July 12, 1938. I. E. FAIR 2,123,236

CRYSTAL HOLDER

Filed April 22, 1936 2 Sheets-Sheet 1

FIG. 1

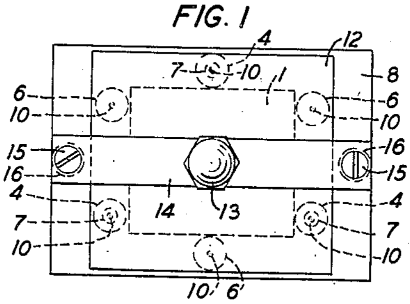


FIG. 3

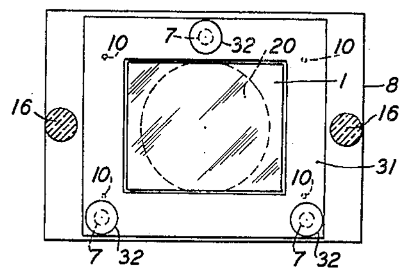


FIG. 2

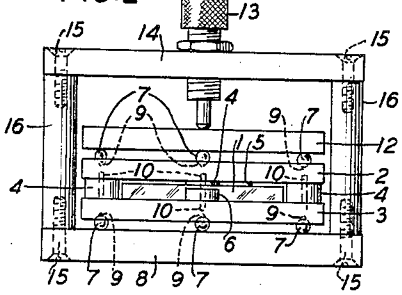


FIG. 4

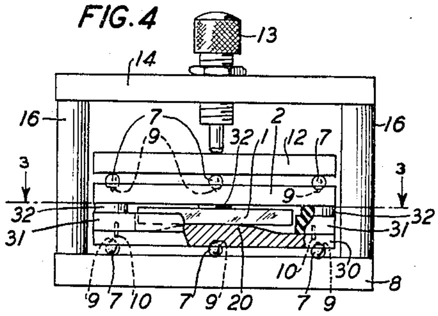


FIG. 5

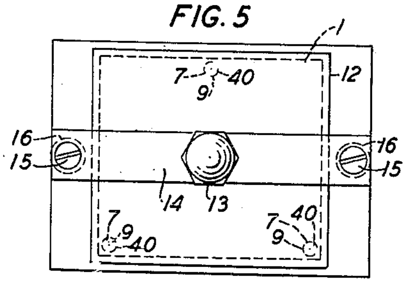


FIG. 7

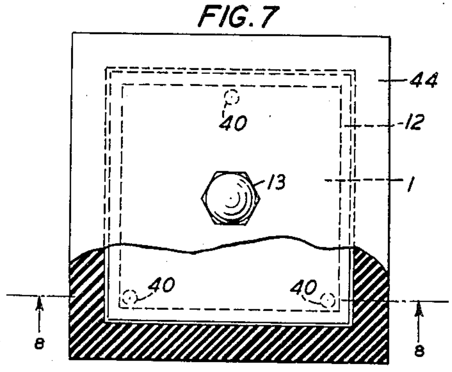


FIG. 6

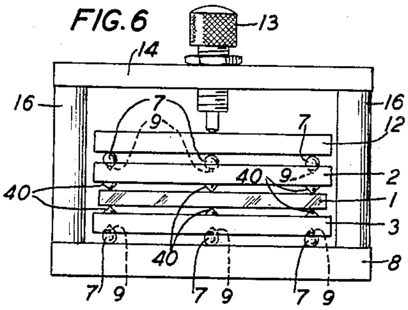


FIG. 8

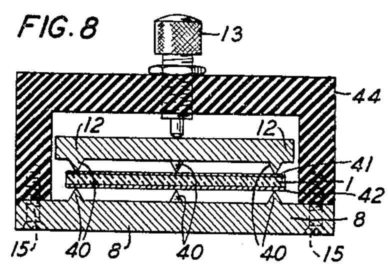
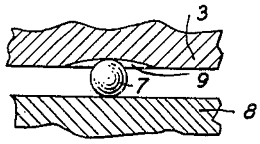


FIG. 9



INVENTOR
I. E. FAIR
BY
W. J. O'Neill
ATTORNEY

FIG. 10

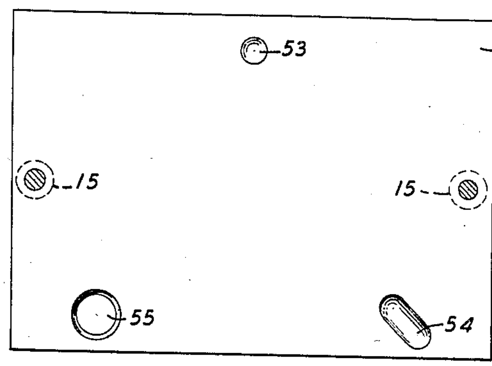


FIG. 11

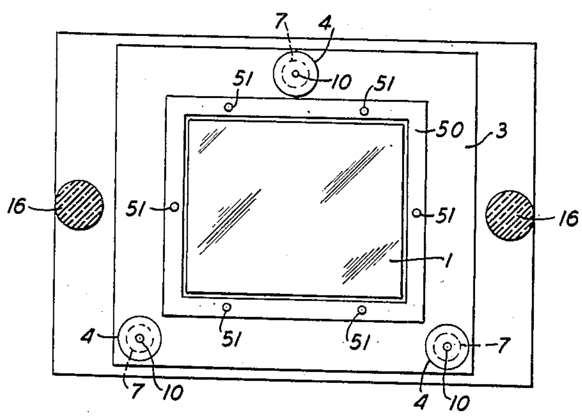
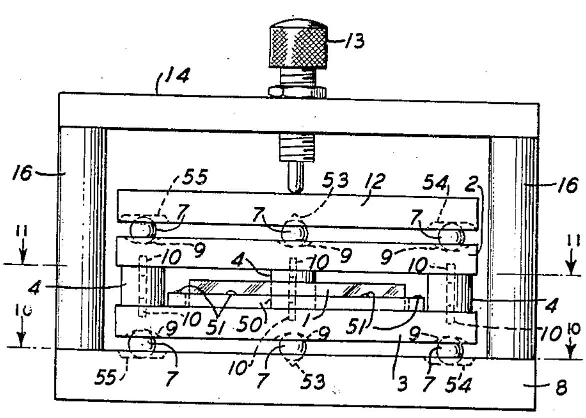


FIG. 12



INVENTOR
I. E. FAIR
BY
W. J. O'Neill
ATTORNEY

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UNITED STATES PATENT OFFICE

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CRYSTAL HOLDER

Irvin E. Fair, Lyndhurst, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 22, 1936, Serial No. 75,727

21 Claims. (Cl. 171—327)

This invention relates to electromechanical vibratory apparatus, such as piezoelectric apparatus, and particularly to piezoelectric crystal mountings and crystal holders suitable for use in connection with controlling the frequency of oscillations of oscillation generators and other oscillatory apparatus, for example.

One of the objects of this invention is to mount a vibrating piezoelectric crystal in such manner as to obtain and maintain a constant value of frequency over a long period of time.

Another object of this invention is to so mount a piezoelectric body as to minimize the effect of aging of the holder or the effect of external vibrations upon the frequency thereof.

Another object of this invention is to reduce to a minimum, strains such as warping or bending, in crystal electrode plates or in crystals.

Another object of this invention is to render the frequency of vibration of a piezoelectric body relatively independent of clamping pressure.

The frequency of a piezoelectric crystal, such as, for example, a quartz, tourmaline, Rochelle salt or other piezoelectric body, may be affected by variation of pressure on the crystal, by variation of pressure on the crystal electrodes or by variation of the spacing, such as the air-gap spacing between the crystal and the crystal electrodes. Such variations in pressures or spacings may produce either slowly changing frequency drifts or sudden frequency changes therein.

In the case of a rigidly clamped piezoelectric crystal, the variation in pressure may be caused by changes in the clamping pressure on the crystal itself or on the crystal electrodes associated therewith. In the case of unclamped crystals, the variation in pressure on the crystal may be caused by a shift in the point of contact of the crystal with the supporting element for the crystal. The variation in the spacing between the crystal and one or more of the crystal electrodes may be caused by variation in pressure on the crystal electrodes with resulting warping or bending thereof which may cause a variation in the frequency of the vibrating piezoelectric crystal device.

In accordance with one feature of this invention, the metal plates, such as the electrode plates, associated with a piezoelectric body such as a quartz crystal plate of any suitable size, shape, cut, orientation and mode of vibration, may be so supported in a holder by proper application of forces to the plates by spring pressure or otherwise that any strains set up therein that would cause bending or warping thereof are substantially eliminated or minimized or prevented, thereby to obtain a constant spacing between the crystal and the metal plates capacitatively associated therewith, and the holder may be so constructed that warping or bending of other parts thereof does not result in a change in the spacing between the crystal and the metal electrode plates associated therewith. Accordingly, a crystal holder constructed in accordance with this invention may prevent or relieve strains, warping and bending in one or more of the crystal electrodes as well as in the crystal.

For a clearer understanding of the nature of this invention and the additional features and objects thereof, reference is made to the following description taken in connection with the accompanying drawings, in which like reference characters represent like or similar parts and in which:

Fig. 1 is a top view of the crystal holder shown in Fig. 2;

Fig. 2 is a front elevation of the crystal holder shown in Fig. 1;

Figs. 3 and 4 are respectively a horizontal sectional view and a front elevational view of a modification of the crystal holder shown in Fig. 1, Fig. 3 being a view taken on the line 3—3 of Fig. 4;

Figs. 5 and 6 are respectively top and front elevational views of another modification;

Figs. 7 and 8 are views of another form of crystal holder, Fig. 8 being a vertical section taken on the line 8—8 of Fig. 7;

Fig. 9 is a vertical sectional view illustrating one form of ball bearing support; and

Figs. 10, 11 and 12 are views of still another modification, Fig. 10 being a horizontal section taken on the line 10—10 of Fig. 12, and Fig. 11 being a horizontal section taken on the line 11—11 of Fig. 12.

Referring to the drawings, the crystal holder may be in the form illustrated in Figs. 1 and 2, in which a piezoelectric crystal plate 1 rests without clamping between two flat metallic electrode plates 2 and 3, each of which may be supported and clamped by a three point aligned suspension arrangement, as illustrated, to prevent warping or bending of the electrode plates 2 and 3. The electrode plates 2 and 3 may be disposed horizontally and separated by three equal length insulating spacers 4 of quartz, glass, Pyrex, Isolantite, Bakelite or other suitable insulating material, to leave a small uniform gap or spacing 5 of the order of about 0.1 millimeter or less, for example, between the upper surface of the crystal 1 and the lower surface of the upper electrode plate 2. The three spacers 4 and three retaining members 6 may partly, or a suitable number of additional retaining members 6 may wholly surround the peripheral edges of the crystal 1 to retain the crystal 1 from lateral movement in the space between the electrode plates 2 and 3. The bottom electrode 3 may rest upon three small equal-diameter steel balls 7 which may be free to adjust their position on the base plate or lower end plate 8 of the crystal holder. The three steel balls 7 may be held in position by three conical or spherical depressions 9 in the bottom surface of the bottom electrode plate 3. The three insulating spacers 4 may be placed between the electrode plates 2 and 3, in positions directly above and in coaxial alignment with the corresponding three steel balls 7. Small pins 10 extending into the electrode plates 2 and 3 may hold the three spacers 4 and the three retainers 6 in position. On top of the upper electrode 2 in coaxial alignment with the corresponding three spacers 4, three additional small equal-diameter steel balls 7 may be set in three conical or spherical depressions 9 in the upper surface of the electrode plate 2. On these steel balls 7, a flat brass end plate 12 may rest and have clamping pressure applied thereto by suitable means, such as a screw 13, supported at the center of a cross-bar 14, for example, or at other points thereof. The cross-bar 14 may be secured by screws 15 to supporting posts 16 which, in turn, may be secured by additional screws 15 to the flat base plate 8. It will be understood that any suitable means may be utilized to apply clamping force to the end plates 8 and 12. In the arrangement illustrated in Figs. 1 and 2, as well as in other figures, since clamping pressure is applied to three points only on the crystal electrodes 2 and 3, and since the pressure points are carefully aligned, no warping or bending of the electrodes 2 and 3 or of the crystal 1 can take place due to shifting of centers of pressure. Where the pressure points on the electrodes 2 and 3 coincide, as in the arrangement shown, the electrodes 2 and 3 may be relatively thin since no bending stresses are exerted thereon.

Both of the electrode plates 2 and 3 may have a flat surface adjacent the crystal 1 which is disposed therebetween as illustrated in Figs. 1 and 2. Such flat surfaces may be as optically flat as practicable as, for example, within about a quarter of a wave-length of sodium light. Or, one of the crystal electrodes, as the electrode 3, may have a spherically convex surface 20 as illustrated in Figs. 3 and 4, making contact with the center of one of the major surfaces of the crystal 1, which central portion may be a node of vibration. The electrodes 2 and 3 may be made of suitable metallic material that does not warp with age, such as, for example, annealed Armco iron or stainless steel.

By utilizing the end plates 8 and 12 and the aligned steel balls 7 and spacers 4 to obtain the three point application of forces to the electrode plates 2 and 3, variations in shape of the electrode plates 2 and 3 are minimized and strains therein are prevented, which strains in time would tend to warp the electrode plates 2 and 3 and cause undesired frequency variations in the oscillatory system associated therewith. It will be noted that where the pressure points are only three in number, as illustrated, there can be no teeter or rocking or changes in pressure that may be caused by supports of more than three points per surface.

Figs. 3 and 4 illustrate a crystal holder similar to that illustrated in Figs. 1 and 2 but having a spherically convex surface 20 in the central part of the upper surface of the lower electrode 30 and also having an insulating retainer 31 completely surrounding the four edge faces of the crystal 1. Three spacers 32, similar in construction and function to the three spacers 4 of Figs. 1 and 2, may be integral with, as shown in Figs. 3 and 4, or may be separate from the retainer 31. Pins 10 extending into openings in the retainer 31 and the plate 30 may hold the parts in aligned position with the balls 7 as described in connection with Figs. 1 and 2. For the same purpose, pins, similar to the pins 10, may extend into the three spacers 32 and into the upper electrode plate 2. The convex surface 20 of the electrode 30 may make contact with the center only of the lower major surface of the crystal 1 to reduce friction therebetween, the center of the crystal 1 being a node of vibration in the example illustrated in Figs. 3 and 4.

By loosely positioning the unclamped crystal 1 between the electrodes 2 and 30 and limiting its lateral motion or wandering by means of a closely but loosely fitting retainer 31 having a recess of rectangular parallelepiped shape surrounding the edges of and just large enough to receive, and of nearly the same dimensions as the crystal 1, the crystal 1 is completely enclosed in a space or cavity only slightly larger than the crystal 1 and is prevented from moving about between the electrodes 2 and 30, but is left free to vibrate therebetween without the introduction of damping or pressure frequency changes, or changes in frequency due to jarring or shaking.

Where a portion of the upper surface 20 of the bottom electrode plate 30 is made slightly spherically convex, the convex portion 20 thereof may touch or be near to a node of the crystal 1 but free from the crystal 1 at the points of vibrational motion thereof. Where only the node of the crystal 1 rests on the electrode surface 20, damping of the crystal 1 is minimized. The node of a crystal is a point or area of maximum voltage and minimum motion.

In another form of crystal holder as illustrated in Figs. 5 and 6, the opposite major surfaces of the crystal 1 may be nodally clamped between three pairs of coaxially aligned projections 40 which may be integral with the electrodes 2 and 3. Each pair of the three pairs of six crystal clamping projections 40 are coaxially aligned. Each of the crystal clamping projections 40 may have sharp metallic needle points disposed in contact with the crystal 1 or with thin metallic platings 41 and 42 deposited thereon as illustrated in Fig. 8. The crystal electrodes 2 and 3 of Figs. 5 and 6 may be supported and clamped by the three point aligned ball bearing arrangement described in connection with Figs. 1 to 4 illustrating the crystal holder adapted to mount an unclamped crystal 1. Where the supporting members for the electrodes 2 and 3 and crystal 1 are aligned and are three in number, as illustrated, warping or bending of the electrode plates 2 and 3 and crystal 1 are prevented.

It will be understood that the electrode plates 2 and 3 may be resiliently clamped by springs such as for example by leaf springs, that the springs may be of approximately the same area as the electrodes 2 and 3 and may have bosses or projections located to register with the projections 40 of the electrodes 2 and 3. Where the pressure points of the spring so coincide with the contact points 40 between the electrodes 2 and 3, and the piezoelectric element 1, the electrodes 2 and 3 may be of thin light weight material since substantially no bending stresses will be exerted on the electrodes 2 and 3. It will be understood that the clamping projections 40 may be placed to suit the nodal area of the crystal 1.

In another form of the crystal holder, as illustrated in Figs. 7 and 8, a crystal 1 having thin metallic electrodes 41 and 42 integral with the opposite surfaces thereof is rigidly held by three pairs of coaxially aligned clamping points 40 resting on the integral electrodes 41 and 42 at nodes of the crystal 1. The electrodes 41 and 42 integral with the crystal 1 may be of any suitable metallic material such as, for example, platinum, aluminum or chromium on top of platinum. The three pairs of clamping points 40 disposed in contact with the integral crystal electrodes 41 and 42 may be sharp metal points as needle points. The nodal points of the crystal 1 may be determined by any suitable method as, for example, by taking a dust pattern. In some crystals, the marginal corners thereof, as illustrated in Figs. 7 and 8, may be utilized as nodal points; in other crystals, the nodal area may be at the center. The projections 40 may be placed to suit the nodal areas of the particular crystal.

Where needle points are utilized to clamp a piezoelectric crystal, such as a metal coated quartz crystal, the frequency change with changes of clamping pressure is reduced and rendered more regular and the frequency may remain constant under conditions of considerable jarring and shaking.

As illustrated in Figs. 7 and 8, the three pairs of coaxially aligned clamping projections 40 may be integral with the end plates 8 and 12 and the clamping pressure on the crystal 1 may be controlled by a manually controlled screw 13 movable in an insulating housing 44 which may be secured to the lower metal end plate 8 by suitable screws 15.

The crystal holder illustrated in Figs. 10, 11 and 12 is similar to that illustrated in Figs. 1 and 2. In Figs. 10 to 12, the three cylindrical insulating spacers 4 and pins 10 serve to space and position the parts as in Figs. 1 and 2. A rectangular-shaped retaining member 50 wholly surrounding the four edge faces of the crystal 1 and separate from the three spacers 4, may be secured by pins 51 to the lower electrode plate 3 and utilized to retain the crystal 1 in position in the same manner as the rectangular retaining member 31 of Figs. 3 and 4. The steel balls 7 and the cavities 9 in the electrode plates 2 and 3 and those in the end plates 8 and 12, all aligned with the three spacers 4, may be provided for the purposes described in connection with Figs. 1 and 2. The cavities 9 may be conical, spherical, or of other suitable form. Fig. 10 illustrates depressions in the end plates 8 and 12 comprising a conical cavity at 53, an elongated groove at 54, and a flat bottom circular groove at 55. The cavities or depressions 9, 53, 54 and 55 are arranged for self-alignment of all plates 2, 3, 8 and 12 without introducing strains in the electrode plates 2 and 3. Electrical connections may be established with the crystal plate 1 through a circuit including the electrode plates 2 and 3, the steel balls 7, the end plates 8 and 12, and the screw 13 and bar 14. In such arrangement, the spacers 4 and supporting posts 16 are constructed of suitable insulating material.

Where spacing is employed between one or more of the electrodes 2 and 3 and the adjacent crystal surfaces, as illustrated in Figs. 10 to 12 for example, the spacing may be of such value and uniformity as to allow the charge to be drawn off evenly over the surface of the crystal 1 and prevent the building up of large voltages between the electrode 2 and the crystal 1 thereby to prevent arcing or sparking therebetween and undesired modulation of the radio frequency output. The spacing may be of the order of about 0.002 inch between an electrode 2 and the upper surface of the crystal 1 adjacent thereto. Also, the upper surface of the crystal 1 may have a thin metallic plating 41, as illustrated in Fig. 8, to prevent such arcing.

The planes of the parallel electrodes 2 and 3 may be angularly mounted in an inclined or slant position intermediate the horizontal and vertical positions to maintain the unclamped crystal 1 in contact at all times with one of the electrodes, as the electrode 3, and with the retaining means, as with one or more of the retaining members 4 and 6 of Fig. 1, or with a side of the retaining ring 31 of Figs. 3 and 4 or 51 of Figs. 10 to 12. Where the electrodes 2 and 3 are inclined, the unclamped crystal 1 remains in one position between the spaced electrodes 2 and 3 with resulting improvement in frequency stability. The electrodes 2 and 3 may be so inclined by mounting the base plate 8 upon a shelf inclined at a suitable angle intermediate the horizontal and vertical positions. Either electrode 2 or 3 may have a series of holes therein for the insertion of pins 10 upon which the inclined crystal 1 may rest and the holes in the electrode may be positioned to accommodate crystals of different sizes between the same pair of electrodes 2 and 3.

To reduce the capacity between the electrodes 2 and 3, the electrodes 2 and 3 may be of relatively small area and may each have three aligned projecting ears (not shown) for clamping three insulating spacers 4 therebetween.

Crystal holders constructed in accordance with the present invention may be advantageously employed in connection with oscillator circuits to attain a constant frequency oscillator of very high stability of frequency.

The effect of temperature variations upon the frequency of vibration of the piezoelectric device 1 may be controlled by any suitable system of temperature control or temperature compensation or other suitable system for eliminating the effect of temperature change such as, for example, by utilizing a piezoelectric crystal which itself has a zero temperature coefficient of frequency.

Although this invention has been described and illustrated in relation to specific arrangements, it is to be understood that it is capable of application in other organizations and is, therefore, not to be limited to the particular embodiments disclosed but only by the scope of the appended claims and the state of the prior art.

What is claimed is:

1. A piezoelectric crystal holder including a plurality of electrode plates, and means including another plate, three members disposed between said another plate and one of said electrode plates and three additional members disposed between said electrode plates at three points opposite said first-mentioned three members for applying pressure at three points only to said one of said electrode plates to prevent bending thereof.

2. A piezoelectric crystal holder including a plurality of electrode plates, an end plate disposed outwardly of each of said electrode plates, and means whereby each of said plates is clamped in aligned relation with another of said plates at three points only.

3. A piezoelectric crystal holder including a plurality of electrode plates, an end plate disposed outwardly of each of said electrode plates, means whereby each of said electrode plates is clamped in aligned relation with another of said plates at three points only, a piezoelectric crystal interposed between said electrode plates, and means for retaining said crystal in position between said electrode plates.

4. A piezoelectric crystal holder including crystal electrodes, and means including three pairs of separate members for holding each of said electrodes in compression, the two separate members of each of said pairs being disjoined and disposed in coaxial alignment with each other and out of alignment with the members of the two other pairs.

5. An electromechanical vibrator including a piezoelectric crystal, electrodes therefor, and means including a ball for clamping said electrodes.

6. An electromechanical vibrator including a piezoelectric crystal, electrodes therefor, and means including a roller contacting a rollway on one of said electrodes for clamping said electrodes.

7. An electromechanical vibrator including a piezoelectric crystal, electrodes therefor, and means for clamping said electrodes including three balls exerting pressure at three non-aligned points on one surface of one of said electrodes.

8. An electromechanical vibrator including a piezoelectric crystal, and means for clamping said crystal including three balls exerting pressure at three non-aligned points on one surface of said crystal.

9. A piezoelectric crystal holder including electrodes, and means clamping said electrodes including three pairs of balls, the balls of each pair being in alignment with each other but out of alignment with the balls of the other two pairs.

10. A piezoelectric crystal holder including crystal electrodes, and means including three sets of aligned members holding one of said electrodes in compression, each of said sets including a ball as a member thereof.

11. A piezoelectric crystal holder including a pair of electrodes, each having three depressions therein, three insulating spacing members disposed between said electrodes, a pair of end plates, three balls disposed between one of said end plates and the three depressions of one of said electrodes, three additional balls disposed between another of said end plates and the three depressions of another of said electrodes, and means clamping said end plates, said spacers and said balls being so aligned that said electrodes are subjected to only three centers of compression.

12. Electromechanical vibratory apparatus including a piezoelectric crystal having plated electrodes integral therewith, and means including three pairs of coaxially aligned projections for clamping said crystal.

13. Electromechanical vibratory apparatus including a piezoelectric crystal, and means including three pairs of coaxially aligned projections for clamping said crystal.

14. Electromechanical vibratory apparatus including a piezoelectric crystal having plated electrodes integral therewith, and means including three pairs of coaxially aligned conductive projections for clamping said crystal.

15. Electromechanical vibratory apparatus including a piezoelectric crystal, electrodes for said crystal, and means including three sets of aligned members having sharp points for holding said crystal in compression.

16. In a piezoelectric crystal holder, an electrode having three spaced non-aligned depressions in one surface thereof and means including three balls in said depressions for applying pressure to said electrode at three points only.

17. A piezoelectric crystal holder including an electrode for the crystal, and means including a plate and a roller disposed between said plate and said electrode for applying pressure to said electrode.

18. A piezoelectric crystal holder including an electrode for the crystal, and means including a plate and three non-aligned rollers disposed between said plate and said electrode for applying pressure at three points only to said electrode.

19. An electromechanical vibrator comprising a piezoelectric crystal having plated electrodes formed integral with opposite surfaces thereof, and means including three pairs of coaxially aligned members having sharp metal points disposed in contact with said electrodes and clamping said crystal.

20. A piezoelectric crystal holder including a pair of electrodes, three non-aligned spacers separating said electrodes, means including members separate and disjoined from said spacers for clamping together said electrodes and spacers only at points coaxially aligned with said spacers, and a crystal retaining member separate from said spacers, secured to one of said electrodes and wholly surrounding the periphery edges of the crystal retained in position thereby.

21. A piezoelectric crystal holder including a pair of electrodes, three non-aligned spacers separating said electrodes, means for clamping together said electrodes and spacers only at points coaxially aligned with said spacers, said clamping means including rollers disposed in contact with said electrodes, and crystal retaining means separate from said spacers, secured to at least one of said electrodes and disposed adjacent the periphery of the crystal retained in position thereby.

IRVIN E. FAIR.