

June 4, 1940.

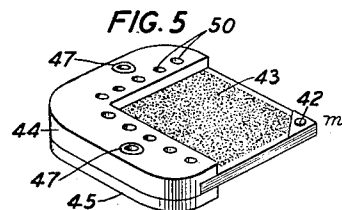
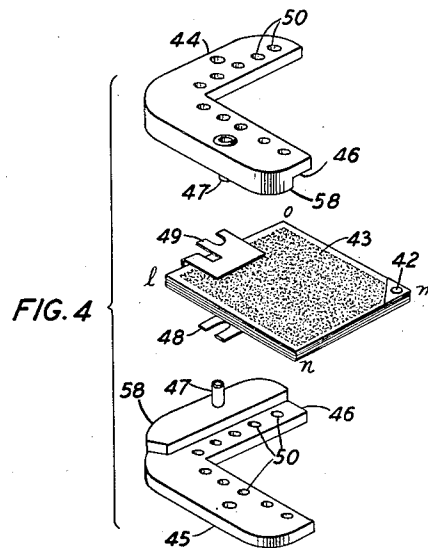
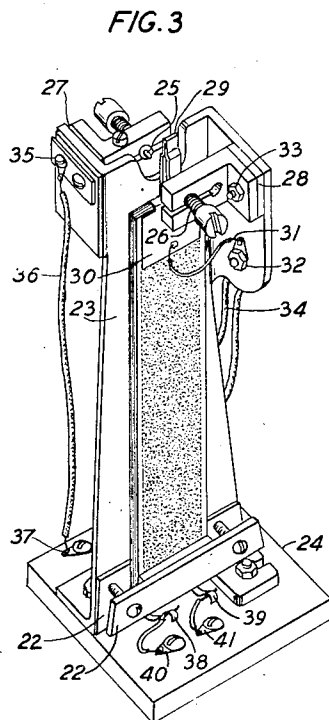
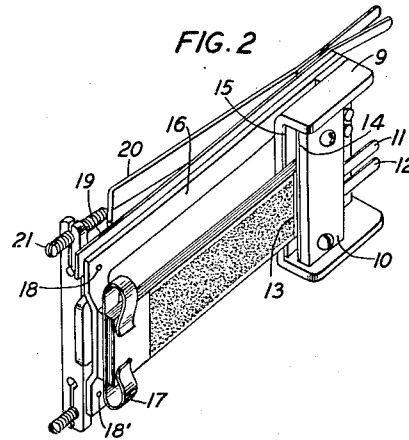
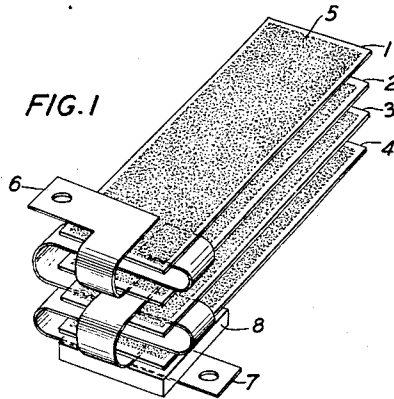
T. G. KINSLEY

2,203,332

PIEZOELECTRIC DEVICE

Filed Sept. 9, 1938

2 Sheets-Sheet 1



INVENTOR
T. G. KINSLEY
BY
E. V. Briggs
ATTORNEY

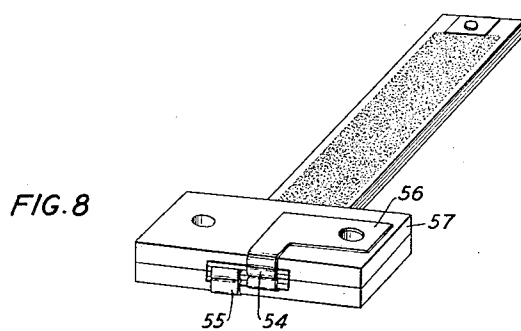
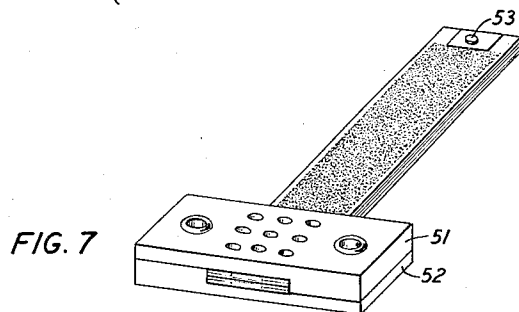
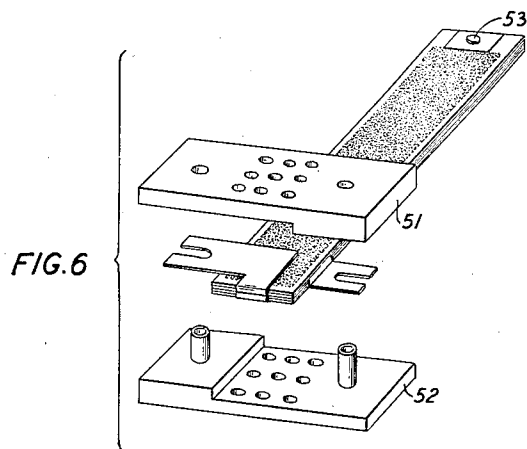
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INVENTOR
T. G. KINSLEY
BY
E. V. Briggs
ATTORNEY

UNITED STATES PATENT OFFICE

2,203,332

PIEZOELECTRIC DEVICE

Thomas G. Kinsley, Whitehouse, N. J., assignor
to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application September 9, 1938, Serial No. 229,131

8 Claims. (Cl. 171-327)

This invention relates to piezoelectric relays. An object of the invention is to provide simple and compact electric terminal apparatus for a piezoelectric relay unit comprising a plurality of superposed plates of piezoelectric material.

Another object of the invention is to provide a "universal" type of piezoelectric relay actuating unit which may be available for various purposes and mountings without likelihood of damage to the fragile piezoelectric plates or to their delicate leads.

According to this invention a plurality of piezoelectric plates having their opposite faces suitably coated with conducting material to constitute electrode faces are superposed in a stack. One end of a very thin foil tape is placed in contact with one of the outer conducting electrode surfaces and the remainder of the tape is carried in folds into the alternate spaces between plates. A second similar tape is placed in contact with the other outer conducting electrode surface and is folded into the spaces intermediate those occupied by the first tape. A pair of conducting clamping members insulated from each other are used to clamp the entire assemblage and to serve as electrical terminals.

In the drawings,

Fig. 1 illustrates a loosely stacked assemblage of four piezoelectric plates;

Fig. 2, a relay employing the assemblage of Fig. 1;

Fig. 3, a modified relay employing a different mounting structure;

Fig. 4, the component elements of a unit having piezoelectric plates clamped at two margins to utilize a warping action;

Fig. 5, the assembled operating unit of Fig. 4;

Fig. 6, the component elements of another modification of the relay unit of Fig. 2;

Fig. 7, the assembled operating unit of Fig. 6; and

Fig. 8, a modification of the structure of Fig. 7.

Referring to Fig. 1, which shows the manner in which the piezoelectric plates and the conducting terminals are assembled, plates 1, 2, 3 and 4 of piezoelectric material may, for example, consist of Rochelle salt, the plates being cut perpendicular to the X axis of the virgin material and at an angle of 45 degrees to the Y and Z axes for longitudinal extension and contraction. Each plate is provided on its two opposite principal faces with a conducting electrode 5 which may consist of a thin metallic coil sheet or of a coating of colloidal graphite obtained by spraying on a graphite suspension such

as the well-known aquadag. Terminal element 6 consists of an extremely thin strip of metallic foil which is folded so as to engage the upper surfaces of plates 1 and 3 and the lower surfaces of plates 2 and 4. Another terminal strip 7 is folded in similar manner to engage the lower surfaces of plates 1 and 3 and the upper surfaces of plates 2 and 4. The margins of the plates 1, 2, 3 and 4 are free from conducting material and an insulating spacer 8 is interposed between the lower end portions of terminal strips 6 and 7 so that the terminal strips are completely insulated from each other.

The strips 6 and 7 are attached to the Rochelle salt plates and the plates are cemented together to form a solid slab. For this purpose clear "Duco" manufactured by the DuPont Company has been found suitable. In order to prevent dehydration of the plates of piezoelectric material and maintain high surface resistance the edges, outer surfaces and spaces between connections may be painted with a water-proof insulating material such as Victron lacquer.

In operation the piezoelectric plates 1 and 2 are caused to extend at the same time that plates 3 and 4 contract, thus making the cemented-together assemblage flex laterally according to the direction of the applied electromotive force. This requires that plates 1 and 2 be relatively reversed so that an electric field downwardly directed through plate 1 will cause a longitudinal change in the same direction as an upwardly directed field through plate 2. In like manner, plates 3 and 4 are arranged to extend or contract together and in reverse manner to plates 1 and 2. The elongation or shrinkage of a crystal slab of this orientation is inversely proportional to the thickness for a given voltage. Accordingly, the two pairs of thin plates for the same applied voltage provide twice the amplitude of displacement obtainable from a device of otherwise identical dimensions composed of only one pair of elements each twice as thick. This feature of thin plates or laminations of piezoelectric material may be carried as far as desirable by the use of a greater number of plates and is limited only by the thickness to which the plates may be ground or machined.

The unit of Fig. 1 is shown assembled with its armature contacts in Fig. 2. The terminal ends of the plates are clamped together by a pair of clamping members 9 and 10 which also tightly clamp the terminals 11 and 12 respectively in contact with terminal strips 6 and 7. The outer electrodes or coatings 5 of conductive material

may be overlaid as indicated at 13 by a conducting foil to assist in electrically connecting the graphite coating to the terminal. Insulating spacers 14 and 15 may also provide a high degree of insulation between the terminals. A flexible U-shaped armature member 16 may be connected to clamping member 9 by screws and to the free end of the plates by an integral clip 17 which extends partly around the plates to constrain the armature member to move with the plates. A thin sheet of dielectric material between clip 17 and the outer coatings 5 precludes short circuiting. Armature member 16 may carry a contact member 18 of which only the stem is shown in Fig. 2, the contacting portion of the member 18 cooperating to close a local circuit upon engagement with a contact, not shown, on the contiguous face of a supporting element 19 which is fastened at one end to the clamping member 9 and is adjustably supported at the end near contact 18 by a spring 20, the position of which is determined by the setting of an adjusting set screw 21 to determine the spacing between contacts in the open circuit position of the relay armature. If desired, a second contact 18' may be arranged in parallel to contact 18 with a similar contact spacing adjusting device. It will, therefore, be apparent that upon application of an electromotive force of suitable magnitude and polarity to terminals 11 and 12 the plates will flex to cause armature 16 to carry contact 18 into engagement with the stationary contact.

In a device of the kind disclosed in Fig. 1, the plates were constructed from Rochelle salt as described with a length of about 3 inches, a breadth of about $\frac{5}{8}$ inch and a thickness of approximately .015 inch. With 75 volts applied a force of the order of 4 grams was exerted between the contacts after operation of the relay.

Fig. 3 illustrates a modified form of mounting of the piezoelectric unit of Fig. 1. The assemblage of piezoelectric plates is provided with terminal connections as described in connection with Figs. 1 and 2 and is clamped between clamping members 22 which are attached to a vertical frame 23 mounted on an insulating base block 24 and serving to carry adjustable back contact member 25 and front contact member 26. The contact members are mounted in supports which are insulated from frame 23 by the insulation sheets 27 and 28 respectively. A movable contact element 29 mounted astride the free end of the piezoelectric plate assemblage is insulated therefrom by thin sheets of mica dielectric 30 and is electrically connected by flexible lead 31 to binding post 32. Front contact 26 is electrically connected through screw 33 insulated from the frame 23 with a conductor 34 connected to a terminal mounted on the insulating base block 24. Back contact member 25 is connected through its support, an insulated screw 35 and lead 36 to terminal 37. The input terminals 38 and 39 which correspond to terminals 11 and 12 of Fig. 2 are respectively connected to terminal members 40 and 41 mounted on the base block. The manner of operation of this device to alternately close two different circuits on its front and back contacts in the manner of a polarized relay depending upon the polarity of the impressed electromotive force will be apparent.

Fig. 4 shows a disassembled view and Fig. 5 an assembly view of a multiplate piezoelectric device having a construction somewhat similar to that of the device of Fig. 2 in so far as the ar-

range of plates and electrical connections is concerned. The piezoelectric plates may consist of Rochelle salt cut perpendicular to the X axis and with their margins parallel to the Y and Z axes. The two upper plates may be so arranged that they tend to extend in a diagonal direction through the corners *l* and *m* and at the same time to contract along the diagonal *o n* while the lower two plates are arranged for the converse operation. Accordingly, the assemblage of plates cemented together as described in connection with Fig. 2 will, upon application of an electric field, undergo a warping action such that if the edges *l o* and *l n* be held fixed the corner *m* will be displaced in an upward or downward direction and contact 42 carried thereby will be moved into or out of engagement with a stationary contact.

The piezoelectric plate assemblage 43 is provided with terminals in the same manner as is the structure of the preceding figures. In order to rigidly mount the device, two identical clamping members 44 and 45 are used. They may be molded of Bakelite or other suitable insulating molding material. Each is provided with a recessed shoulder portion 46 with an adjacent upstanding projection 58 to receive the piezoelectric plates. The clamping members may be fixed together by means of grommets 47 which may be molded into the clamping members and in assembly of the device may be spun in well-known manner. Terminals 48 and 49 may each be provided with U-shaped tongues which contact respectively with the peripheries of the two grommets to simplify electrical connections.

Rochelle salt crystals are very easily cracked or broken in clamping if the surfaces are not extremely true and flat. It is therefore advisable to so proportion and dimension the clamping members 44 and 45 as to allow space for the crystal and some clearance. The extra space may then be filled with a cement which will dry hard when given sufficient ventilation. Each of the members 44 and 45 is provided with a series of ventilating apertures 50 to permit drying of the cement used to hold the piezoelectric plates and the Bakelite unit rigidly together. The filling of the space with cement increases the efficiency of the unit by eliminating any freedom which might otherwise exist at the clamped base due to irregularities in the crystal unit or the mounting details.

It will be apparent that the assembled unit of Fig. 5 may be very simply and inexpensively made and that it will be rugged and will afford considerable protection to the crystal elements against mechanical injury. It is, moreover, capable of mounting and use in a wide variety of structures in which an old unit may be quickly replaced by a new unit whenever necessary or desirable.

Figs. 6 and 7 illustrate a modified form of relay unit operating by virtue of longitudinal or extensional displacements to cause lateral flexure in the manner of the structure of Figs. 1, 2 and 3. The multiplate assemblage is held clamped and cemented between identical molded members 51 and 52. The grommets serve in this instance both as rivets and as electric terminals. It will be understood that the free end of the piezoelectric plates may carry a contact as at 53 or a contact of the type illustrated in Fig. 3 may be provided. The unit of Fig. 7 is adapted to be used in a structure such as that of Fig. 3 and when provided with both front and back contacts may be employed to close either of two circuits as in the apparatus of Fig. 3.

Fig. 8 discloses a modification of the structure of Fig. 7 in which the terminal strips 54 and 55 are both brought out at the end of the piezoelectric plate with sufficient lateral separation to provide the necessary insulation. The end tabs 56 may be cemented to their respective base members 57 in addition to being held by the grommets or the grommets alone may be employed to hold them in position. It will be obvious that this structure may, like that of Fig. 7, be provided with one or two contacts and may be mounted in a structure similar to that of Fig. 3.

Various circuits for operating piezoelectric relays and for permitting electric charges to be applied and withdrawn in order to determine the operation and release periods are disclosed in W. P. Mason, application Serial No. 131,160, filed March 16, 1937, relating to Piezoelectric apparatus and circuits; W. P. Mason, application Serial No. 173,770, filed November 10, 1937, relating to Vibrating piezoelectric relays; and D. G. Blattner and L. Vieth application Serial No. 228,357, filed September 3, 1938, relating to Delay type piezoelectric relays.

What is claimed is:

1. An electrostatic device comprising a flat plate of piezoelectric material, conductive surfaces applied to the opposite faces and insulated from each other and a rigid casing holding a portion of the periphery of the plate in fixed position, the remaining portion of the periphery being free to flex, said casing comprising two similar rigid clamping members each having a spacing projection to form a recess between the members to receive the plate of piezoelectric material, the projection on one member being interrupted for a portion of the length of the member and the projection on the other member occupying only the space provided by the interruption of the projection on said one member and terminals connected respectively to the conductive surfaces and mounted on the casing.

2. A device according to claim 1, characterized in this, that the flat plate is rectangular and that the casing extends along and holds two adjacent margins of the plate leaving the other two margins free to flex.

3. An assemblage of piezoelectric plates each having conductive surfaces associated with their principal plate faces and said plates being stacked with the conductive surfaces in juxtaposition, two flat terminal strips of coating foil each having folds to enter the spaces between the plates and make contact with the conducting surfaces, the folds of one strip alternating with the folds of

the other with respect to the spaces which they occupy and means for rigidly holding the assemblage together.

4. A piezoelectric relay comprising a pair of identical preformed clamping members adapted to fit together to provide an intervening recess in which a piezoelectric plate may be clamped, the members each being provided with apertures adjacent the recessed portion to permit drying of adhesive used to mount the plate, a piezoelectric plate positioned in the recess between the members and means fastening the clamping members together to tightly clamp the piezoelectric plate in position.

5. In combination, a pair of identical preformed clamping members each having an upstanding projection extending along a portion only of its length whereby a recess is formed between them, a plurality of piezoelectric elements fitting into the recess and having conductive surfaces, means for impressing an electric charge between the surfaces on the opposite principal faces of said elements, and means cooperating to rigidly hold the clamping members in engagement with the piezoelectric elements.

6. An assemblage of flat piezoelectric plates each having its two opposite principal faces overlaid with a layer of conducting material, the plates being stacked with their respectively adjacent conductive surfaces in juxtaposition, two flat terminal strips of coating foil, each having folds to enter the space between the plates and make contact with the conducting surfaces, the folds of one strip alternating with the folds of the other with respect to the spaces which they occupy, a pair of rigid clamping members each engaging the stack on one of its opposite principal faces, the outer free end of one terminal strip extending partly along and attached to one clamping member to be protected thereby and the outer free end of the other terminal strip similarly extending along and attached to the other clamping member.

7. The combination according to claim 6, characterized in this, that the extending free ends of the terminal strips are covered by the respectively adjacent clamping members.

8. The combination in accordance with claim 6, characterized in this, that the extending free ends of the terminal strips are electrically connected respectively to terminals mounted on the respectively adjacent associated clamping members.

THOMAS G. KINSLEY.