Oct. 16, 1934. W. G. CADY 1,977,169

PIEZO ELECTRIC SYSTEM

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FIG. 1

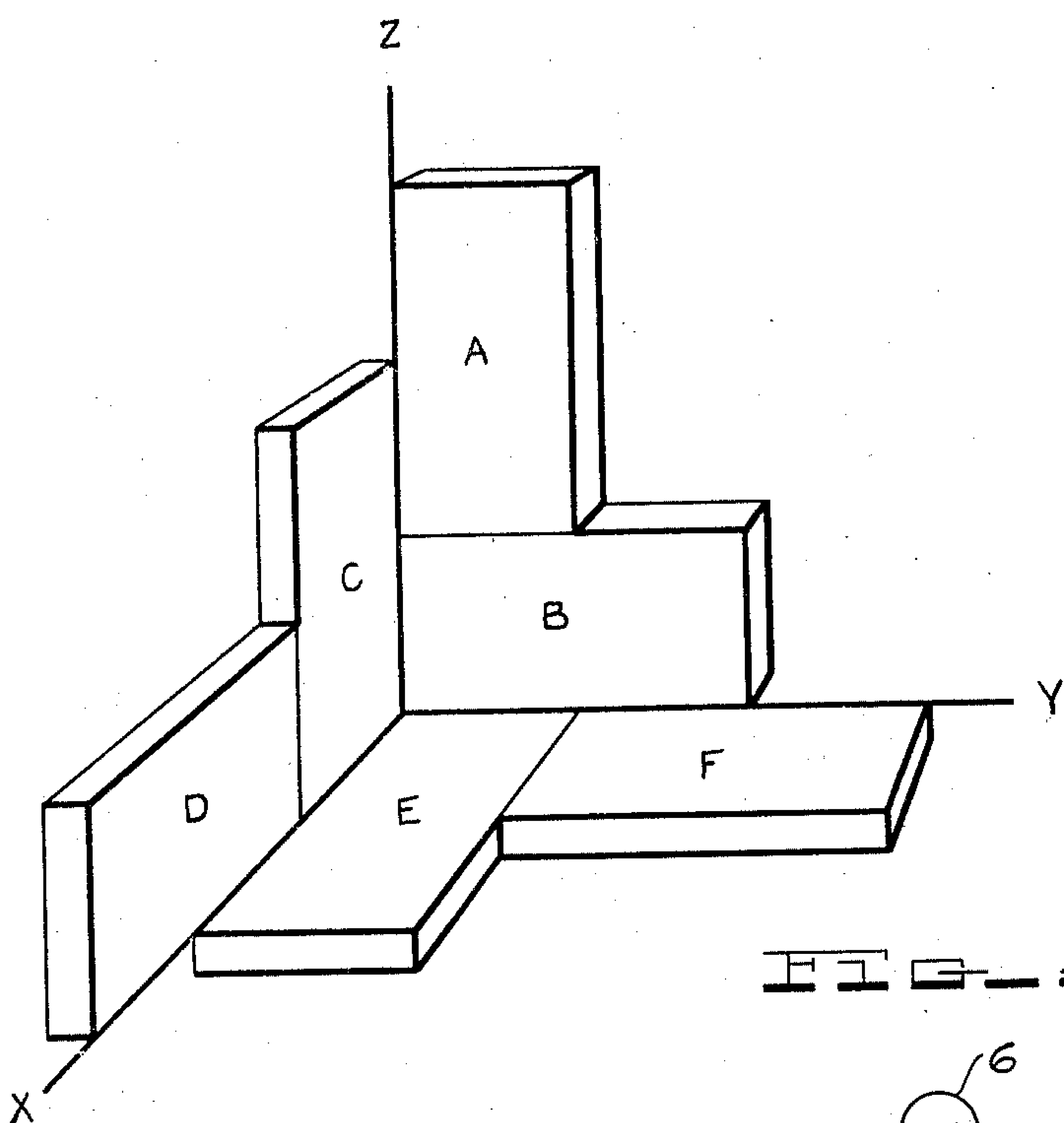



FIG. 4

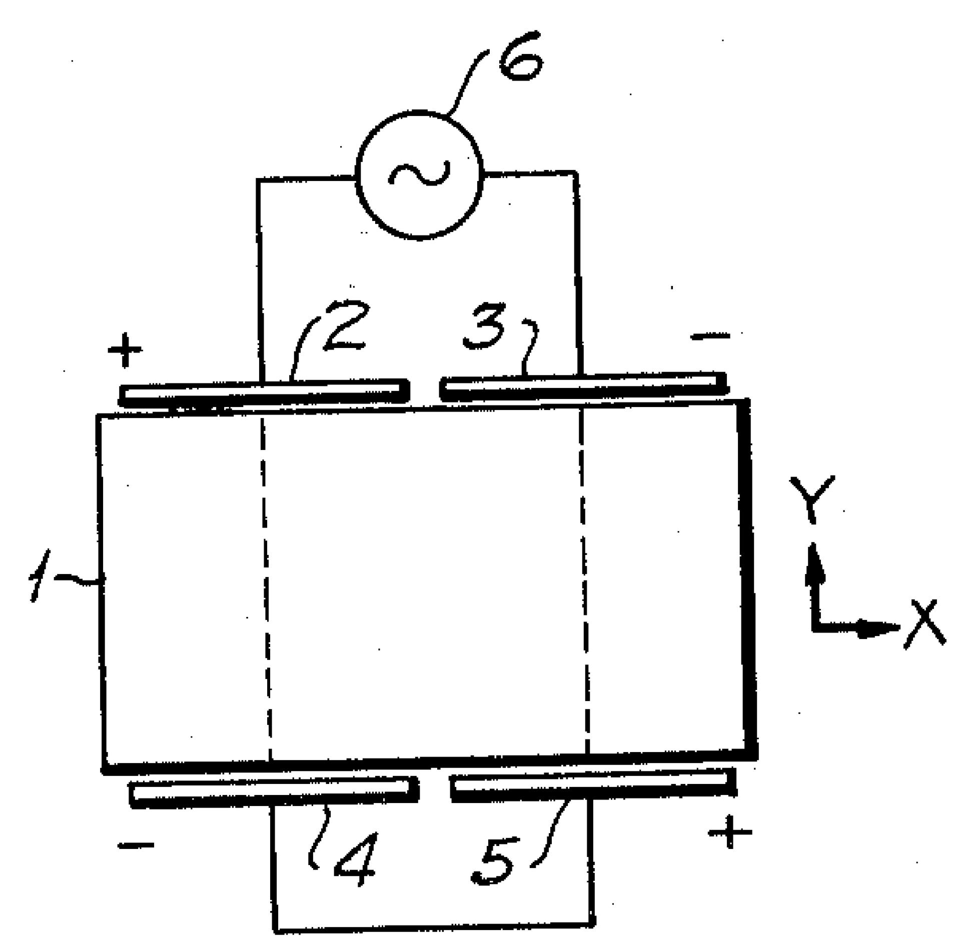



FIG. 2

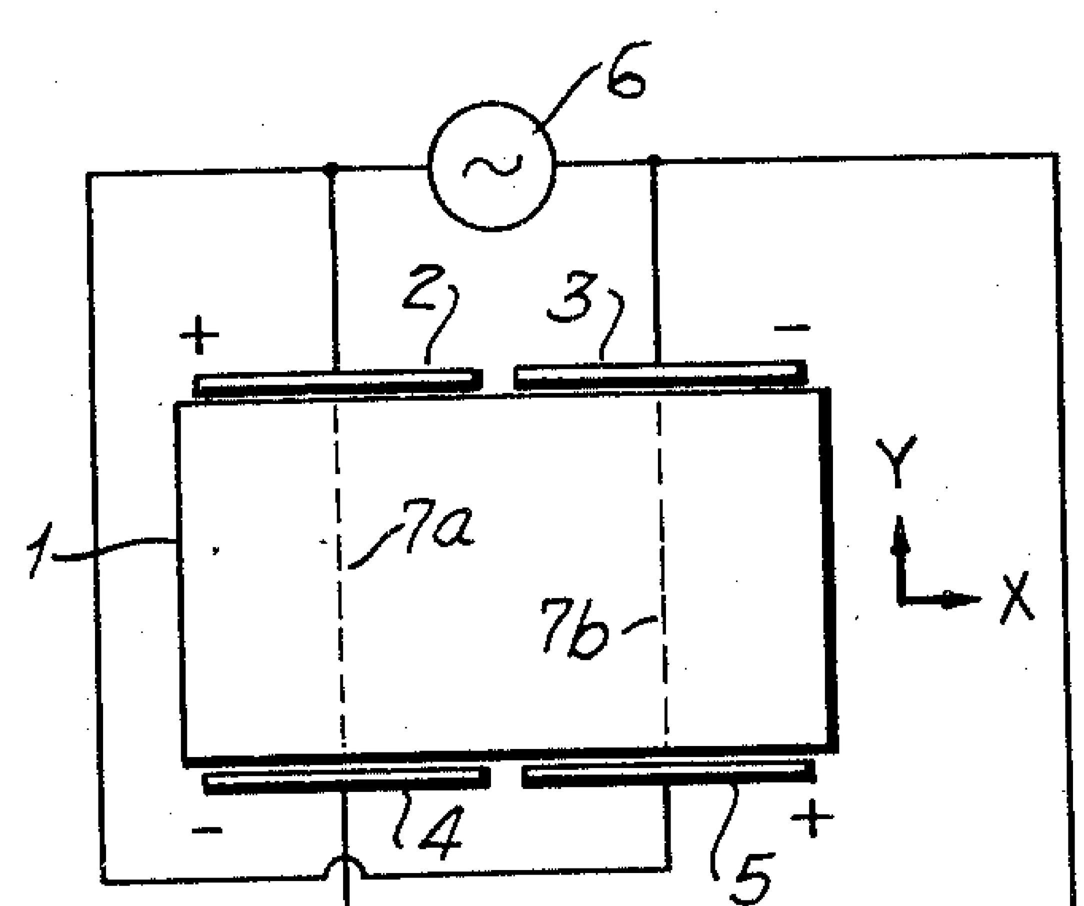



FIG. 5

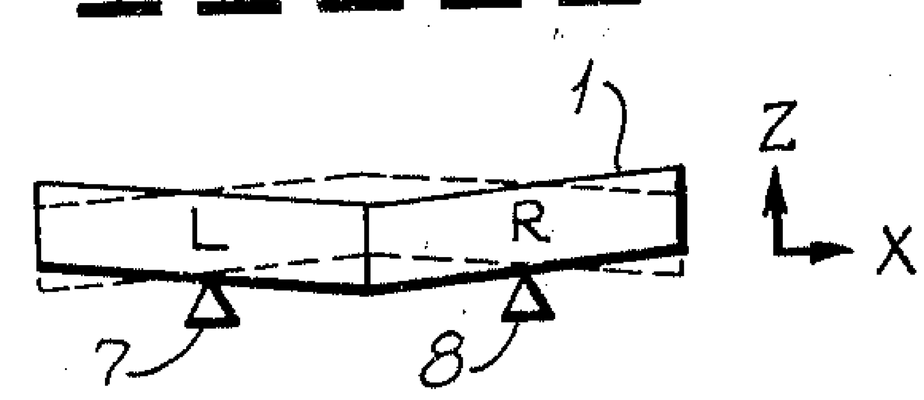
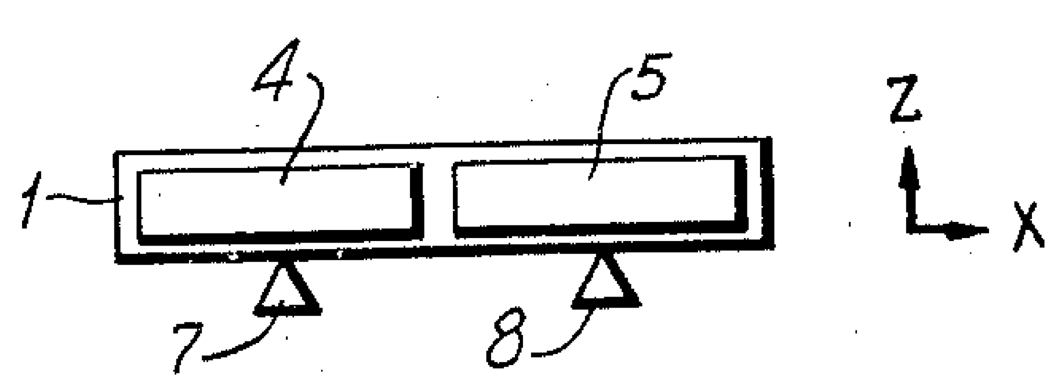



FIG. 3

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PIEZO ELECTRIC SYSTEM

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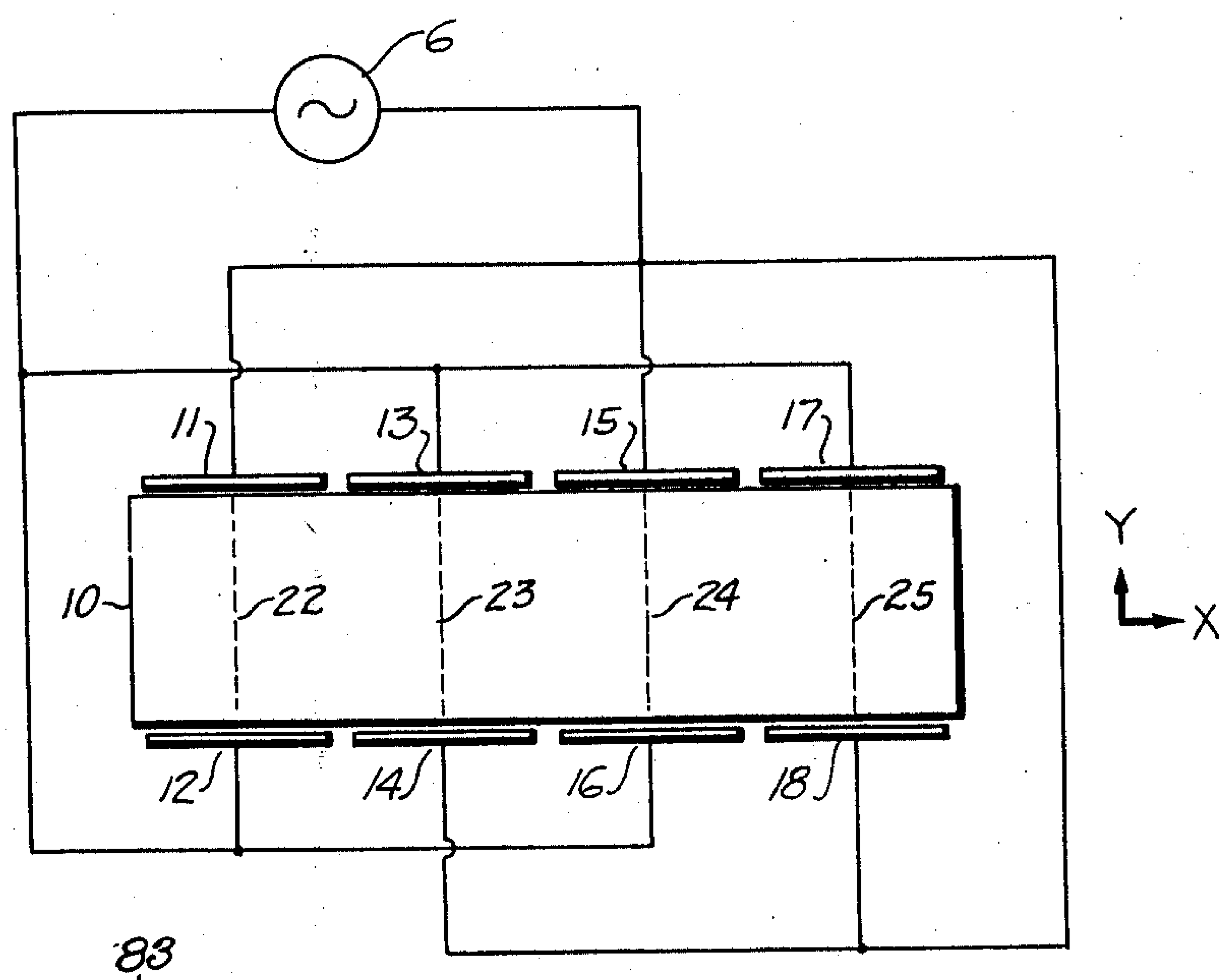
FIG_6



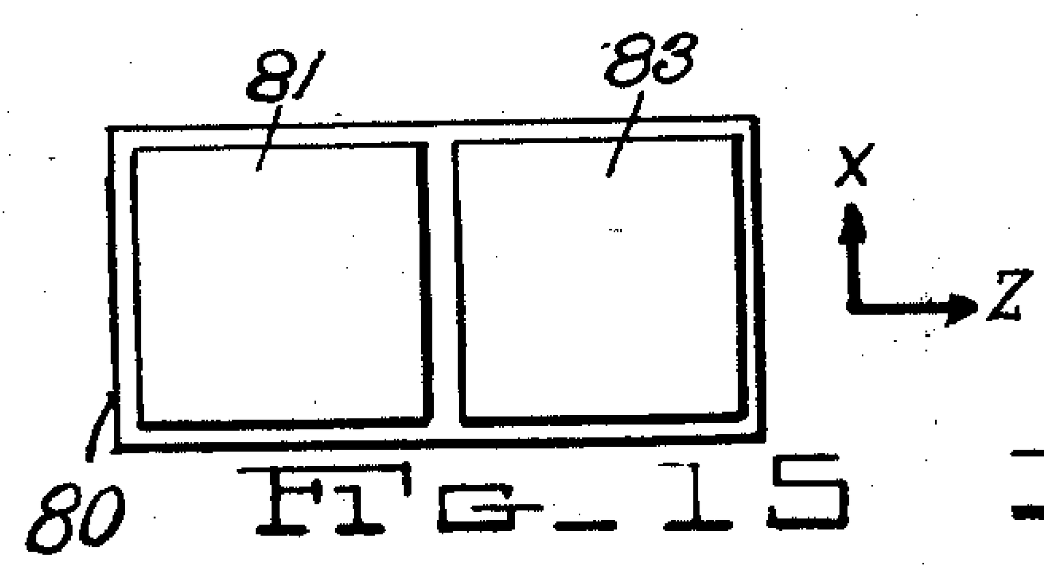




FIG_15

FIG_17

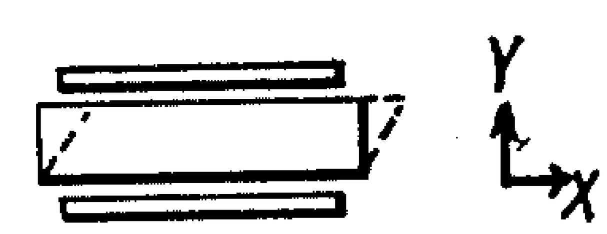



FIG_7

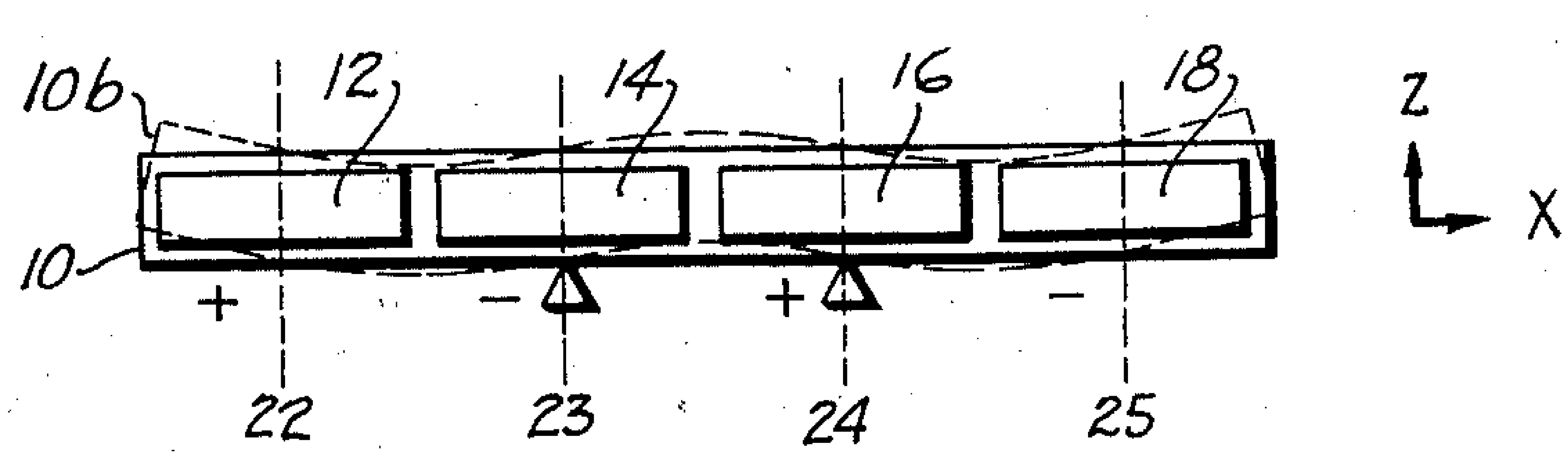
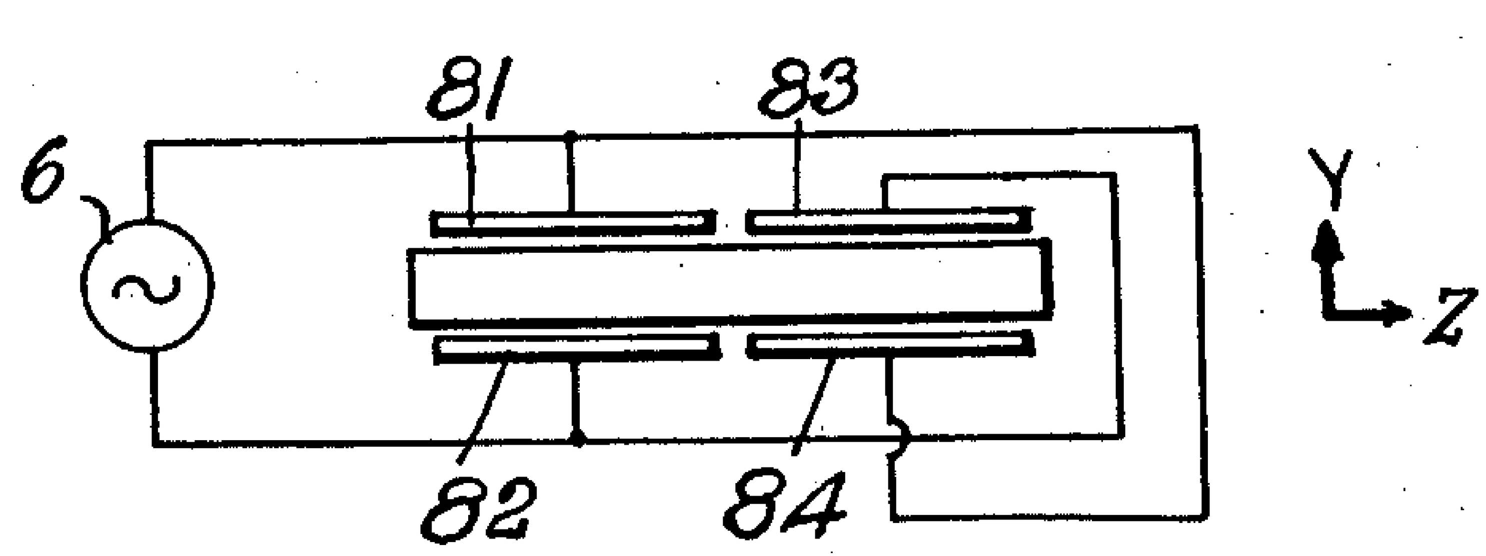



FIG_16

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PIEZO ELECTRIC SYSTEM

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FIG. 8

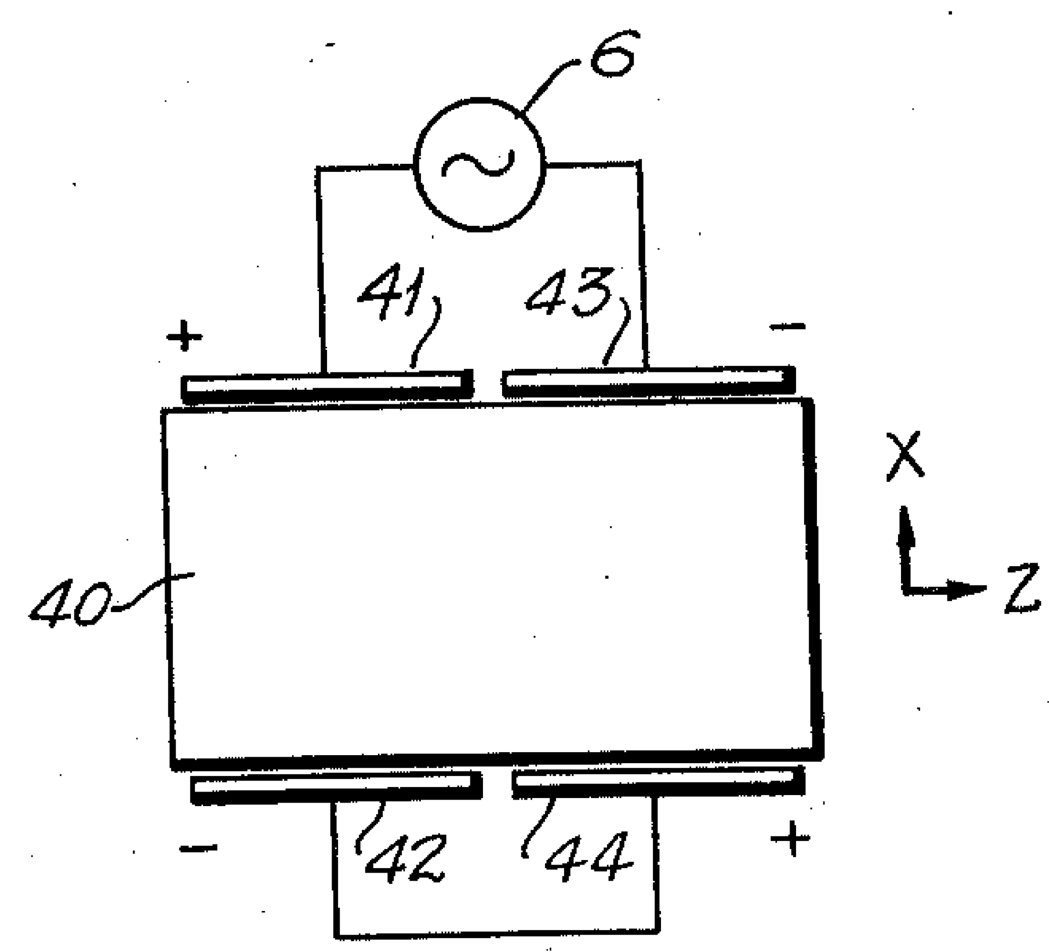



FIG. 9

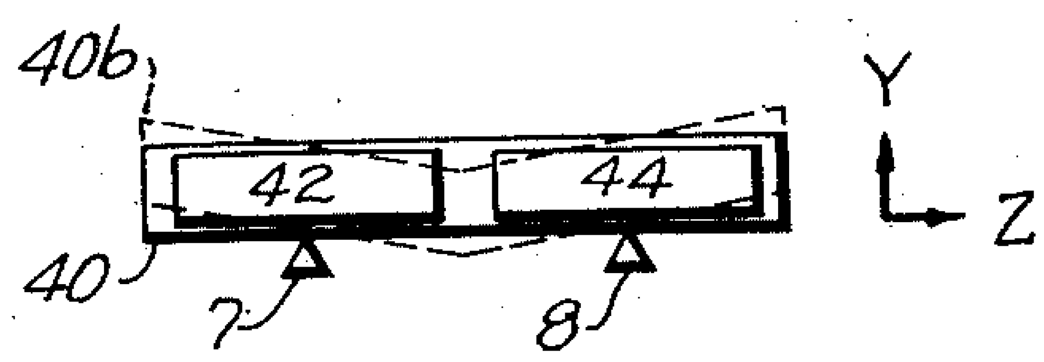



FIG. 11

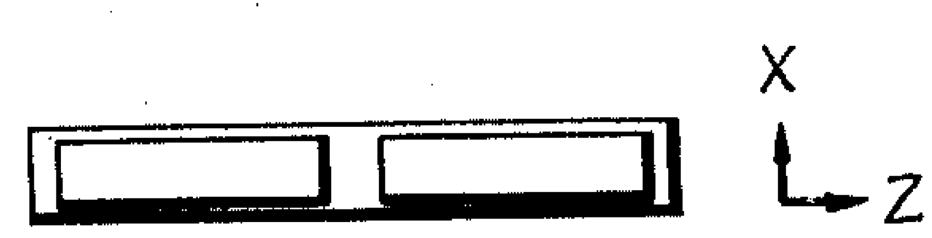



FIG. 10

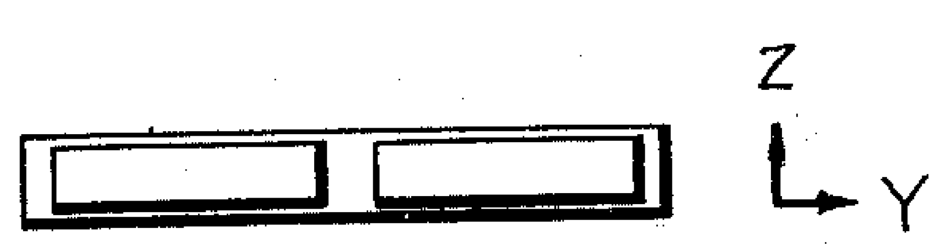



FIG. 12

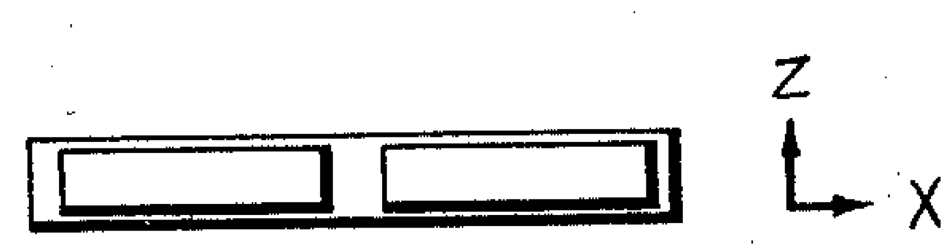



FIG. 13

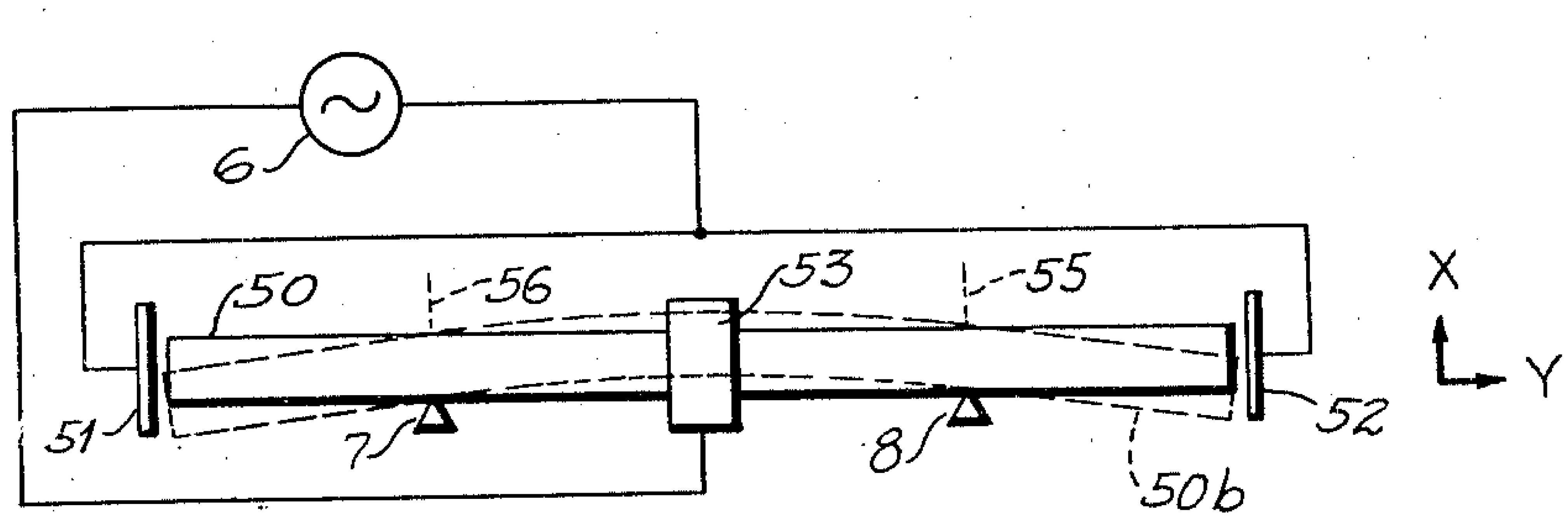
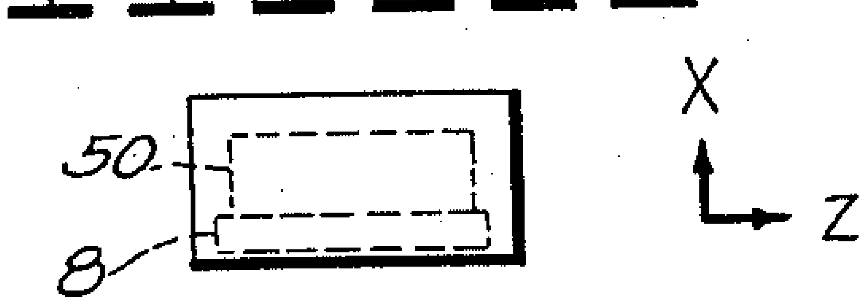



FIG. 14

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Patented Oct. 16, 1934

1,977,169

# UNITED STATES PATENT OFFICE

1,977,169

## PIEZO-ELECTRIC SYSTEM

Walter G. Cady, Middletown, Conn.

Application December 17, 1931, Serial No. 581,630

6 Claims. (Cl. 171—327)

My invention pertains in general to piezo-electricity and specifically relates to means for producing vibrations in piezo-electric bodies by shearing stresses.

One of the objects of my invention consists in providing an electrical system having a piezo-electric body set in vibration by shearing stresses.

Another object consists in producing a piezo-electric resonator adapted to vibrate at extremely low frequencies.

A further object comprises providing an electrical system including a piezo-electric element having pairs of electrodes for producing electric fields traversing the piezo-electric element in opposite directions to produce shearing stresses for causing piezo-electric vibrations in predetermined modes, such as flexural or torsional vibrations.

I accomplish these and other desirable objects in a novel piezo-electric system having means for causing shearing stresses in a piezo-electric element to produce vibrations therein.

In the drawings which accompany and form a part of this specification and in which like reference numerals designate corresponding parts throughout:

Fig. 1 is a perspective view of several crystal plates showing their orientation with respect to the crystallographic axes of the natural crystal;

Fig. 2 is a schematic plan view of a Rochelle salt crystal plate, together with an electrical circuit employed therewith, in one embodiment of my invention;

Fig. 3 is a side elevation of the representation of Fig. 2;

Fig. 4 is a representation corresponding to Fig. 2 but showing a different arrangement of the electrical circuit;

Fig. 5 is a theoretical representation of the deformation of a crystal plate in accordance with my invention;

Fig. 6 is a schematic plan view of a Rochelle salt crystal plate and circuit employed therewith, for producing overtone frequencies;

Fig. 7 is a side elevation of the representation of Fig. 6;

Fig. 8 is a schematic plan view of a quartz crystal and circuit employed therewith for producing flexural vibrations in accordance with my invention;

Fig. 9 is a schematic elevation of the representation of Fig. 8 showing the deformation of a crystal at a particular instant;

Figs. 10–12 are schematic representations corresponding to Fig. 9 but indicating different orientations of crystals that may be used in the system shown in Fig. 8;

Fig. 13 is a schematic representation of a quartz crystal and circuit employed therewith in a further embodiment of my invention;

Fig. 14 is an end elevation of the crystal and electrodes of Fig. 13;

Fig. 15 is a plan view of a quartz crystal and the electrodes employed therewith in one embodiment of my invention for producing torsional vibrations;

Fig. 16 is a side elevation of the crystal of Fig. 18 together with the electrical circuit employed therewith; and

Fig. 17 is an end elevation of the crystal of Fig. 18 showing the deformation of a transverse section thereof in accordance with the principles of my invention.

My invention is directed to providing means for producing shearing stresses in a piezo-electric body for setting up vibrations therein in predetermined modes. The use of such vibrations as produced according to my system may be of extremely low frequencies as compared with the frequency of piezo-electric vibrations produced by systems heretofore known. In the present state of the art, in order to produce, by modes of vibrations now known, piezo-electric vibrations of frequencies even approaching those which I have obtained in the systems of my invention, it would be necessary to provide very large piezo-electric elements as compared with the size of those which I employ. It will be easily understood that use of large piezo-electric elements, especially of quartz and Rochelle salt crystals, is undesirable and prohibitive owing to their high cost and easy breakage.

In the present specification I will disclose how shearing stresses may be produced in both Rochelle salt crystals and quartz crystals for producing predetermined modes of vibrations therein. It will be understood, of course, that although I illustrate my invention in connection with Rochelle salt crystals and quartz crystals, other piezo-electric bodies having like characteristics may be similarly employed. Further, it is to be understood, throughout the following description, that the source of energy for supplying voltages to excite the crystals is adjusted so that the frequency of the applied alternating voltage is equal to the natural frequency of vibration of a particular crystal with reference to the desired mode of vibration. This natural frequency is, of course, dependent upon the material of the crystal, that is, whether it is composed of quartz, Rochelle salt, or some other material, and on the orientation of the crystal with respect to the crystallographic axes, and on the dimensions of the crystal.

The modes of vibrations produced by shearing stresses in piezo-electric bodies in accordance with my invention are of two general types, viz., flexural vibrations and torsional vibrations. For simplicity of exposition, consideration will be given, in the order named, to the production of flexural vibrations by shearing stresses in Rochelle salt crystals and quartz crystals, and the production of torsional vibrations in Rochelle salt crystals and quartz crystals.

*Flexural vibrations in Rochelle salt crystals*

Referring to the drawings, Fig. 1 is a perspective representation of several crystal plates of different orientations showing the relation to the X, Y, and Z axes of a natural crystal. The three axes here referred to as the X, Y, and Z axes are the same, respectively, as the *a*, *b*, and *c*, axes in the terminology commonly employed by crystallographers. Plates A and B are X-cut plates, since they are in the form of plates or flat slabs cut perpendicular to the X axis. Similarly, the plates C and D are Y-cut, and the plates E and F are Z-cut. Such nomenclature is in accordance with accepted usage.

Heretofore in the art it has been customary in the case of X-cut, Y-cut, and Z-cut plates, to apply the electric field in a direction parallel to the X, Y, and Z axes, respectively. In accordance with my system for producing flexural vibrations, the electric field for any given crystal plate is applied in a direction parallel to the breadth of the plate.

Fig. 2 illustrates how a particular one of the plates shown in Fig. 1 may be utilized in accordance with the principles of my invention for producing flexural vibrations. With respect to orientation, the plate 1 in Fig. 2 will be considered as corresponding to plate "E" of Fig. 1. Plate 1 is therefore a Rochelle salt Z-cut plate having the length and breadth in the XY plane and the thickness in the Z plane. Fig. 5 is a side elevation of the plate 1 of Fig. 2 taken in the XZ plane.

Referring to Fig. 3, two triangular strips 7 and 8 are provided having their thin edges supporting the plate 1 across the breadth of the plate 1 at the regions where the nodes of vibration occur. These nodal regions are indicated in Fig. 2 by the dotted lines 7*a* and 7*b*. Obviously we may use for 7 and 8 two narrow strips of any suitable solid material extending across the breadth of the crystal plate. Referring to Fig. 2, there are provided electrodes 2, 4 and 3, 5 disposed upon opposite sides of plate 1 as shown. The pairs of electrodes 2—4 and 3—5 are centered at the nodes 7*a* and 7*b* of the plate 1, respectively, for producing electric fields in directions parallel to the breadth of the plate 1 in the instance under consideration, and parallel to the Y axis. The electrodes 2—4 and 3—5 are mounted as closely as possible to the crystal without actually touching it. If preferred, very thin conducting electrodes may be applied directly to the crystal. It will be understood that these electrodes, together with the supporting strips 7 and 8, are mechanically mounted in any suitable housing structure, which, for the sake of simplicity, is not shown in the drawings.

In Fig. 2, the electrodes 2 and 5 are connected together, and electrodes 3 and 4 are connected together in circuit with a source of energy 6 for supplying alternating voltages across electrode pairs 2—4 and 3—5. It will be evident, from the connection, that adjacent electrodes on either side of the crystal plate will be of opposite instantaneous polarity and that, therefore, the fields produced between the pairs of electrodes 2—4 and 3—5, respectively, will be in opposite directions.

Fig. 4 illustrates an alternative method of connecting the electrodes 2—4 and 3—5. It will be seen that the electrodes 2 and 3 are connected with the source of energy 6 and that the electrodes 4 and 5 are interconnected. This form of connection will also produce fields of opposite directions between the electrode pairs when alternating voltages are supplied from the source of energy 6. The plus and minus signs in Figs. 2 and 4 are indicative of the relation of the polarity of the electrodes for a particular instant.

Fig. 5 is an exaggerated representation of the deformation of plate 1 due to shearing stresses as produced in the circuit arrangements of Figs. 2 and 4. For purposes of illustration, the plate 1, in Fig. 5, will be considered as comprising two halves designated as "R", the right half, and "L", the left half, under influence of the field produced between the electrode pairs 3—5 and 2—4, respectively. Under influence of an electric field in one direction, the "R" half of the plate 1 will be deformed by shearing stresses into a parallelogram configuration as shown, while the "L" half, under influence of an electric field in the opposite direction, will be deformed by shearing stresses into a parallelogram configuration of the opposite direction. When the fields are reversed in direction, the "R" and "L" halves of the plate 1 will be deformed by shearing stresses in an opposite direction as shown by the dotted line parallelograms in Fig. 5. Under influence of alternating electric fields of opposite directions, opposed shearing stresses will be set up in the plate 1 whereby the plate will be set into flexural vibrations. The representation of Fig. 5 corresponds to that of Fig. 3, the plate 1 being shown as an elevation in the XZ plane and the electric fields being applied in directions perpendicular to the paper.

Although the initial stresses produced in the plate 1 are of the nature of pure shears, the resulting flexural vibrations are determined as to frequency by the elasticity of compression of the piezo-electric material.

It will be noted in Fig. 1, that the plates shown have lengths approximately twice the breadth, which I found, in practice, to be a convenient ratio. However, the exact value of breadth of the plate is a matter of no consequence as the frequency of the vibration is dependent only on the length and thickness. There is nothing in principle to prevent having the breadth even greater than the length, if desired. For example, in the case of plate 1 which corresponds to the plate "E" of Fig. 1, we might regard the dimensions parallel to the Y and X axes as the length and breadth, respectively. We would then place the electrodes at the ends of the plate, instead of along the sides, so that the electric fields would be in directions parallel to the X axis. The plane of flexure would then be in the plane containing the Y and Z axes. Similarly, by placing the electrodes so that the electric field is parallel to the Z axis, flexural vibrations, as produced by shearing stresses, would take place in the XY plane.

Thus, from one Rochelle salt plate, we may obtain three different fundamental frequencies of flexural vibration. In each case, the particular frequency will depend, according to formulæ for flexural vibration, on the two dimensions of the plate that are at right angles to the electric field, and on the value of Young's modulus in the direction of the effective length of the plate.

Where only one frequency is desired it may be found advisable, for economy of material and also to secure a greater field strength with a given supply voltage, to make the breadth of the plate, that is, the dimension parallel to Y in Fig. 2, even less than the thickness. This applies to all of the types of flexural vibrator described below.

In the foregoing, consideration has been given to the use of plate "E" of Fig. 1 for producing flexural vibrations by shearing stresses. The other plates shown in Fig. 1 may also be utilized for the production of flexural vibrations in a similar manner. For example, for plate "F", the electrodes would be placed so as to cause the electric field to be parallel to the X axis.

Consideration will now be given to the use of shearing stresses in a Rochelle salt plate for producing flexural vibrations at frequencies which are overtones of the fundamental frequency. Fig. 6 is a plan view of a Rochelle salt crystal plate employed in accordance with my invention for producing flexural overtone vibrations. Fig. 7 is a side elevation of the crystal of Fig. 6 showing, in dotted lines, in an exaggerated manner, the deformation of the crystal plate, at a particular instant, due to shearing stresses.

Referring to Fig. 6, the plate 10 is provided with pairs of electrodes 11—12, 13—14, 15—16, and 17—18. In the embodiment shown, the electrodes 11, 14, 15, and 18 are connected together and the electrodes 12, 13, 16, and 17, are connected together in circuit with a source of energy 6. The source of energy 6 is any suitable means for supplying voltages to the electrodes just mentioned for producing alternating electric fields therebetween. Owing to the connections of the electrodes, adjacent pairs of electrodes produce fields having different instantaneous directions.

The nodes of vibration of the plate 10 are indicated by the dotted lines 22, 23, 24, and 25. As in Fig. 3, the plate is supported by strips 7 and 8 positioned transversely of the crystal at two of the nodes as 23 and 24. The electrodes positioned on either side of the plate 10 are of a size such as to extend substantially from anti-node to anti-node.

To excite the $n$th overtone of the fundamental frequency, it has been found that, for best results, $n+2$ pairs of electrodes should be used, the connections with the source of energy being such that electric fields simultaneously produced by the adjacent pairs of electrodes on either side are of opposite direction.

Owing to the electric fields between each pair of the electrodes, shearing stresses will be set up in each portion of the crystal plate 10 between each pair of electrodes whereby the crystal as a whole will be deformed as exaggeratively depicted for a particular instant by the dotted line 10$b$ in Fig. 7. The deformation will take place in the opposite direction when the fields are reversed, whereby the plate 10, under the influence of the alternating electric fields will be set into flexural vibrations at a frequency which is an overtone of the fundamental flexural frequency.

*Flexural vibration in quartz crystals*

In accordance with my invention use is made of opposed electric fields applied to a quartz plate for producing shearing stresses for causing flexural vibrations in accordance with either of two equations, relating electrical fields with mechanical shears, which, for quartz, may be written thus:

$$Y_z = e_{14}E_1 \quad (1)$$
$$Z_x = e_{14}E_2 \quad (2)$$

In the two foregoing equations, $E_1$ and $E_2$ represent electric fields parallel to the X and Y axes, respectively, and $Y_z$ and $Z_x$ are the shearing stresses about the X and Y axes, respectively, while $e_{14}$ is a piezo-electric constant of quartz. In applying these equations I find it most convenient to express the stresses in dynes per square centimeter and the other quantities in electrostatic units.

In accordance with one embodiment of my system, I provide a quartz plate 40 having its length, breadth and thickness parallel to the Z, X, and Y axes, respectively, as shown in Fig. 8. Two pairs of electrodes 41—42 and 43—44 are positioned as shown. The electrodes 42—44 are connected together, and the electrodes 41—43 are connected to the source of energy 6. The source of energy 6 supplies voltages for producing alternating electric fields between the electrode pair 41—42 and the electrode pair 43—44, the field between the electrodes 41 and 42 being in a direction opposite to the direction of the field produced between the electrodes 43 and 44. The plus and minus signs in Fig. 8 are indicative of the relative polarities of the electrodes for a particular instant. The electric fields traversing the plate 40 in directions parallel to the X axis produce shearing stresses about the X axis, that is, in the YZ plane. Electric fields produced between the adjacent pairs of electrodes are in opposite directions so therefore the shearing stresses are also in corresponding directions.

Fig. 9 is a side view in the YZ plane of plate 40. Figs. 10, 11, and 12, are similar views of quartz plates having different orientations with respect to the crystallographic axes and which may be utilized in accordance with my invention.

The dotted line 40$b$ in Fig. 9 is exaggeratively indicative of the deformation of the plate 40, at a particular instant, as caused by shearing stresses in the right and left hand halves of the plate produced by the electric fields of different directions between the electrode pairs 41—42 and 43—44.

In conformity with Equations (1) and (2), the method of flexural excitation of quartz plates is applicable to plates cut with any of the orientations shown in Figs. 9–12, inclusive, when electric fields are applied in directions perpendicular to the plane of the paper. In each instance the shear takes place about the third axis perpendicular to the paper, that is, the plane of the shear is in the plane of the paper. In accordance with the principles of flexural vibration, the natural frequency of the plate will be decreased as the longest dimension of the plate is increased, and the shorter dimension of the plate is decreased. Equation 1 applies to Figs. 9 and 10 and Equation 2 applies to the Figs. 11 and 12.

In experiments, a plate such as in Fig. 9 was employed, in which the dimensions parallel to the X, Y, and Z axes were 20 millimeters, 3 millimeters, and 50 millimeters, respectively. Such a piezo-electric plate may be used as an oscillator as disclosed in my Patent Number 1,472,583, issued October 30, 1923.

Another method for producing flexural vibrations by shearing stresses in quartz plates is based on the equation

$$X_y = e_{11}E_2 \quad (3)$$

wherein $E_2$ is the impressed electric field parallel to the Y axis, $e_{11}$ is the appropriate piezo-electric constant, and $X_y$ represents a shearing stress about the Z axis. In this instance the equation is the same that governs the vibrations commonly employed in the well-known Y-cut plates. However, according to my invention, I dispose the electrodes in a manner such as to cause flexural vibrations to be generated about the Z axis, that is, in the XY plane. This arrangement is illustrated in Fig. 13.

In Fig. 13, a quartz plate 50 is provided having the length and thickness parallel to the Y and X axes. Electrodes 51 and 52 are positioned at opposite ends around rod 50 while an encircling band electrode 53 is centrally disposed around the plate 50. Electrodes 51 and 52 are connected together in circuit with the source of alternating voltage 6, which is also connected to the electrode 53. In accordance with my invention, for the fundamental frequency of vibration, the plate should be so mounted that supports 7 and 8 come approximately 0.22 of the length from each end at the points 55 and 56 in Fig. 20. The nodes of vibration are located in these regions.

When the source of energy 6 supplies voltages of the proper frequency to the electrodes, electric fields are set up traversing the rod 50 in directions extending from the electrode 53 to the electrodes 51 and 52, or vice versa, depending upon the polarity of the electrodes. Opposite shears are thereby produced in the rod 50 for producing flexural vibrations. The source of energy 6 supplies alternating voltages preferably of a frequency for producing resonant flexural vibrations of the fundamental frequency of the crystal rod 50. In order to strengthen the electric field and to concentrate it most effectively it may be found advantageous to have electrodes 51 and 52 in the form of bands (later described in connection with Rochelle salt) 72 and 73 shown in Fig. 17 and loosely encircling the crystal plate.

In one experiment with quartz plates of the type indicated in Fig. 13, I employed a plate having dimensions of 0.24, 3.71, and 0.55 cm. in the X, Y, and Z axes, respectively. The electrodes were connected to a source of energy comprising a vacuum tube generator circuit of a frequency of 9200 cycles per second. The plate was excited to resonant flexural vibrations of the fundamental frequency.

In another experiment I utilized a quartz plate having X, Y, and Z, dimensions of 0.1 cm, 9.3 cm, and 0.5 cm, respectively, which, as a master oscillator produced flexural vibrations at a frequency of 3,000 cycles per second. This frequency is believed to be, by far, the lowest frequency yet produced in a quartz plate utilized as an oscillator.

*Torsional vibrations in Rochelle salt crystals*

Torsional vibrations in Rochelle salt plates take place in accordance with the following three equations:

$$Y_z = e_{14}E_1 \quad (4)$$
$$Z_x = e_{25}E_2 \quad (5)$$
$$X_y = e_{36}E_3 \quad (6)$$

These three equations are, of course, the same that express the stresses employed in the flexural vibrations with quartz described above. In Figs. 1–12 the plates are so cut and the electrodes so disposed that the stresses set up in accordance with these equations produce, under the influence of alternating electric fields of the proper frequency, flexural vibrations as previously described. I shall now show how, by a different arrangement of electrodes, the same shearing stresses may be caused to set up torsional vibrations. It is, of course, assumed that the applied voltages shall in each case be of a frequency substantially equal to the natural frequency of torsional vibration of the crystal plate. In the foregoing three equations $E_1$, $E_2$, and $E_3$ represent impressed electric fields parallel to the X, Y, and Z axes respectively, $e_{14}$, $e_{25}$, and $e_{36}$, are the three piezo-electric constants, and $Y_z$, $Z_x$, and $X_y$ are shearing stresses about the X, Y, and Z axes respectively. The plate is preferably in the form of a rod with its length parallel to one of the crystal axes. The cross-section may be circular, square, or of other convenient shape. In the present description the cross-sectional form is, for convenience, assumed to be rectangular.

*Torsional vibrations in quartz crystals*

Consideration will now be given to producing torsional vibrations in quartz crystals by means of shearing stresses in accordance with my invention. To obtain torsional vibrations about the X or Y axes the quartz plate is orientated and the electrodes disposed so as to conform to Equations (1) and (2), respectively. For producing torsional vibrations about the Z axis, conditions must prevail in accordance with Equation (3). As explained above in connection with torsional vibrations in Rochelle salt, so also in the case of quartz it is true that the same shearing stresses that produce flexural vibrations can, with proper orientation of the crystal plate, disposition of electrodes, and choice of frequency, be made to produce torsional vibrations as well. The arrangement based on Equation (3) will be considered first.

A quartz crystal plate 80, Figs. 15 and 16, is provided having length, breadth, and thickness parallel to the Z, X, and Y axes, respectively. The two pairs of electrodes 81—82, and 83—84, are provided as shown on opposite sides of the plate 80 and are connected to the source of energy 6 for producing electric fields which, in Fig. 15 will be perpendicular to the plane of the paper but always in opposite directions. The field parallel to the Y axis produces a shearing stress about the Z axis. Fig. 17 represents the resulting deformation of a rectangular section of plate 80 into the dotted parallelogram. Such a deformation will take place for both right hand and left hand halves of the crystal but in opposite directions due to the different directions of the electric fields. It follows, then, that the plate 80, is subjected to a twisting moment about the Z axis. The source of energy 6 supplies alternating voltages of a frequency proper for producing resonant torsional vibrations in the plate 80. The plate may then be used as a resonator or oscillator. This mode of vibration is especially useful and desirable for the production of extremely low frequencies of vibration. For producing low frequencies, the Z dimension should be relatively large and the other dimensions small.

In order to produce torsional vibrations in quartz about the X or Y axes, in conformity with Equations (1) or (2), I dispose the electrodes as in Fig. 13. The quartz plate is so oriented that the electric field lies in the direction of that axis about which torsion is to take place, which may be either the X or Y axis.

It will be apparent from the foregoing that my invention provides means for producing torsional and flexural vibrations of low frequency in piezo-electric bodies through the agency of shearing stresses.

In practicing my invention, it is not essential that the quartz or Rochelle salt plates or bars be precisely oriented with respect to the crystallographic axes. In general there will be a component of electric field capable of producing the desired result even though the geometric axes of the plate depart somewhat from the crystallographic axes. Further, it is not essential that the cross-section be everywhere the same. For example, in order to secure still lower frequencies it is possible to load the plate or bar at each end, either by cutting it from the parent crystal with the ends relatively wide or thick, or by affixing a mass of metal or other suitable material at each end.

One of the chief advantages to be derived from my invention resides in that vibrations of extremely low frequencies can be produced with great stability and precision. Any of the crystal plates herein disclosed can be utilized as resonators or oscillators in conjunction with appropriate electrical circuits. For example, the crystal plates can be incorporated in the electrical circuit disclosed in my Patent Number 1,472,583, as before stated. Although I have disclosed my invention in certain forms and modifications, I do not desire to be limited thereto except insofar as may be pointed out in the appended claims.

What I claim as new and original and desire to secure by Letters Patent of the United States is:

1. A piezo-electric system comprising a Rochelle salt plate having its length parallel to one of the crystallographic axes, a plurality of electrodes disposed upon opposite sides of said plate and in planes parallel to said crystallographic axis and one of the other two crystallographic axes, a source of alternating voltage, connections between said electrodes and said source of voltage whereby adjacent electrodes on either side of said plate are of different relative polarities for producing electric fields traversing said Rochelle salt plate in opposite directions to produce adjacently opposed shearing stresses in said plate to cause the same to vibrate flexurally, said electrodes being of a configuration such as to extend approximately from anti-node to anti-node of the vibration.

2. In a piezo-electric system, a Rochelle salt plate, and means for causing said plate to vibrate at the $n$th harmonic of the fundamental frequency of flexural vibration comprising, $n+2$ pairs of electrodes, each of said pairs comprising electrodes disposed on opposite sides of said plate, and means for energizing said electrodes to produce alternating electric fields traversing said piezo-electric element, adjacent electrodes on either side of said piezo-electric element being of opposite instantaneous polarity.

3. A piezo-electric system comprising, an elongated piezo-electric element the major dimension of which is in a direction substantially perpendicular to the optical and electrical axes thereof, means for producing an electric field traversing said element alternately from the central portion thereof towards both ends and from the ends thereof towards the central portion in directions substantially parallel to the direction of said major dimension for setting up opposite shearing stresses in said element to cause the same to vibrate.

4. A piezo-electric system comprising, a rectangular plate of Rochelle salt having its dimensions parallel to the three crystal axes respectively, pairs of electrodes operatively related to said plate to cause said plate to flexurally vibrate in a particular plane and at a particular predetermined frequency, and means including said electrodes to produce opposing alternating electric fields traversing said plate in directions perpendicular to said plane of flexural vibration.

5. A piezo-electric system comprising, a rectangular plate of Rochelle salt having its dimensions parallel to the three crystal axes respectively, two pairs of electrodes operatively related to said plate to cause said plate to vibrate flexurally in a particular plane and at a particular predetermined frequency and means including said electrodes to produce opposing alternating electric fields traversing said plate in directions perpendicular to said plane of flexual vibrations.

6. A piezo-electric system comprising, a quartz plate and means including electrodes positioned on either side of said plate for simultaneously producing alternating electric fields traversing one of the smaller dimensions of said plate for producing opposing shearing stresses in said plate to cause the same to flexurally vibrate in a plane at right angles to a line drawn between the centers of said electrodes.

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