tie rod passing internally through each cap, row of crystals and said base plate, and an acoustic diaphragm secured to each cap.

In testimony whereof I hereunto affix my signature.

ALEXANDER McLEAN NICOLSON.