July 14, 1942. J. M. WOLFSKILL 2,289,950

PIEZOELECTRIC CRYSTAL APPARATUS

Filed April 28, 1941

Fig. 1.

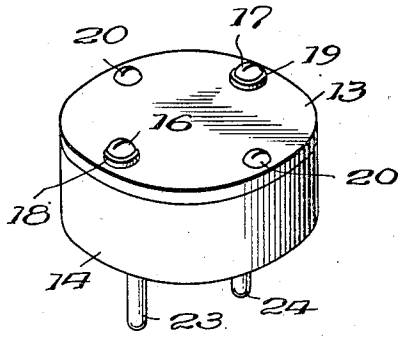


Fig. 2.

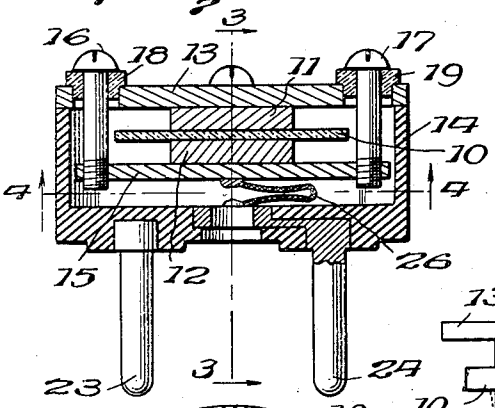
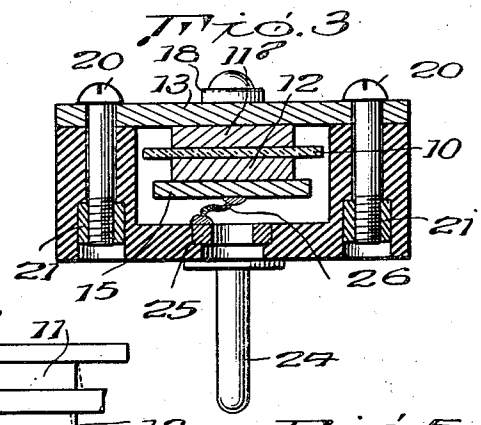


Fig. 3.



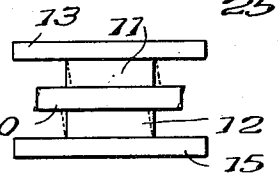
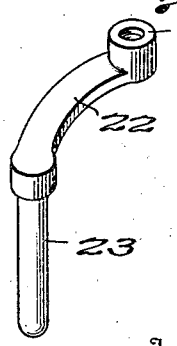


Fig. 6.

Fig. 5.



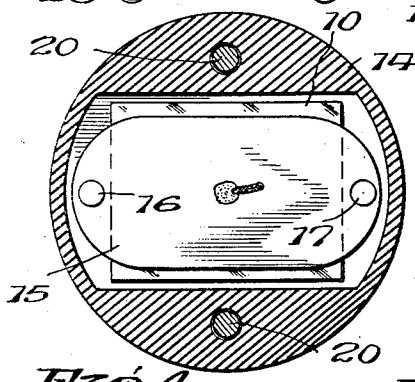


Fig. 4.

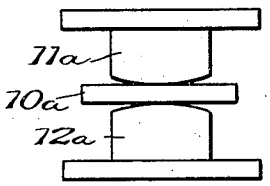
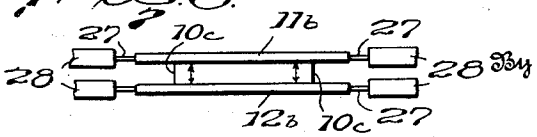


Fig. 7.

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Fig. 8.



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his Attorney

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UNITED STATES PATENT OFFICE

2,289,950

PIEZOELECTRIC CRYSTAL APPARATUS

John M. Wolfskill, Erie, Pa., assignor to Bliley Electric Company, Erie, Pa., a partnership composed of F. Dawson Bliley and Charles Collman

Application April 28, 1941, Serial No. 390,830

15 Claims. (Cl. 171—327)

This invention relates to piezo-electric crystal apparatus in general and more particularly to a method and apparatus of mounting crystals in such a way that they are rigidly supported without having crystal characteristics affected by the clamping or mounting means.

This invention relates to a crystal holder of the general type disclosed in my application Serial No. 343,468, Patent No. 2,240,453.

An object of this invention is to provide a mounting for piezo-electric crystals in which the crystal may be rigidly clamped without in any way affecting its piezo-electric activity.

Another object is to provide a piezo-electric crystal holder or mounting in which resonant clamping means are employed for supporting the crystal rigidly.

Another object is to provide a mounting or holder for high frequency piezo-electric crystals in which the crystal is rigidly clamped so that its position will be maintained regardless of the vibration of the crystal or any slight jars or vibrations to the holder proper.

A further object is to provide a holder for piezo-electric crystals in which the mounting means also serve as the electrodes themselves, being resonant to the crystal frequency.

In the prior art, the mounting of crystals in suitable electrodes throughout certain frequency ranges has always presented a problem, primarily because the electrodes, when placed against the crystal face, abrade the crystal because of the relative movement of the crystal to the electrodes. This movement, although very minute, is sufficient to cause deleterious effects both to the crystal and the electrodes. There is a tendency for small amounts of quartz to be worn off and pieces of metal imbedded in the crystal faces. This naturally causes frequency changes to the unit, and also tends to lower the Q or dampen the vibration of the crystal. This effect is cumulative and can over long periods of time cause complete stoppage of oscillation of the crystal. In air-gap type holders, this effect is eliminated except on the base electrode, on which the crystal rests, but here the pressure is very light, being only the weight of the crystal, and the effect is not serious. However, where the crystal is to be clamped to avoid frequency variation due to vibration, the effect again becomes noticeable and most crystals above about 1500 kc. are used in holders in which the electrodes are in direct contact with the crystal face.

Various means have been used to overcome this, and my co-pending application, Serial No. 331,050, Patent No. 2,240,451, uses a recessed electrode such that the crystal is in contact with the metal electrode only on the four corners. Other means of using recessed electrodes or clamping the crystal only on the periphery of the electrode have been used, but in these types of mountings the crystal portions in the clamped areas oscillate only very weakly, and the activity of the entire crystal unit is therefore somewhat affected by the clamping means.

My invention completely eliminates any abrasive action between the quartz and the electrode, because there is no relative movement therebetween since the electrode is proportioned in such a way as to be resonant at the crystal frequency or harmonic thereof, and therefore moves with the crystal face. The activity of the crystal is also not affected by the clamping or mounting means, because the electrode is resonant to the crystal frequency or harmonic thereof and no damping action results from the clamping. The crystal is therefore rigidly supported and clamped between two resonant members which are resonant to the crystal frequency or a harmonic thereof. These resonant members can be used either on the first, second, or third mode in order to get a practical proportion between the length and diameter.

The present invention uses resonant members to serve both as the supporting means and as the electrodes for the crystal and has its main usefulness in the mounting of crystals from about 1500 kc., up to and including the high and ultra high frequencies.

Further details of this invention will be apparent to those skilled in the art to which it relates from the following specification, claims and drawing in which, briefly,

Fig. 1 is an external perspective view of the crystal holder of my invention;

Fig. 2 is a vertical sectional view through the crystal holder shown in Fig. 1;

Fig. 3 is a view along the line 3—3 of Fig. 2;

Fig. 4 is a view along the line 4—4 of Fig. 2;

Fig. 5 is a view of one of the connecting pins of the holder;

Fig. 6 is a view of the electrodes and crystal employed for the purpose of explaining features of this invention;

Fig. 7 is an exaggerated view of a holder with convex electrodes; and

Fig. 8 is a view of a holder adapted for longitudinal mode plate type crystals.

Referring to the drawing in detail, reference numeral 10 designates a piezoelectric crystal ele-

ment clamped between the button electrodes 11 and 12 which will be referred to as resonant buttons since the lengths of these buttons in a direction normal to the clamped faces of the crystal element are mechanically resonant or some multiple or submultiple of the crystal element frequency. The electrode 11 is soldered, welded, brazed or otherwise attached to the metal cover 13 of the crystal housing 14 which is of insulation material. The electrodes 11 and 12 may be made of material such as stainless steel with the faces thereof contacting the crystal faces ground practically to a polish.

The bottom electrode 12 is attached as by soldering, welding, brazing and the like to the member 15 which is supported by the machine screws 16 and 17 from the cover 13. The screws 16 and 17 are provided with porcelain, "Isolantite" or similar insulation bushings 18 and 19 respectively between them and the cover 13 to prevent electrical short circuit of the crystal element. These screws are employed for the purpose of clamping the crystal element and electrodes together and for that purpose the screws are threaded into the plate member 15 although if desired these screws may pass through suitable holes of somewhat larger size in the plate 15 and engage in threaded nuts on the other side of said plate. In that case coil springs may be used between the nuts and the plate to add resilience to the electrode and crystal assembly.

The cover 13 is attached to the insulation housing 14 by suitable machine screws 20 which engage threaded nuts 21 embedded in the insulation walls of the housing. One of these nuts 21 is attached to a connecting member 22 shown in Fig. 5 and this is embedded in the base of the housing for the purpose of forming electrical connection with the base pin 23. The other base pin 24 is connected to the connecting member 25 partially embedded in the base and this in turn is connected through the flexible lead 26 to the plate member 15.

In Fig. 6 I have shown an exaggerated view of the manner in which the button electrodes 11 and 12 vibrate in the shear mode. The amplitude of the vibration in one direction is shown in dotted lines and this illustrates the shearing action of the vibration accomplished when the lengths of the electrodes in the direction normal to the faces of the crystal contacted by the electrodes, are mechanically resonant to the frequency of the crystal or some multiple or submultiple thereof.

The formulas that apply for computing the length of the button required to be resonant at the specified crystal frequency are as follows. These have been determined from the fundamental considerations given in "Mechanical Vibrations," by Den Hartog for a clamped free bar in which the resonant member acts as a cantilever, and these equations are given below.

$$F=\frac{1.63T}{L^2}\sqrt{\frac{E}{D}}$$

where

E=Young's modulus in dynes/sq. cm.
D=Density or specific gravity
L=Length in cm.
T=Thickness of section in cm.
F=Frequency in cycles/sec.

This equation is for a square or approximately square section in which the bending moment is taken about an axis at right angles to the thickness T. Substituting representative values for steel of E and D, $E=20\times10^{11}$ dynes/sq. cm. and $D=8$, we get

$$F=\frac{81.000T}{L^2}$$

For a round section,

$$F=\frac{.140d}{L^2}\sqrt{\frac{E}{D}}$$

where d=diameter of section. Again substituting values for E and D,

$$F=\frac{70.000d}{L^2}$$

For these equations, we can compute the length of the electrode to be resonant at any frequency F. The dimension T or the diameter d can be fixed at some value which is reasonable and the length for resonance computed. As an example of the use of these equations, we will assume a round steel electrode of 1.27 cm. diameter and a crystal frequency of 2000 kilocycles.

$$F=\frac{70,000(1.27)}{L^2}$$

$$L^2=\frac{70,000(1.27)}{2,000,000}$$

$$L=.211 \text{ cm.}$$

For a crystal frequency of 10,000,000 cycles and the same diameter button of 1.27 cm.,

$$L^2=\frac{70,000(1.27)}{10,000,000}$$

$$L=.0944 \text{ cm.}$$

All of these equations are given for the first natural mode of vibration of a cantilever. In some cases, it may be desirable to use a second or even a third mode of vibration at the high frequencies to get a slightly longer or actually thicker resonant button electrode. Under conditions of second mode vibration, the constant in the frequency equation must be multiplied approximately 6.25 times. The length of the pin vibrating in the second mode will then be increased by the square root of 6.25 or 2.5 times. A second mode button then would be 2.5 times as long as a fundamental button for the same frequency. This is of course assuming the same diameter. The third or higher modes may be used in the same manner. The length for the examples computed for the 2 megacycle crystal on the second mode would be .527 cm., and the length for the 10 mc. crystal would be .236 cm.

Because of the high frequency at which this button type electrode is used and the consequent small motion of the crystal, the relatively small ratio between the length of the electrode, or it actually might be considered thickness, to the diameter is of little consequence. It still operates as a cantilever or a clamped free bar. It has been found necessary at the lower frequency ranges where this type of electrode can be employed to put a slightly convex face on the ends of the button electrodes 11a and 12a which contact the crystal 10a so that the motion is not impeded as shown in Fig. 7. The convexing need only be of the order of several thousandths of an inch over the half inch or more diameter. As the frequency is increased, however, this is no longer necessary, and around 3 or 4 megacycles the end of the electrode or resonant member can be flat.

This type of holder is well adapted to the

mounting of high frequency crystals, and it has been checked experimentally throughout the frequency range from 2 megacycles to 30 megacycles with excellent results. All of these holders assume the use of a plate type crystal operating in a shear mode. If a longitudinal mode plate type crystal 10c, such as an X-cut, is employed as shown in Fig. 8 the electrodes 11b and 12b and crystal 10c may be mounted in a resonant pin arrangement in which small resonant pins 27 are used to hold the electrodes at right angles to the movement of said electrodes. The crystal 10c vibrates in the direction indicated by the arrows so that the pins 27 engaging the edges of the electrodes 11b and 12b vibrate as cantilevers with respect to the firm supports 28. In this case it may be desirable to apply pressure to the electrodes 11b and 12b. If these electrodes are plated or sprayed on the crystal faces the pins 27 may engage the edges 10c of the crystal if the crystal is of sufficient thickness.

It has been found in actual practice that the length of the resonant member is not critical and that it may vary within relatively wide limits because the pressure applied to the crystal to support it can be relatively high before affecting the crystal performance, and consequently some adjustment in the resonant frequency of the electrodes may be obtained by adjusting the pressure. The pressure can be made so high that there is no need for any other means of supporting the crystal or restraining the movement in the holder.

Various other modifications of this invention may be made without departing from the spirit and scope thereof and therefore I do not desire to limit this invention to the exact details illustrated and described, except as these details may be defined in the claims.

What I claim is as follows:

1. A piezoelectric crystal holder, comprising: a piezoelectric crystal, a pair of electrodes having faces for clamping said crystal faces therebetween each of said electrodes having a length in a direction normal to said crystal faces dimensioned so as to be substantially mechanically resonant to a frequency of vibration of said piezoelectric crystal, said electrodes having a diameter parallel to the faces of said crystal equal to several times the length thereof.

2. A piezoelectric crystal holder, comprising: a piezoelectric crystal, a pair of substantially flat electrodes for clamping portions of the faces of said crystal therebetween, each of said electrodes having a length in a direction normal to said crystal faces dimensioned so that said length is substantially mechanically resonant to a frequency of vibration of said crystal, said electrodes having a diameter parallel to the faces of said crystal equal to several times the length thereof, and means for pressing said electrodes into clamping relation with the corresponding faces of said crystal.

3. Piezoelectric crystal apparatus, comprising: a piezoelectric crystal, plug shaped electrodes each having a length in a direction normal to said crystal faces proportioned to vibrate with said crystal and a diameter equal to several times said length and means for clamping said crystal between said plug shaped electrodes.

4. Piezoelectric crystal apparatus, comprising: a piezoelectric crystal, thin disc electrodes having faces engaging faces of said crystal, the thickness of said disc electrodes being proportioned to vibrate sympathetically with said crystal and the long dimensions of said disc electrodes being equal to several times said thickness dimensions.

5. Piezoelectric crystal apparatus, comprising: a piezoelectric crystal, thin disc electrodes having faces engaging faces of said crystal, the thicknesses of said disc electrodes being proportioned to vibrate sympathetically with said crystal and the long dimensions of said disc electrodes being equal to several times said thickness dimensions and means for clamping said crystal firmly between said disc electrodes.

6. Piezoelectric crystal apparatus, comprising: a piezoelectric crystal, thin disc electrodes having faces engaging faces of said crystal, said electrode faces being slightly convex, the thicknesses of said disc electrodes being proportioned to vibrate sympathetically with said crystal and the long dimensions of said disc electrodes being equal to several times said thickness dimensions.

7. Piezoelectric crystal apparatus, comprising: a piezoelectric crystal, thin disc electrodes having faces engaging faces of said crystal, said electrode faces being slightly convex, the thicknesses of said disc electrodes being proportioned to vibrate sympathetically with said crystal and the long dimensions of said disc electrodes being equal to several times said thickness dimensions and means for clamping said crystal firmly between said slightly convex disc electrode faces.

8. Piezoelectric crystal apparatus, comprising: a piezoelectric crystal adapted to vibrate in the direction of its thickness, electrodes for said crystal adapted to engage the faces of said crystal, and supporting means engaging the side edges of said electrodes, said supporting means being proportioned to vibrate sympathetically with said crystal and said electrodes.

9. Piezoelectric crystal apparatus, comprising: a piezoelectric crystal adapted to vibrate in the direction of its thickness, electrodes for said crystal, means engaging side edges of said electrodes for holding said electrodes adjacent to faces of said crystal and for supporting said crystal, said last means being proportioned to vibrate sympathetically with said crystal and said electrodes.

10. Piezoelectric crystal apparatus, comprising: a piezoelectric crystal adapted to vibrate in the direction of its thickness, electrodes for said crystal, means for clamping said electrodes to faces of said crystal including resonant pins mechanically resonant to a vibrating frequency of said crystal engaging side edges of said electrodes.

11. Piezoelectric crystal apparatus, comprising: a piezoelectric crystal adapted to vibrate in the direction of its thickness, electrodes for the faces of said crystal, and pins substantially mechanically resonant to a vibrating frequency or harmonic or sub-harmonic of said crystal for clamping the side edges of at least one of said electrodes.

12. Piezoelectric crystal apparatus, comprising: a high frequency piezoelectric crystal, and means resonant substantially to the frequency of oscillation of said piezoelectric crystal for supporting said crystal, said resonant means having areas substantially in contact with said piezoelectric crystal equal to or greater than one-fourth the area of an electrode face of said crystal sufficient to function as electrodes for said crystal.

13. Piezoelectric crystal apparatus, comprising: a high frequency piezoelectric crystal, and means resonant substantially to the frequency of oscilla-

tion of said crystal for mechanically clamping and supporting said crystal, said resonant means having areas substantially in contact with said piezoelectric crystal equal to or greater than one-fourth the area of an electrode face of said crystal sufficient to function as electrodes for said crystal.

14. Piezoelectric crystal apparatus, comprising: a high frequency piezoelectric crystal, and means resonant substantially to a harmonic of the frequency of oscillation of said piezoelectric crystal for supporting said crystal, said resonant means having areas substantially in contact with said piezoelectric crystal equal to or greater than one-fourth the area of an electrode face of said crystal sufficient to function as electrodes for said crystal.

15. Piezoelectric crystal apparatus, comprising: a high frequency piezoelectric crystal, and means resonant substantially to a harmonic of the frequency of oscillation of said crystal for mechanically clamping and supporting said crystal, said resonant means having areas substantially in contact with said piezoelectric crystal equal to or greater than one-fourth the area of an electrode face of said crystal sufficient to function as electrodes for said crystal.

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