

July 9, 1940.

C. K. GRAVLEY

2,207,539

PIEZOELECTRIC APPARATUS

Filed July 26, 1939

2 Sheets-Sheet 1

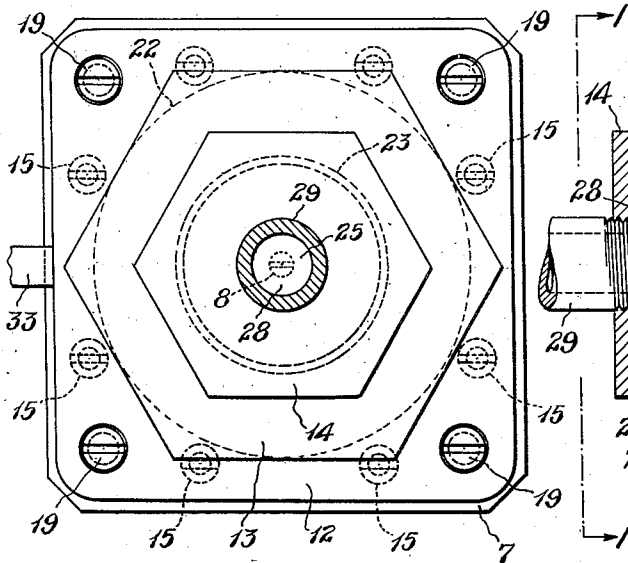


FIG. 1.

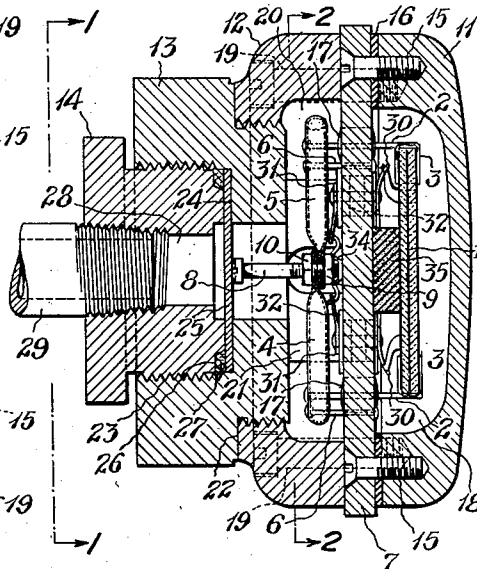


FIG. 3.

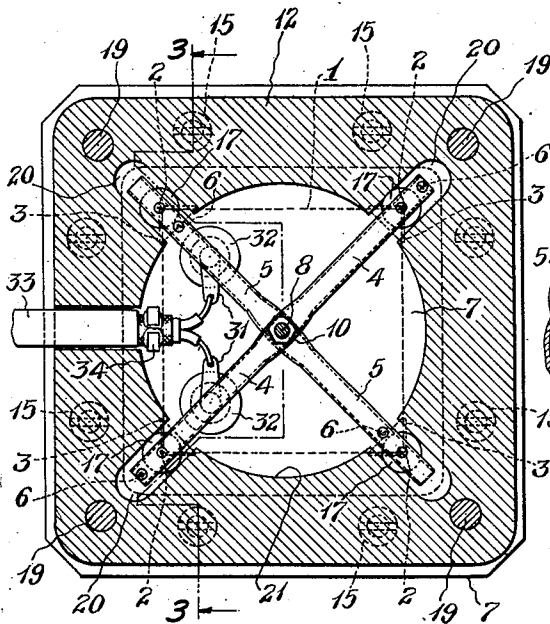


FIG. 2.

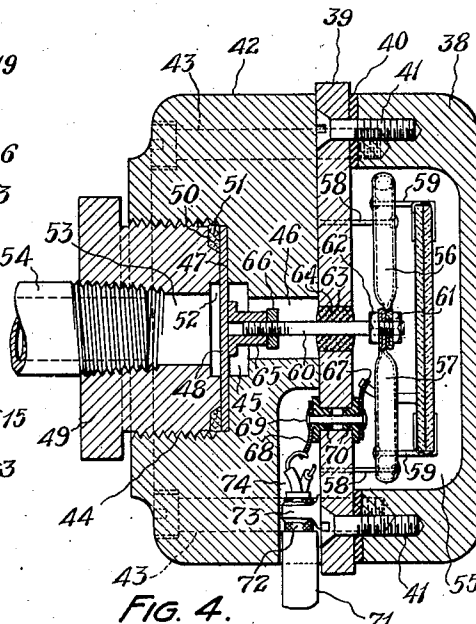


FIG. 4.

INVENTOR:
CHARLES K GRAVLEY
BY *GG Christensen*
ATTORNEY.

July 9, 1940.

C. K. GRAVLEY

2,207,539

PIEZOELECTRIC APPARATUS

Filed July 26, 1939

2 Sheets-Sheet 2

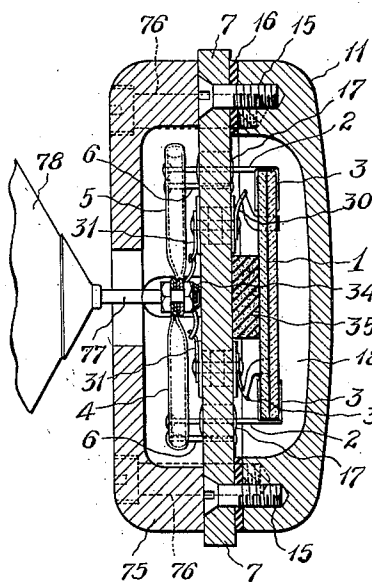


FIG. 5

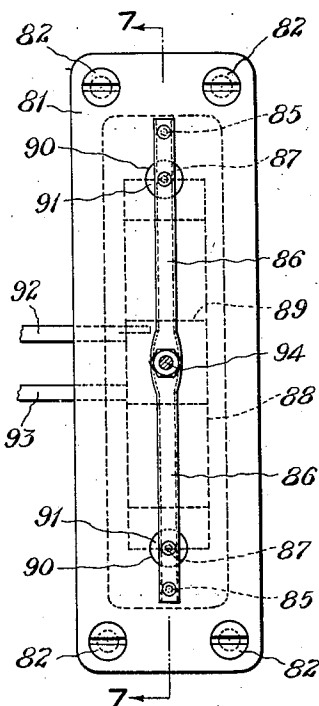


FIG. 6

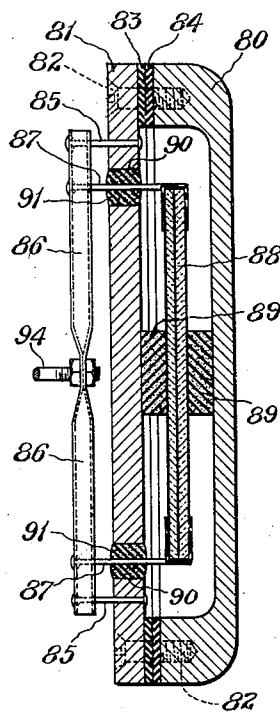


FIG. 7

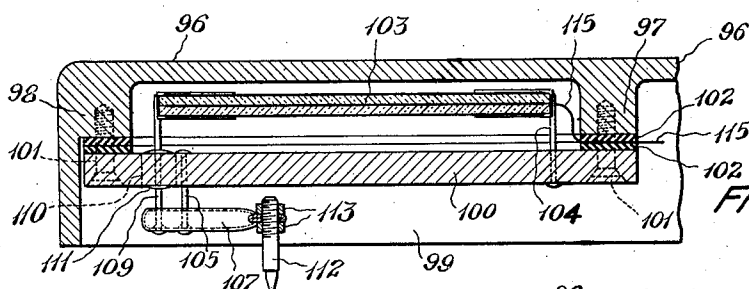


FIG. 8

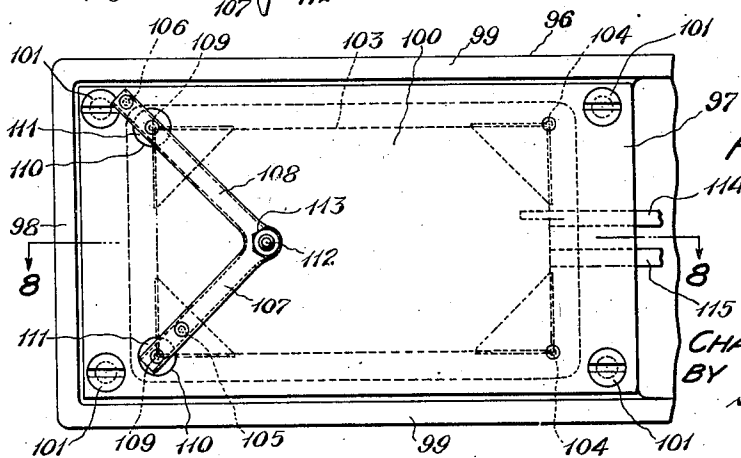


FIG. 9

INVENTOR:
CHARLES K. GRAVLEY
BY *G. Christensen*
ATTORNEY.

UNITED STATES PATENT OFFICE

2,207,539

PIEZOELECTRIC APPARATUS

Charles K. Gravley, Cleveland, Ohio, assignor to
The Brush Development Company, Cleveland,
Ohio, a corporation of Ohio

Application July 26, 1939, Serial No. 286,579

10 Claims. (Cl. 171—327)

This invention relates to piezoelectric transducers in general and more particularly to a crystal mounting and lever arrangement suitable for use in piezoelectric devices of various types and especially in a pickup device for measuring fluctuations in fluid pressure.

An object of the invention is to provide a lever arrangement suitable for use in piezoelectric transducers of various types.

Another object is to provide a lever system having low stiffness for motion in a desired direction and relatively high stiffness for motion in other directions.

Another object is to provide a pressure pickup which is relatively insensitive to all vibrations except those which occur in the fluid medium actuating the device.

Another object is to provide a device for measuring fluctuations in fluid pressure which embodies means permitting the device to be altered readily to accommodate a wide range of static pressures.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings in which,

Fig. 1 is a plan view of a pressure pickup constructed in accordance with the invention, the view being taken on line 1, 1 of Fig. 3.

Fig. 2 is a sectional plan view of the pickup taken along line 2, 2 of Fig. 3.

Fig. 3 is a sectional view along line 3, 3 of Fig. 2.

Fig. 4 is a sectional view of a modified form of the pressure pickup.

Fig. 5 is a sectional view of a loudspeaker embodying the invention.

Figs. 6 and 7 show a simplified form of the invention suitable for use with a bender type piezoelectric unit in which Fig. 6 is a plan view, and Fig. 7 is a sectional view taken on line 7, 7 of Fig. 6.

Figs. 8 and 9 show a device embodying another modified construction which is particularly adapted for use as a phonograph pickup or record cutter, to be used in hill-and-dale type recordings, Fig. 8 being a vertical sectional view taken along line 8, 8 of Fig. 9, and Fig. 9 being a bottom plan view of the device.

A pickup device for measuring fluctuations in fluid pressure (for example, a device for measuring fluctuations in pressure in an oil or gas pipe line) should be capable of indicating relatively slow pressure changes. A piezoelectric crystal

pickup is particularly well suited for this purpose because the voltage generated by a piezoelectric unit is approximately proportional to the displacement. However, in order to prevent false indications it is essential that the piezoelectric unit be mounted so that physical shock or vibration of the case of the device, or of its support will not cause any appreciable voltage to be generated. This can be accomplished by the type of construction illustrated in Figs. 1 to 4 inclusive. In Figs. 1 to 3 a square piezoelectric bimorph unit 1 of the torque type such as is disclosed in United States patents numbered 2,105,011 and Reissue 20,680 is connected at its four corners to wire drive links 2, 2. This may be done conveniently by first soldering the drive links 2, 2 to corner clips 3, 3 and then cementing the corner clips to the piezoelectric unit. The other ends of the drive links are soldered to levers 4, 4 and 5, 5. Each pair of levers is embodied in a single piece of metal tubing flattened at its midpoint as shown in the drawings. Levers made in this way are very desirable because they are rigid, yet have low inertia. The length of tubing is flattened at its midpoint to obtain flexibility and to facilitate attachment of a suitable drive rod. Levers 5, 5 are levers of the first class, while levers 4, 4 are levers of the second class. The ratios of all of these levers should preferably be the same. The levers are fulcrumed on wires 6, 6 which serve not only as supports for the lever mechanism but indirectly serve as supports for the piezoelectric unit. It is desirable to solder the fulcrums to both the levers and the assembly plate. The two lengths of tubing constituting the levers are connected together at their flattened midpoints by means of an adjustable drive screw 8 threaded into a lock nut 10 and into nut 9 which is soldered to the levers 5, 5. The entire mechanism is mounted in a rigid case adapted to enclose opposite faces of the assembly plate 7 and consisting of a cup shaped base cap 11, top cap 12, nut 13, and plug 14.

The base cap is secured to assembly plate 7 by means of countersunk screws 15, 15 a gasket 16 being disposed between their adjacent surfaces to secure a substantially air-tight joint. The drive links 2, 2 are surrounded by flexible rubber bushings 17, 17 where they pass through assembly plate 7. Likewise all other openings in plate 7 are closed and made substantially airtight so that cavity 18 in which the piezoelectric unit 1 is disposed is effectively sealed against the ingress of moisture. Top cap 12 is secured to assembly plate 7 by means of screws 19 which

pass through plate 7 and are threaded into the wall of base cap 11. There are four recessed portions 20 in the top cap which extend radially outwardly from the central circular opening 21, and which are adapted to fit around the ends of the levers 4, 4 and 5, 5. This construction permits thicker walls on the cap than would result if the central opening 21 were made large enough to fit around the levers. The greater thickness produces increased rigidity of top cap 12. The central opening 21 is closed at one end by nut 13 which is threaded thereto. The nut is provided with an annular external shoulder 22 which engages a surface of cap 12 and limits the depth to which nut 13 extends into the central cavity of cap 12. The nut 13 is also provided with a threaded opening 23 which terminates in a flat faced flange 24 on which is disposed a sheet metal diaphragm 25. Plug 14 is adapted to be threaded into opening 23 and press diaphragm 25 firmly against flange 24. The plug is recessed adjacent the outer periphery of its inner end to form an annular cavity 26 which is substantially filled with compressed packing material 27. The plug is provided with a central opening 28 which is closed at one end by diaphragm 25 and which is threaded at its other end to receive tube 29 or other conduit which communicates with a source of fluid pressure.

Drive screw 8 is adjusted with respect to levers 4, 4 and 5, 5 so that its head bears against diaphragm 25 with moderate force when the latter is firmly clamped in place upon flange 24. When the device is assembled in this way, it will be understood that fluid pressure admitted through tube 29 deforms the diaphragm toward plate 7, displacing drive screw 8 and actuating levers 4, 4 and 5, 5 to flex the piezoelectric unit 1. Thereafter, fluctuations in the pressure acting on the diaphragm cause the unit to vibrate in such a manner that an opposite pair of corners will move in one direction, while the other pair of corners move in the opposite direction. In other words, the unit is twisted. When the tongue is flexed in this manner it generates a potential difference at its terminals which is approximately proportional to the displacement. The potential differences thus generated may be caused to actuate an appropriate electrical instrument connected to the terminals of the unit. Connections to the terminals are made through lugs 30, 30 and lugs 31, 31 which are secured on opposite faces of plate 7 by a rivet, the lugs and rivet being insulated from the plate by flanged insulating bushings 32, 32. The terminals of the piezoelectric unit are connected to lugs 30, 30 while terminals of a shielded cable 33 may be soldered to lugs 31, 31 the cable being secured to the device by soldering its woven metal shield to a clamp 34. It has been found desirable to dispose the drive links 2, 2 as nearly parallel to each other as practicable in order to eliminate as far as possible any endwise component of force due to sidewise vibration of the piezoelectric unit such as might be induced by mechanical vibration of the pickup assembly as a whole. A small pad 35 of viscoloid or other suitable damping material is placed between the crystal unit and the assembly plate 7 in order to reduce to a minimum sidewise vibration of the crystal.

If the pickup device is designed to have relatively large lever ratios and a relatively thick diaphragm then the displacement of the diaphragm per unit of fluid pressure will depend substantially only on the constants of the diaphragm.

This may be advantageous for applications where known pressures are not available for calibration. The displacement of the diaphragm as a function of fluid pressure may be calculated from its dimensions and known constants without considering the effect of the lever-crystal mechanism. The lever-crystal mechanism may be calibrated in terms of voltage output per unit displacement of drive screw 8 and this calibration may be combined with the calculated data for the diaphragm to obtain a calibration for the complete device in terms of voltage output as a function of fluid pressure.

Fig. 4 shows a modified construction which provides even greater rigidity than is found in the construction shown in Figs. 1 to 3. The device shown here comprises a cup-shaped base cap 36 disposed adjacent one face of assembly plate 39 with a gasket 40 between the adjacent surfaces of the two members, plate 39 being secured to cap 36 by a plurality of screws 41. A top cap 42 is secured firmly upon the opposite face of plate 39 by screws 43 passing through the latter and threadably engaging the walls of cap 36. The top cap 43 is provided with a plurality of contiguous coaxial openings 44, 45 and 46 which extend between its opposite surfaces. Opening 44 terminates at a flat faced annular flange 47. Contiguous opening 45 is shallow and has an appropriate diameter, while opening 46 extends between opening 45 and the base of the top cap, and has as small a diameter as practicable. A diaphragm 48 rests on flange 47 and is firmly clamped thereon by plug 49 which is threaded into opening 44. The base of the plug has an annular recess 50 adjacent its circumference in which is disposed packing material 51. The base of the plug is also provided with a shallow central opening 52 recessed therein and having the same diameter as opening 45. An opening 53 extends between opening 52 and the opposite face of the plug, and is threaded to receive a tube 54 which communicates with a source of fluid pressure.

A lever and piezoelectric unit assembly are disposed within the cavity 55 formed between plate 39 and cap 36. The assembly comprises two pairs of intersecting levers 56, 56 and 57, 57 each pair being made of a single length of tubing flattened at its midpoint, and supported on wire fulcrums 58, 58 soldered to the levers and also soldered to plate 39. One pair of levers is of the first class, while the other pair is of a different class, second class levers being shown in the drawing. Each lever is provided with a connecting link 59 which is soldered thereto at one end and which is secured at its other end to a corner of a piezoelectric torque unit in the same manner as previously described in connection with the construction shown in Figs. 1 to 3. It will be noted that the levers are disposed between the piezoelectric unit and the plate 39. The levers are fastened together at their midpoints by a threaded drive-pin 60 engaging nuts 61 and 62. The drive pin passes through an opening 63 in plate 39 having a flexible rubber bushing 64 secured therein and effectively closing the space between the drive pin 60 and the walls of the opening 63. The other end of drive pin 60 is threaded into a nut 65 and a lock nut 66. The nut 65 may be adjustably positioned on drive pin 60 so as to bear firmly against diaphragm 48, and may be retained in adjustment by lock nut 66.

Electrical connections with the terminals of the piezoelectric unit are made through a pair of

lug assemblies each of which consists of lugs 67 and 68 disposed on opposite sides of plate 39 and secured together by a rivet 69, the rivet and lugs being insulated from plate 39 by a pair of flanged bushings 70, 70. The terminals of the piezo-electric unit are secured to lugs 67 while the terminals of a shielded cable 71 are soldered to lugs 68. The woven metal shield 72 of the cable 71 is soldered to clamp 73. The cable passes through an opening 74 recessed in the base of top cap 42.

It should be noted that both of the constructions shown in Figs. 1 to 4 permit diaphragm 25 or diaphragm 48 to be replaced readily without disturbing the adjustment of the cooperating drive pin and lever assembly. Thus it is possible to replace the diaphragm with one of greater or less thickness and thereby alter the device readily so as to make it respond to fluctuations in a wide range of static pressures.

Both of the above constructions may be designed to employ a piezo-electric unit of the bender type in place of the torque type unit described, it being necessary merely to connect the levers to the midpoints of opposite sides of the bender unit instead of to the corners of the torque unit. This change is made necessary by reason of the disposition of the crystalline axes of the unit with respect to its boundary edges, as will be explained below in more detail.

It will be noted that the constructions shown in Figs. 1 through 4 have a symmetrical lever arrangement which produces a balance of forces in the system. It has been found that this type of structure, when incorporated in a housing having appreciable rigidity, is substantially insensitive to vibrations applied elsewhere than to the drive rod. By virtue of this inherent property, the structure is particularly suited for use in pressure pickups of the type described, especially since such pickups are likely to be mounted in use on a pipeline or mechanical device which is in a state of rather violent vibration.

The invention is not limited in its application to devices such as shown in Figs. 1 to 4, since a multiple lever assembly may be used in conjunction with a piezoelectric unit in a variety of ways. For example, Fig. 5 shows a loudspeaker which utilizes the lever and plate assembly of Figs. 1 to 3. In this loudspeaker construction, the assembly comprising base cap 11, assembly plate 7, piezoelectric unit 1, levers 4, 4, and 5, 5, and the other associated elements carried on assembly plate 7 of Figs. 1 to 3 are employed as a unit and disposed upon a suitable support such as the cup shaped member 75 in Fig. 5, being secured thereto by screws 76. A drive pin 77 is secured at one end to the levers 4, 4 and 5, 5 at their flattened midpoints. The drive pin is secured at its other end to a sound radiating diaphragm such as a cone 78 supported in the usual manner around its periphery. In this construction, electrical impulses of sound frequency are applied to the terminals of the piezoelectric unit causing it to flex and to actuate the levers which in turn actuate the cone. As indicated above, piezoelectric torque unit 1 may be replaced with a piezoelectric unit of the bender type by connecting the drive links of the levers to appropriate points on the bender unit.

The invention may also be applied in a simplified form in a device such as is shown in Figs. 6 and 7. Here a base cap 80 is secured to an assembly plate 81 by screws 82, two gaskets 83 and 84 being disposed between their adjacent

surfaces. Two wire fulcrums 85, 85 are secured as by soldering to the plate 81, and fulcrum a pair of levers 86, 86 which are embodied in a single length of tubing flattened at its midpoint. Each lever has a drive link 87 secured to it at a point lying between its fulcrum and the midpoint of the length of tubing. The drive links are secured to opposite ends of an elongated bending-type piezoelectric unit 88. Supports 89, 89 are disposed on opposite sides of the unit adjacent its midpoint and serve to hold the center of the unit substantially fixed relative to plate 81 and the adjacent wall portion of cap 80. The supports may be made of damping material if desired. The drive links 87 pass through openings 90, 90 in the base plate, the space between the drive link and the wall of each opening being substantially closed with a flexible rubber bushing 91. The terminals 92 and 93 of the piezoelectric unit pass between the gaskets 83 and 84 and may be connected to any suitable electric circuit. A drive pin 94 may be secured to the flattened portion of the tubing composing levers 86, 86 and may be coupled to any suitable mechanical system. It will be understood that if the drive pin is actuated, the ends of the piezoelectric unit will be flexed with respect to the center and the unit thereby caused to generate a potential difference at its terminals. Conversely, potential differences may be applied to the terminals of the piezoelectric unit causing it to flex and thereby to actuate the levers and drive pin.

Figs. 8 and 9 illustrate another modified construction; one which is particularly adapted for use in a hill-and-dale type record cutter or phonograph pickup. A record cutter has been shown in the drawings and is seen to consist of a cutter arm 96 having a cup-shaped cavity defined by end walls 97 and 98, and side walls 99, 99. The cavity is closed by an assembly plate 100 secured thereto by screws 101, a pair of gaskets 102, 102 being disposed between the adjacent surfaces. A piezoelectric unit 103 of the torque type is disposed within the cavity and supported at one end by two fixed wire supports 104, 104 secured to its corners and in turn secured to the assembly plate 100. Disposed on the opposite side of the assembly plate are two wire fulcrums 105, 106 each secured at one end to the assembly plate and at its other end to a lever. The levers 107 and 108 are formed of a length of tubing bent into an L shape and flattened at the corner of the L. Lever 107 is shorter than lever 108 and is secured to fulcrum 105 so as to function as a lever of the first class. Lever 108 is secured to fulcrum 106 so as to function as a lever of a different class, such as the third class lever, illustrated. Each lever has a drive link 109 secured to it at an appropriate point, the link being connected at its other end to one of the unsupported corners of the piezoelectric unit. The drive links pass through openings 110, 110, in plate 100, the space between the drive pin and the wall of the opening being closed by a flexible rubber bushing 111. A cutting stylus 112 is secured to the flattened portion of the levers by means of nuts 113, 113. The terminals 114, 115 of the piezoelectric unit pass between the two gaskets 102, 102 and may be connected to an appropriate electrical circuit adapted to cause the unit to respond to electrical impulses of sound frequency. In operation, these impulses cause the piezoelectric unit to twist about an axis passing through the midpoints of its two

short sides, so that the unsupported corners which lie on opposite sides of the twisting axis move in opposite directions about the axis. Since the levers are of the first and third class, these motions of the corners cause the common point of the levers to move toward or away from assembly plate 100. Thus, when a recording disc is moved under the cutting stylus, electrical impulses applied to the terminals of the piezo-electric unit cause the stylus to cut a hill-and-dale type groove in the disc. Conversely, up and down vibrations imparted to a pickup stylus by a hill-and-dale type record twist the piezoelectric unit and cause it to generate a potential difference at its terminals.

Many other forms of the invention will occur to those skilled in the art, particularly when the principles of mechanics are applied in combination with the principles of operation of piezoelectric units. The principles of mechanics are well understood and need but little mention here. In order to point out the scope of the invention, however, the principles of operation of bimorph piezoelectric units will be discussed briefly, while reference is made to the three United States patents numbered 2,105,011, Re. 20,213 and Re. 20,680, for a more extended discussion. Bimorph (multiple) units are units of the flexing type and are divided into two classes in accordance with the type of flexing motion which they exhibit or respond to; namely, the bender type, and the torque type. For example, a torque type unit, when made of Rochelle salt may contain a square or rectangular plate which has been cut so as to have its edges substantially parallel to the major crystalline axes of the Rochelle salt. When this plate is secured to a constraining member, whether the latter be another plate of piezoelectric material properly oriented with respect to the former or merely a plate of non-piezoelectric material, a bimorph unit results. When a potential difference is applied to the electrodes of the unit, it twists about its major axes so that parts of the unit move out of the original plane of the unflexed unit. In square or rectangular units the greatest motion is at the corners, and the least motion occurs along the axes. Stated in another way, if a square piezoelectric torque unit were supported at its center of gravity and were flexed by applying a potential difference to its terminals, points lying on the crystalline axes, passing through the center of gravity, (that is, points lying on the lines passing through the midpoints of opposite sides of the piezoelectric plate) would remain stationary and define a stationary plane. All points of the crystal except those lying on the axes would move out of the plane and the motion would be such that a pair of opposite corners would move out of the plane in one direction while the other pair of opposite corners would move in the opposite direction.

The bender type Rochelle salt bimorph unit contains a piezoelectric plate which is cut, if square, so that the crystalline axes are parallel to the diagonals of the square. This plate is secured to another restraining member, as in the torque bimorph, which causes the assembly to flex when a potential difference is applied to the terminals of the piezoelectric material. If such a square unit were supported at its center of gravity and flexed by applying a potential difference to its terminals, the flexure would be such that points lying on the diagonals of the square would remain stationary while all other points of

the unit would move out of the plane defined by the diagonals, points lying on one pair of opposite quadrants moving in one direction out of the plane while points lying in the other pair of opposite quadrants move in the opposite direction. It will thus be appreciated that the unit assumes a saddle shape double curvature. In an elongated rectangular unit, it will be understood that the unit will flex along its length in a manner which appears to be mere simple bending since the bending along its length predominates while the bending across its width is negligible. Piezoelectric unit 88 in Figs. 6 and 7 flexes in this manner, and conversely is flexed by the levers in a manner simulating mere simple bending.

When the above differences between the torque unit and the bender unit are recognized, it becomes obvious that the units may be used interchangeably in a device of the kinds described above by merely coupling the connecting links of the levers to the appropriate points.

It should be recognized that to be operative for the purpose of interconverting electrical and mechanical vibratory energy, it is necessary that the piezoelectric unit be properly supported; that is, the support must permit the points of the unit at which the connecting links are coupled to move relative to the support. In addition, the points of support must be disposed relative to the moving points so as to maintain a condition of substantial equilibrium between all forces acting on the unit. This condition may be described by saying that the unit is reactively supported, since the forces acting on the unit through the supports react against the forces which tend to displace the unit, thus causing the unit to be flexed. For example, in Figs. 1 through 5, the reactive supports consist of one pair of levers which oppose the action of the other pair of levers. The reactive nature of the support thus provided is particularly apparent since it will be noted that the four levers cooperate to hold the center of gravity substantially stationary. The unit accordingly flexes or is flexed as though it were supported at its center of gravity in the manner described above; i. e., as though it were flexing in free space. In Figs. 6 and 7, the unit is reactively supported substantially at its midpoint since the support opposes the motion induced by the lever system. In Figs. 8 and 9, torsional forces are induced in the unit by the lever system, the torsion being the result of a mechanical couple. The unit is reactively supported at the opposite end by supports which induce a mechanical couple opposing any couple established by the pair of actuating levers.

Referring again to the lever constructions of Figs. 1 through 5, I call attention to another feature inherent therein which is worthy of note. As already noted above the center of gravity remains substantially stationary, and it will be observed that the piezoelectric unit is flexed in substantially the same manner as it would be flexed if unsupported and actuated by a voltage applied to its terminals. This being so, the torsional forces resulting from the inertia of the unit as it flexes are equal in magnitude but oppositely directed, and consequently neutralize each other in so far as the stresses on the supports are concerned. This feature assumes importance in devices which by their nature require the use of heavy piezoelectric units since the inertia effects of such heavy units may become so great, if not balanced out in the above manner, that even an

extremely rigid housing member may be set into vibration. Furthermore, these inertia effects may greatly increase the stresses on the lever assembly, its connecting link, and its fulcrums, thereby necessitating the use of dimensions therein which could be materially reduced if the inertia effects were balanced out. Since in this construction the piezoelectric unit flexes in the same manner as it would if unsupported, its frequency of mechanical resonance, neglecting mass loading of the lever mechanism, is the same as the free resonance of the unit. The resonance frequency of the piezoelectric unit supported in this manner is usually from two to eight times higher than it would be if the unit were mounted in a manner to permit inertia forces to react on the supporting structure. Thus for any required resonance frequency this construction permits the use of a larger piezoelectric unit. Large units are advantageous since they have lower electrical impedance and are usually easier to handle in assembly.

While the invention has been disclosed by reference to certain specific embodiments thereof, it is to be understood that it is not limited thereto, but that various modifications and changes, within the scope of the appended claims, may be made therein without departing from the spirit and essence of the invention.

What I claim is:

1. A device particularly adapted for interconverting electrical and mechanical vibratory energy, said device comprising: a piezoelectric crystal unit of the flexing type having a pair of terminals; reactive supporting means for said unit, said supporting means permitting a selected pair of spaced points on said unit to be displaced with respect thereto and to do work, when a potential difference is applied to the terminals of the unit; a pair of fulcrumed levers adapted to transfer energy between a first and a second coupling point thereon, said levers having their first coupling points connected to a common link, and having their second coupling points connected to the pair of spaced points on the unit, the fulcrums of the levers being disposed relative to the coupling points of their respective levers to cause the common link to be displaced when a potential difference is applied to the terminals of the unit, and conversely to displace said points relative to the supporting means when the common link is displaced.

2. A device as claimed in claim 1 wherein the reactive supporting means comprises at least one additional fulcrumed lever having its first coupling point connected to the common link, and having its second coupling point connected to a point on the piezoelectric unit distinct from the said pair of spaced points thereon.

3. A device as claimed in claim 1 wherein the reactive supporting means consists of a second pair of fulcrumed levers having their first coupling points connected to the common link, and having their second coupling points connected to the piezoelectric unit at points which are distinct from said pair of spaced points and which permit said levers reactively to support said unit.

4. A device as claimed in claim 1 wherein said piezoelectric unit is a four cornered unit of the torque type having two adjacent corners connected to the second coupling points of the said pair of levers; and wherein the reactive supporting means comprises fixed supports acting substantially at the other two corners.

5. A device as claimed in claim 1 having vibra-

tion-responsive means coupled to the common link.

6. A device as claimed in claim 1 wherein the reactive supporting means consists of a second pair of levers having their first coupling points connected to the common link of the first pair of levers, and having their second coupling points connected to the piezoelectric unit at points which are distinct from the said pair of spaced points and which permit said levers reactively to support said unit, the device including a common support for the fulcrums of the two pair of levers and for a fluid-pressure-responsive diaphragm connected to the common link.

7. A device as claimed in claim 1 wherein the said pair of levers are connected to the flexing type units at points which are substantially equidistant from the center of gravity on a line passing therethrough and which lie on opposite sides of both the major crystalline axes which pass through the center of gravity; and wherein the reactive supporting means consists of a support disposed substantially at the center of gravity.

8. A device as claimed in claim 1 wherein said piezoelectric unit is a four-cornered unit of the torque type and has two opposite corners connected to the second coupling points of the said pair of levers, and is reactively supported substantially at its other two corners.

9. A device as claimed in claim 1 wherein said piezoelectric unit consists of a substantially square unit; and wherein said pair of levers are of the first class and are fulcrumed on supports secured to a rigid casing member providing circumferential support for a disc diaphragm adapted to be vibrated by fluid pressure acting on a surface thereof, the second coupling points of said pair of levers being connected to opposite corners of the piezoelectric unit; and wherein said reactive supporting means consists of a second pair of levers of a different class and are fulcrumed on supports secured to said casing member and have their first coupling points connected to the said common link, and have their second coupling points connected to the other two corners of the piezoelectric unit; the common link of said two pairs of levers being disposed approximately on a line passing through the geometrical center of the diaphragm and the geometrical center of the unit and coupled to said diaphragm substantially at its geometrical center, said construction having the characteristic that fluctuations of the fluid pressure acting on the diaphragm flex the piezoelectric unit and generate a potential difference at its terminals, while vibrations acting elsewhere on the device are substantially ineffective in flexing the piezoelectric unit.

10. A device as claimed in claim 1 wherein the reactive supporting means consists of a second pair of fulcrumed levers having their first coupling points connected to the common link, and having their second coupling points connected to the piezoelectric unit at points which are distinct from said pair of spaced points and which permit said levers reactively to support said unit, the fulcrums of said second pair of levers being disposed relative to the coupling points thereof to permit the center of gravity of the unit to remain substantially stationary when the unit is flexed by the application of a potential difference to its terminals or by displacement of the common link.

CHARLES K. GRAVLEY.

CERTIFICATE OF CORRECTION.

Patent No. 2,207,539.

July 9, 1940.

CHARLES K. GRAVLEY.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 44, for "tonque" read --torque unit--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 17th day of September, A. D. 1940.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.

CERTIFICATE OF CORRECTION.

Patent No. 2,207,539.

July 9, 1940.

CHARLES K. GRAVLEY.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 44, for "tonque" read --torque unit--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 17th day of September, A. D. 1940.

Henry Van Arsdale,
Acting Commissioner of Patents.

(Seal)