Jan. 13, 1931. A. McL. NICOLSON 1,788,405

COMPOSITE PIEZO-ELECTRIC ACOUSTIC DEVICE

Filed Jan. 11, 1927

Fig. 1

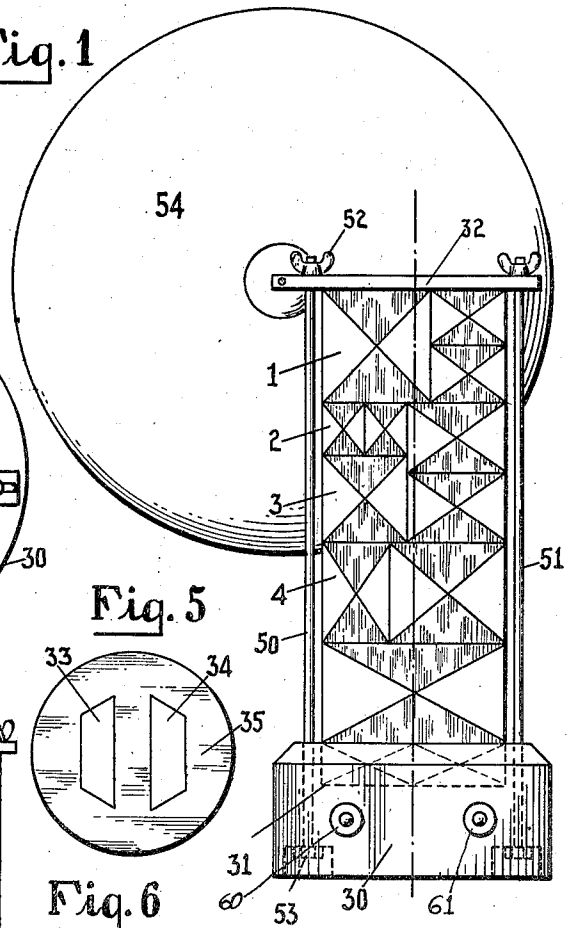


Fig. 2

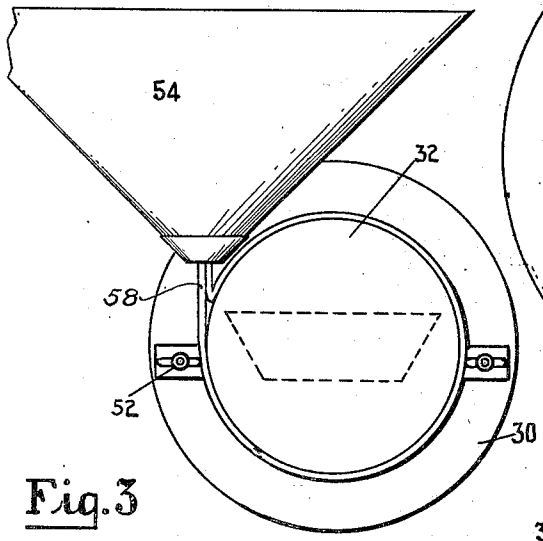


Fig. 3

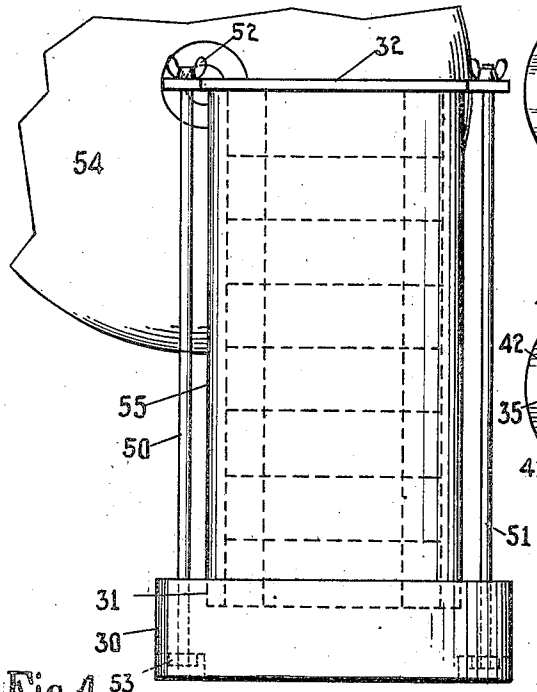


Fig. 5

Fig. 6

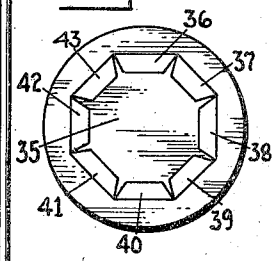


Fig. 7

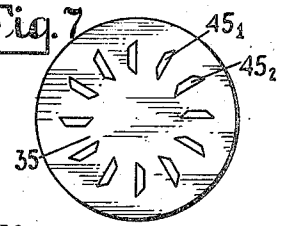


Fig. 8

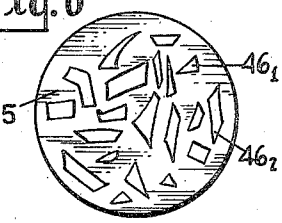


Fig. 9

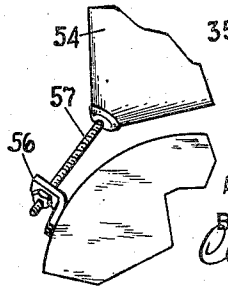
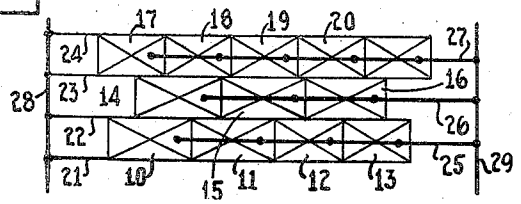


Fig. 4



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UNITED STATES PATENT OFFICE

ALEXANDER McLEAN NICOLSON, OF NEW YORK, N. Y., ASSIGNOR, BY MESNE ASSIGNMENTS, TO FEDERAL TELEGRAPH COMPANY, A CORPORATION OF CALIFORNIA

COMPOSITE PIEZO-ELECTRIC ACOUSTIC DEVICE

Application filed January 11, 1927. Serial No. 160,358.

This invention relates to a piezo-electric crystal 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. 155,899, filed Dec. 20th, 1926, entitled "Composite piezo-electric torsion device", I have shown and described a composite piezo-electric crystal device, comprising a multiplicity of chemically and optically similar heterogeneous piezo-electric crystals physically secured into a single entity, and arranged so that the piezo-electric effects of the individual component crystals may be integrated.

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 a piezo-electric 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 and characterized by extreme simplicity and reliability, 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 of high sensitivity, in which a piezo-electric element of any desired size and shape may be provided without the expense and wastage involved in the cutting or grinding of crystals to the desired size and shape.

It is still a further object of this invention to provide a generally improved device of the class described. Still further objects of this invention 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 be best understood by reference to the specification and accompanying drawing, in which:

Fig. 1 is a front elevation of one form of piezo-electric acoustic device according to my invention, showing the cover removed and the diaphragm in place.

Fig. 2 is a top plan view of another form thereof.

Fig. 3 is a front elevation thereof showing the cover in place.

Fig. 4 is a diagrammatic view of the crystal structure, which may be utilized in the piezo-electric element, and,

Figs. 5–8 are diagrammatic views normal to the *c*-axis, of additional forms of crystal structure which may be utilized in the piezo-electric crystal element.

Fig. 9 is a detail showing one method of mounting the diaphragm on the cover.

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, because they do not occur concurrently.

After the component crystals have been selected, I may then proceed to build up a composite structure by arranging the crystals in the desired fashion, being careful to orient each crystal properly with respect to the *c*-axis so that the piezo-electric effects of the various component crystals may be integrated, as more particularly described and claimed in my copending applications entitled "Composite piezo-electric crystal device", Serial No. 155,898, and "Orientation of component crystals in composite piezo-electric devices", Serial No. 155,902. Since crystals of like chemical and optical form are always analogous to either a right-handed screw thread, or a left-handed screw thread, depending on whether the crystals are dextro or lævo asymmetrical, it suffices merely to arrange the crystals with their *c*-axes parallel and with symmetrical electrodes, for applying or drawing electricity of the proper sign from the component crystals.

The electrodes may comprise plates of metal foil secured to the crystals at proper points forming mechanically and electrically opposite poles. For example, one electrode may comprise an equatorial belt of conducting material forming a loop around the crystal in a plane normal to the *c*-axis, and the other electrode may be attached to the basal plane of the crystal, as more particularly described in the applications referred to above.

Observing this requirement, the component crystals may be assembled into a composite structure in a number of ways. Referring now more particularly to Fig. 1, I have shown a number of crystals 1, 2, 3, 4, etc., assembled into a composite cylindrical structure, in which there are arranged a number of crystals in line with the *c*-axis, which is shown as a dot and dash line. The component crystals herein shown are arranged in any desired manner so as to build up a composite structure of the desired dimensions, and various sized crystals may be juxtaposed in a manner more or less analogous to that of a stone mason in fashioning a wall from stones of different size and shape.

The various component crystals may be secured together physically into a single entity in any desired manner, but I prefer to use a cement of the same elastic properties as those of the component crystals, so that stress waves will be transmitted to all of the components. In the case of Rochelle salt crystals, I prefer to use what I term "Rochelle salt cement" or a "melt" of Rochelle salt which has been melted at a temperature controlled according to the amount of water of crystallization it is desired to retain in the salt.

After the composite crystal has been formed, it may be mounted at one end in a base 30, provided with a depression 31 adapted to receive it, and secured therein by "melt" or "cement" if desired. A cap or stress distributing member 32, adapted to embrace the other end, is sufficiently rigidly secured thereto so that an acoustic diaphragm may be attached thereto so as to be vibrated by torsional vibration of the device, or so as to impart vibrations or stresses to the device. In addition, a plurality of mechanical clamping means, such as tie rods 50 and 51, may be provided passing through the base and cap, threaded to receive nuts 52 and 53 by which the crystal structure may be put under compression.

The stress plate 32 may include a metal strap 58 adapted to snugly embrace the upper end of the composite crystal device, and to it is secured an acoustic diaphragm such as a cone 54, although it will be understood that any other suitable type of diaphragm may be substituted if desired.

A modified arrangement is shown in Figs. 2 and 3, in which a cover 55 is provided for the purpose of sealing the crystal device within an airtight chamber formed by the base and by the casing.

The cover 55 may comprise a metallic member in the form of a cylinder open at one end and closed at the other, arranged to be placed over the composite crystal. The lower end of the cylinder may pass into the depression 31 in the base 30, and be sealed therein by suitable packing. The end and sides, if desired, of the composite crystal are preferably sealed to the inner side of the cover 50, in any suitable way, as for instance by Rochelle salt "cement" or "melt", in such manner that torsional vibration of the composite crystal carries with it the cover.

Suitable means for exerting compression on the crystals may be provided, such as tie rods 50 and 51, which may be passed through extensions 60 and 61 provided on the cover, and threaded nuts 52 and 53, by which the desired compression may be obtained.

The acoustic diaphragm 54 will preferably be clamped or otherwise firmly secured to the cover in such a manner that torsional vibration of the cover causes substantially reciprocatory vibration of the diaphragm and vice versa. This may be accomplished by mounting a bracket 52 upon the cover, as shown in Fig. 9, which bracket is provided with an opening adapted to receive a driving rod 57 which is suitably secured to the diaphragm 54. The rod 53 may be suitably threaded and held in position by nuts and washers as shown.

Referring now to Fig. 4, I have shown a

more regular arrangement of the component crystals. In this instance one row of crystals may consist of crystals 10, 11, 12, and 13, all arranged with their c-axes parallel, and being arranged in lines normal to the c-axes. It will be understood that a plurality of crystals may be arranged also in the same plane with crystals 10, 11, 12, and 13, but normal to the line of those crystals, thereby forming a solid structure in which there are a plurality of crystals arranged in lines normal to the c-axis and normal to each other. A second layer of crystals 14, 15, and 16 may be disposed above the first layer, and an additional layer of crystals 17, 18, 19 and 20 may be arranged. More layers may be added as desired, with the object of bringing the composite structure to the dimensions desired, corresponding electrodes (shown diagrammatically) being provided whereby corresponding poles on the component crystals may be connected together, as for example by means of leads 21, 22, 23 and 24 connected to main lead 28, on the one hand, and leads 25, 26, and 27, connected to main lead 29.

It will be uderstood that if mechanical stresses be applied to these structures, so as to torsionally stress the crystals about the c-axis, an electromotive force will manifest itself upon leads 28 and 29, and conversely, the application of an electromotive force to these leads will cause a corresponding stress of the composite crystal, whereby it will be understood that the structure may operate either as a motor or generator, and that in either case, the electrical 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 Figs. 5–8 which are diagrammatic views taken on planes normal to the c-axis of the component crystals, I have shown additional ways of arranging the various component crystals so that the piezo-electric effects of the component crystals may be integrated. In Fig. 5, it will be noted, the crystals 33 and 34 are arranged in a symmetrical arrangement, the remaining space being partially or completely filled by the binder such as "cement" or "melt" 35.

The arrangement in Fig. 6 is symmetrical, comprising crystals 36—43, and the remaining space being taken by the binder 35 as before. In the arrangement shown in Fig. 7, the various crystals 45_1, 45_2, -45_n are arranged in a ring, which may be partially or completely filled by the binder 35. The arrangement shown in Fig. 8 is a heterogeneous arrangement of crystals 46_1, 46_2, -46_n, of varying sizes and shapes, the interstices being occupied by the binder 35.

It will be understood that leads may be carried to the individual crystals through the container in any suitable way. For instance, a pair of terminals may be provided on the base, such as 60 and 61, and the leads may be taken therefrom internally therethrough in a manner such as to be entirely contained within the cover 55, when the same is placed upon the composite device.

Also, while I have referred to Rochelle salt "cement" or "melt" as the binder, it will be understood that other substances such as hard wax, etc., may be used as described in my application referred to above.

While I have shown and described certain preferred embodiments of my invention, it will be 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. In piezo-electric acoustic apparatus having a substantially uniform frequency response characteristic, in combination, a composite piezo-electric device comprising a multiplicity of chemically and optically similar component piezo-electric crystals physically secured into a single entity, said crystals being so arranged that piezo-electric torsional vibration of said individual components may be integrated, and an acoustic diaphragm, a band circumscribing said composite device at a point of maximum torsional vibration thereof and means for attaching said band to said diaphragm, in a manner such that torsional vibration of said composite piezo-electric device effects vibration of said diaphragm.

2. In piezo-electric acoustic apparatus having a substantially uniform frequency response characteristic, in combination, a composite piezo-electric device comprising a multiplicity of chemically and optically similar component piezo-electric crystals physically cemented into a single entity, said crystals being so arranged that piezo-electric torsional vibration of said individual components may be integrated, an acoustic diaphragm, and means comprising a band circumscribing said piezo-electric device for securing said diaphragm to said device in such manner that torsional vibration of said device causes reciprocatory vibration of said diaphragm.

3. In piezo-electric acoustic apparatus having a substantially uniform frequency response characteristic, in combination, a composite piezo-electric crystal device comprising a plurality of chemically and optically similar piezo-electric crystals of heterogeneous size and shape, physically secured in a unitary structure and so arranged that piezo-electric effects of said component crystals may be integrated, a base therefor, an air-tight casing mounted thereover, an acoustic diaphragm, means comprising a band circumscribing said casing for securing said diaphragm to said casing in such manner that vibration of said crystal device causes vibra-

tion of said diaphragm, and means for applying compression to said device.

4. In a linkage system for mechanically connecting an acoustic diaphragm to a piezo-electric device, a band circumscribing said piezo-electric device at a point of torsional vibration thereof, and means for attaching said band to said diaphragm.

5. In a linkage system for mechanically connecting an acoustic diaphragm to a piezo-electric device comprising a multiplicity of chemically and optially similar component piezo-electric crystals physically cemented into a single entity, said crystals being so arranged that piezo-electric torsional vibration of said individual components may be integrated, a band circumscribing said piezo-electric device in a plane of torsional vibration thereof and means for attaching said band to said diaphragm.

6. In a linkage system for mechanically connecting an acoustic diaphragm to a piezo-electric device mounted in a casing in such manner that mechanical vibrations of said piezo-electric device are transmitted to said casing, a band passing around the periphery of said casing, and means for attaching said band to said diaphragm.

In testimony whereof I hereunto affix my signature.

ALEXANDER McLEAN NICOLSON.