

March 3, 1942.

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2,275,122

PIEZOELECTRIC CRYSTAL APPARATUS

Filed June 5, 1940

2 Sheets-Sheet 1

FIG. 1

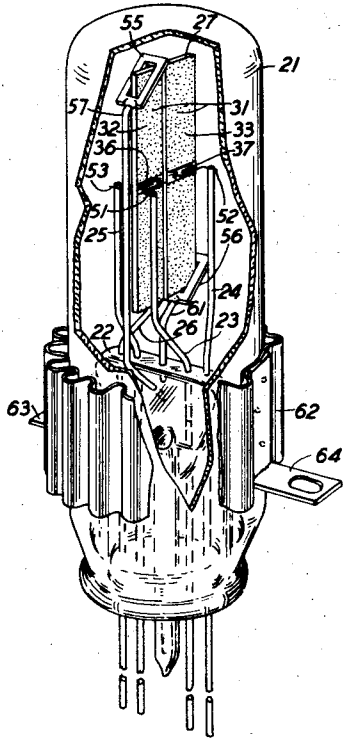


FIG. 6

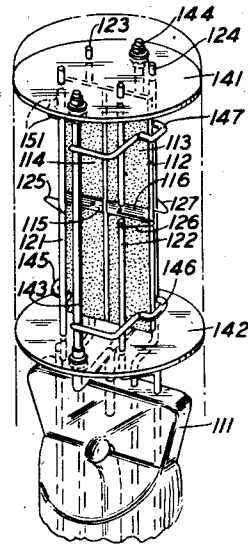


FIG. 3

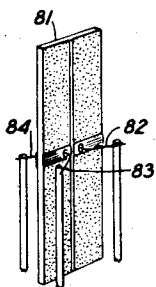


FIG. 4

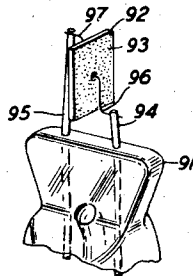


FIG. 5

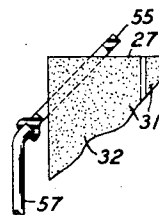
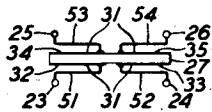


FIG. 2



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2 Sheets-Sheet 2

FIG. 7

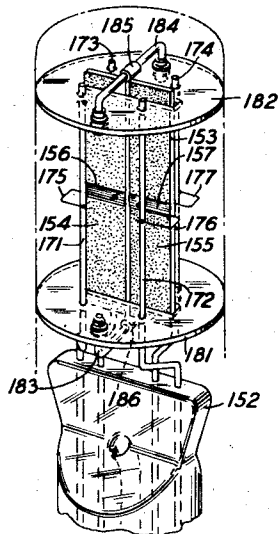
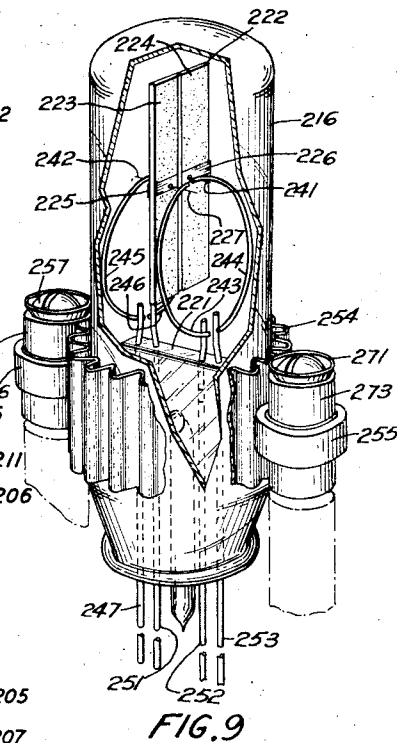
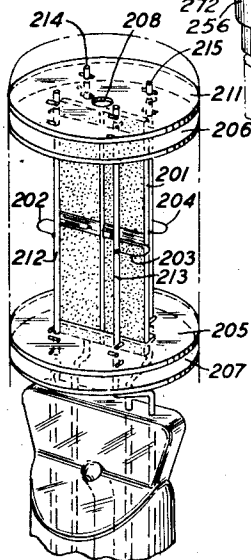


FIG. 8



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2,275,122

PIEZOELECTRIC CRYSTAL APPARATUS

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Application June 5, 1940, Serial No. 338,871

18 Claims. (Cl. 171—327)

This invention relates to piezoelectric crystal apparatus and more particularly to crystal mountings.

An object of the invention is to improve the performance of piezoelectric crystal apparatus and to lessen the cost of producing such apparatus.

A further object of the invention is to obtain an improved electrical connection between a piezoelectric plate and other elements of an electrical circuit.

Another object of the invention is to satisfactorily support piezoelectric crystal plates directly by the lead wires associated therewith.

A more specific object of the invention is the prevention of damage to the crystal assembly resulting from mechanical shock.

To facilitate the use of piezoelectric crystal plates in electrical circuits, it is common practice, as is well known, to provide a coating of suitable conductive material on one or more of the electrode surfaces of the crystal plate, the necessary circuit lead wires then being electrically connected to the coating. Various methods of obtaining this electrical connection and for supporting the crystal plate have been proposed in the past, a representative arrangement being that disclosed in my Patent 2,218,735, issued October 22, 1940 entitled "Piezoelectric plate holder" which arrangement involves mechanical clamping projections.

With a view toward improving the performance of piezoelectric crystal elements it has been proposed to obtain electrical connection between the circuit lead wires and the electrode coating of the plate by attaching the lead wires directly to the electrode coating by soldering or other similar process involving metal fusion.

The present invention is particularly adaptable to crystal assemblies in which the lead wires have been attached directly to the electrode coatings of the piezoelectric crystal plate.

A feature of the invention is crystal supporting lead wires having an extremely high degree of compliance whereby the transmission of mechanical shocks to the junction of lead wires and crystal plate is effectively prevented and damage to the crystal assembly resulting from such shocks is prevented.

A further feature of the invention is means for positively preventing displacement beyond predetermined limits of the crystal plate from its normal position.

In accordance with one embodiment of the in-

vention, a piezoelectric crystal plate is supported within a glass vessel which is evacuated in order to increase the "Q" of the crystal and to eliminate the effects of standing air waves. The plate is supported directly by the lead wires each of which wires is bent in a definite manner in order to substantially increase the compliance thereof. Due to the ability of these non-linear wires to effectively prevent the transmission of mechanical shock in the event the assembly is suddenly displaced, the stress initially set up at the point of junction of lead wire and electrode coating is definitely limited. Mechanical stops are provided closely adjacent to the crystal plate which, while interfering in no way with the desired electrically induced vibrations of the plate, positively prevent bodily displacement of the plate beyond predetermined limits resulting from mechanical shock. The ends of the lead wires remote from the piezoelectric plate are mechanically and electrically connected to rigid lead-in wires brought in through the press of the vessel.

The exact arrangement and advantageous features of the embodiment referred to above, as well as of other embodiments, will be gained from consideration of the following detailed description and the drawings in which:

Fig. 1 is a view in perspective of one embodiment of the invention, a portion of the enclosing vessel and supporting ring therefor being broken away to show the internal structure of the device more clearly;

Fig. 2 is a diagrammatic end view showing particularly the form of the lead wires of the device of Fig. 1 and their attachment to the crystal plate;

Fig. 3 is a perspective view of a crystal plate together with a part of the supporting arrangement therefor, a different form of lead wire from that of Fig. 1 being shown;

Fig. 4 is a perspective view of a crystal plate supported by still another form of lead wire;

Fig. 5 is a view of a portion of the device of Fig. 1 and shows particularly the arrangement of one of the mechanical stops or bumpers and the location thereof with respect to the crystal plate;

Fig. 6 is a view in perspective of another embodiment of the device the enclosing vessel not being shown except in so far as its outline is represented by the broken line;

Fig. 7 is a view in perspective of another embodiment of the invention differing from the device of Fig. 6 in the form of the mechanical stop and the lead wires;

Fig. 8 is a view in perspective of another embodiment of the device showing still other forms of mechanical stop and lead wires; and

Fig. 9 is a view in perspective of still another embodiment of the device, the enclosing vessel and supporting ring being illustrated but being broken away to show the internal structure of the device more clearly.

Referring now to Fig. 1, the device illustrated comprises a glass enclosing vessel 21 provided with a reentrant stem which terminates in press 22. Four conductive rigid wires or rods 23, 24, 25 and 26 are brought in through the press of the vessel from the exterior thereof being bent transversely as shown. A piezoelectric crystal plate 27, for example of quartz, is positioned within the vessel, the plate being provided with suitable conductive electrode coatings 31 on the opposing major surfaces thereof.

Electrode coatings 31 may, for example, be formed integral with the major surfaces of the plate 27 and may by way of example consist of thin coatings of aluminum or silver deposited upon the surfaces of the plate by the thermal evaporation process as disclosed in Patent No. 2,241,228, issued May 6, 1941, to H. W. Weinhart entitled "Coating machine." These electrode coatings may be longitudinally centrally divided, as shown, in order to form four separate electrodes, 32, 33, 34, 35 (Fig. 2), whereby two separate circuits of equal frequency may be obtained from the single crystal plate 27. This division of electrode coatings may be accomplished by a suitable etching process, for example, or by use of a device of the general nature described in the copending application of W. L. Bond, filed January 25, 1939, Serial No. 252,787, now Patent No. 2,248,057, July 8, 1941, entitled "Electrical cutting device."

A heavier coating of suitable metal may be applied directly to the bare crystal or over each electrode coating along the nodal line of crystal plate 27, two of these coatings, 36 and 37, being shown in Fig. 1. This coating may be, for example, baked silver paste.

Crystal plate 27 is supported from, and electrically connected to, the lead-in wires 23, 24, 25 and 26 by four phosphor bronze lead wires 51, 52, 53 and 54, the diameter of which is preferably of the order of from .003 inch to .005 inch. One end of each of these lead wires is attached to crystal plate 27 in the nodal zone by soldering or other suitable method while the other end of each lead wire is attached by soldering to a respective one of the rigid lead-in wires 23, 24, 25 and 26. These lead wires may, if desired, be provided with a disc-like head at the end which is to be attached to the crystal plate.

As shown more clearly in Fig. 2, each of the lead wires 51, 52, 53 and 54 is so bent in two places that it follows, first, a relatively short path perpendicular to the face of the crystal plate; second, a longer path parallel to the face of the plate, and finally a second short path perpendicular to the face of the plate whereby the wire takes roughly a Z shape.

The bends provided in the lead wires are of supreme significance and importance as they result in a substantial increase in the compliance of the wires as compared to their compliance when straight. As a result, the wires prevent the transmission of mechanical shock in the event the assembly is suddenly displaced and effectively limit the stress initially set up at the point of junction of the wires and the electrode

coatings. Sudden movements of the lead-in wires 23, 24, 25 and 26, which might result, for example, if the vessel were struck sharply or accidentally dropped, are not therefore transmitted through wires 51, 52, 53 and 54 to the crystal plate. It has been found, moreover, that when the lead wires are so shaped there is no appreciable absorption thereby of the electrically induced vibrations of the crystal plate so that the "Q" of the crystal is not adversely affected as is often the case when other types of mountings are utilized. While the lead wires are attached to the crystal plate within the nodal zone thereof, it is impossible of course with the divided electrode type of crystal to make the connections only at the precise nodal point when it is at the geometrical center of the crystal plate. It is important, therefore, that the mounting means be substantially non-absorptive with respect to the electrically induced vibrations of the plate.

In order to positively prevent the movement of plate 27 beyond predetermined limits and thereby assure that lead wires 51, 52, 53 and 54 will not be distorted beyond their elastic limits, mechanical stops or bumpers 55 and 56 are provided being supported by respective rigid support wires 57 and 61 which are anchored in press 22. These stop members are disposed about two diagonally opposite corners of plate 27 and, as more clearly shown in Fig. 5, are so mounted that there is a small clearance between the crystal plate and the stop member, when the plate is in its normal position. The desired electrically induced vibrations of the plate, which are of small amplitude, are not interfered with therefore although excessive mechanically induced bodily movement of the plate in any direction is prevented. The portions of the stop members which are in position to engage plate 27 should preferably be constructed of relatively soft insulating material of a nature which will not tend to chip the crystal plate when the plate contacts an edge of the stop, and the material also should be such that no gas will be given off thereby that might deleteriously affect the operation of the crystal plate. Among the materials which have been found suitable for the purpose is that described in W. H. Carothers Patent 2,130,948, issued September 20, 1938, assigned to E. I. du Pont de Nemours & Co.

For supporting purposes, the vessel 21 may be placed in corrugated metal band 62 to which are attached two arms 63 and 64. Suitable supporting members (not shown) may be associated with these arms. Corrugated ring 62 is sufficiently resilient to accommodate vessels of slightly different diameters thereby allowing for slight dimensional variations which may arise during manufacture.

Referring now to Fig. 3, crystal plate 81 is illustrated supported by four conductive lead wires, three of which 82, 83 and 84 are shown. It will be noted that these curved lead wires are of a different shape than those of Fig. 1; the purpose and action of the lead wires of both devices are the same, however. It will be understood that the crystal plate 81 is similar to plate 27 and that it may be mounted in an enclosing vessel in the manner illustrated in Fig. 1. Mechanical stops of the type illustrated in Fig. 1 may be used with plate 81, if desired.

Referring now to Fig. 4, a portion of a crystal unit of the general nature of that of Fig. 1 is illustrated, press 91 being the only portion of the glass vessel that is shown. Crystal plate 92

is somewhat smaller than the plates of Figs. 1 and 3 and the metallic electrode coatings, which may be in this instance platinum, provided on each of the major surfaces (electrode coating 93 (being shown) are not divided. The plate is supported from, and electrically connected to, rigid wires 94 and 95, by non-linear lead wires 96 and 97. Lead wires 96 and 97, while preferably of the same material as lead wires 51, 52, 53 and 54 of Fig. 1, may be of a slightly smaller diameter and are attached directly to the electrode coatings at the nodal point of the crystal plate by soldering or other suitable method. It will be noticed that lead wires 96 and 97 are each bent in two places so that they, like the lead wires of Fig. 1, assume roughly a Z shape. Lead wires 96 and 97 are so arranged in this instance, however, that their greater length extends in a vertical plane rather than a horizontal plane as in the instance of Fig. 1, although it will be understood that other arrangements may be followed if desired.

The purpose of non-linear wires 96 and 97 is to absorb mechanical shocks and to prevent the transfer of such shocks from wires 94 and 97 to the point of junction of lead wires 96 and 97 and the respective electrode coating of crystal plate 92.

Referring now to Fig. 6, the device there illustrated comprises a glass enclosing vessel (the outlines thereof being represented by the broken line), the reentrant stem of which terminates in press 111. Crystal plate 112, which is positioned in the vessel is similar, generally, to plate 27 of Fig. 1, and is provided with two separate electrode coatings on each major surface, coatings 113 and 114 being shown. A thicker metallic coating may be applied under or over each electrode coating in the nodal zone of the plate as in the case of plate 27, coatings 115 and 116 being shown.

Four rigid wires or rods 121, 122, 123 and 124 extend vertically from press 111 into the vessel, crystal plate 112 being supported therefrom, and electrically connected thereto, by four non-linear conductive lead wires three of which, 125, 126 and 127, are shown. (A portion of rod 122 has been broken away in order to show more clearly the shape of lead wire 126 and its connection to the crystal plate.) These lead wires, while preferably of the same size and material as the lead wires 51, 52, 53 and 54 of the device of Fig. 1, differ somewhat in their shape. It will be noted that the lead wires of Fig. 6 are so curved that they take, roughly, a V shape. One end of each of the lead wires is attached to crystal plate 112 along the nodal line by soldering or other suitable method while the other end of each is attached by soldering or welding to a respective one of the rigid wires 121, 122, 123 and 124.

The function of lead wires 125, 126, 127 and the fourth wire, not shown, is the same as that of the lead wires previously described, i. e., to prevent transmission of vibrations resulting from mechanical shock to the junction point of lead wire and electrode coating. With this arrangement of lead wire also, as was the case with the embodiments previously described, it has been found that there is substantially no absorption by the lead wires of the electrically induced vibrations of the crystal plate so that there is no depressing effect on the "Q" of the crystal.

Two discs 141 and 142, of suitable insulating material, for example mica, are provided within the vessel being supported on upright rigid rods

143 and 144 which are anchored in press 111. The discs may be maintained in proper position on rods 143 and 144 by means of eyelets which may be welded, soldered, or attached by other suitable methods to the rods. The discs are so located that, when crystal plate 112 is in its normal position, there is a small, but definite, clearance between the upper end of the plate and disc 141 and between the lower end of the plate and disc 142. The discs do not interfere therefore with the electrically induced vibrations of the crystal plate which are of small amplitude but do act as stops or bumpers to definitely prevent excessive vertical movement of the plate either upward or downward which might tend to be induced if the unit should be subjected to sudden mechanical shock.

In order to prevent excessive lateral movement of plate 112, four additional stops or bumpers 145, 146, 147 and 151 are provided. These stops are in the form of wire hooks supported from rigid upright rods 143 and 144. In order to prevent chipping the crystal plate, the portions of the stops which are in position to contact the plate when it is moved beyond the predetermined allowable limit is coated with a suitable insulating material, for example the material referred to above as being described in W. H. Carothers Patent 2,130,948.

Referring now to Fig. 7, the device illustrated comprises an enclosing vessel, (the outlines of which are represented by the broken line) the reentrant stem of which terminates in press 152. Crystal plate 153, which is positioned in the vessel is similar, generally, to crystal plate 27 of Fig. 1 and is provided with two separate electrode coatings on each major surface, electrode coatings 154 and 155 being shown. A narrow, thicker coating may be applied under or over each electrode coating substantially along the nodal line as in the instance of plate 27, coatings 156 and 157 being shown.

Four conductive rigid wires or rods 171, 172, 173 and 174 extend vertically into the vessel from press 152, crystal plate 153 being supported therefrom, and electrically connected thereto, by means of four conductive non-linear lead wires, three of which, 175, 176 and 177, are shown. These lead wires, while preferably of the same size and material as the lead wires of the device of Fig. 1, differ somewhat therefrom in their shape; it will be noticed that the lead wires of Fig. 7 are each bent at three points rather than at two points. One end of each lead wire is attached to plate 153 substantially along the nodal line by soldering or other suitable method, while the other end of each lead wire is attached by soldering to a respective one of the vertical rigid wires 171, 172, 173 and 174.

The function and action of lead wires 175, 176, 177 and the fourth wire, not shown, are the same as those of the lead wires of the devices of Figs. 1, 6 and the other figures previously described and will not be described in detail at this point therefore.

Two discs, 181 and 182, of suitable insulating material such as mica are supported within the vessel by vertical rigid wires 171, 172, 173 and 174, the discs being held in proper position on the rods by suitable means such as eyelets or stakes. Each disc is provided with a centrally located rectangular slot the dimensions of which are slightly greater than the corresponding dimensions of plate 153. The lower disc 181 is so positioned that the lower end of plate 153 pro-

jects through the slot in the disc a short distance and the upper disc 182 is positioned in a corresponding manner with respect to the upper end of plate 153. In view of the fact that, as previously stated, the dimensions of the slot are slightly greater than the corresponding dimensions of the crystal plate, there will be, when plate 153 is in normal position, a small, definite, clearance between the surfaces of the plate and the defining edges of the slots. The electrically induced vibrations of the crystal plate, which are of small amplitude, are not interfered with therefore but any lateral bodily movement of the plate beyond predetermined limits is positively prevented by contact of a surface of the plate with an edge of one of the slots.

In order to prevent excessive movement of plate 153 in a vertical direction two bent stop wires are provided, stop wire 183 being mounted on disc 181 and stop wire 184 being mounted on disc 182. These stop wires are so positioned with respect to plate 153 that, when the plate is in normal position, there is a small but definite clearance between stop wire 183 and the lower end of plate 153 and a similar clearance between stop wire 184 and the upper end of plate 153. Therefore, while the wires positively prevent excessive bodily movement of the plate in a vertical direction, the electrically induced vibrations of the plate are not interfered with as they are of small amplitude.

A bushing 185 of suitable insulating material, for example, the material described by the Carothers patent referred to above is positioned on stop wire 184 at the point of possible contact with the end of plate 153; a similar bushing 183 is provided on stop wire 183. These bushings tend to prevent damage to the plate 153 resulting from contact with the rigid stop wires.

Referring now to Fig. 8, the device illustrated is similar, in general, to that of Fig. 7 and will be described in detail only with respect to the points of difference over Fig. 7.

Crystal plate 201, which is similar to plate 153 of Fig. 7, is supported by four conductive non-linear lead wires, three of which, 202, 203 and 204 are shown. These lead wires function similarly to the lead wires of the device of Fig. 7 but it will be noticed that they are of a somewhat different shape, being curved rather than sharply bent at a plurality of points as in the instance of the lead wires of Fig. 7.

Slotted discs 205 and 206 are similar respectively to discs 181 and 182 of Fig. 7 and function in a similar manner to prevent excessive lateral movement of plate 201. The function of stop wires 183 and 184 of Fig. 7, i. e., prevention of excessive bodily displacement of the plate in a vertical direction is fulfilled in the instance of the device of Fig. 8, however, by discs 207 and 211 respectively. These discs, which are similar to the discs previously described except for the omission of the rectangular slots, are supported on the rigid vertical rods or wires 212, 213, 214 and 215. Disc 207 is so positioned that, when crystal plate 201 is in normal position, there is a slight clearance between the lower end of plate 201 and disc 207, and disc 211 is so supported that, when plate 201 is in normal position, there is a small clearance between the upper end of the plate and disc 211. The electrically induced vibrations of the plate being of small amplitude are not interfered with by discs 207 and 211, while excessive displacement of the plate in a vertical direction is positively prevented.

If desired, an aperture, 208, may be provided in disc 211 to facilitate frequency adjustments of plate 201 before the assembled unit has been placed in the vessel.

Referring now to Fig. 9, the device there illustrated comprises a glass enclosing vessel 216, the reentrant stem of which terminates in press 221. Crystal plate 222 mounted within the vessel is similar to plate 27 of Fig. 1 and likewise is provided with four separated electrode coatings, two of which, 223 and 224, are shown. A narrow thicker coating may be provided along the nodal line of the plate under or over each electrode coating as in the instance of the plate of Fig. 1, two of these thicker coatings, 225 and 226, being shown. A short length of conductive spring wire of a diameter of the order of from .003 inch to .008 inch is attached to each of the four thicker coatings by soldering or other suitable method; three of these wires, 227, 241 and 242 are shown. The other end of each of the short spring wires is attached, by soldering or welding, to one end of a respective one of four semicircular phosphor bronze spring wires 243, 244, 245 and 246. The diameter of these last-mentioned wires may be in the neighborhood of .0142 inch. Four rigid wires or rods 247, 251, 252 and 253, are brought into the vessel through the press 221 and terminate just above the press in the form of short rigid stubs. One end of each of the semicircular spring wires is attached to each of these stub portions.

Each semicircular wire 243, 244, 245 and 246, is inclined inwardly toward plate 222 at its upper end so that a slight compression effect is achieved which tends to assure the permanency of the connection of the short spring wires with the coated portions of the crystal plate. The semicircular spring wires 243, 244, 245 and 246 perform the function of the non-linear lead wires previously described in that they absorb vibrations resulting from mechanical shock and prevent the transmission of stress caused by such shocks to the point of junction of spring wire and electrode coating. The flexible system is designed to be sufficiently effective as to render the provision of mechanical stops or bumpers unnecessary in most cases.

The vessel may be supported by a corrugated metal ring 254 to which are attached ears 255 and 256. Suitable supporting posts may be secured in these ears by machine screws 257 and 271, resilient bushings 272 and 273 being provided for the purpose of reducing transmission of vibration from the supporting posts to the crystal unit.

While certain specific embodiments of the invention have been selected for detailed disclosure the invention is not, of course, limited in its application to such embodiments. It will be apparent, for example, that various combinations of the different types of stop members which are disclosed may be utilized as occasion demand. For example, one or more of the rectangular frame stops may be used in conjunction with one or more of the wire hook members. In short, the embodiments described should be taken as illustrative of the invention and not as restrictive thereof.

What is claimed is:

1. A piezoelectric unit comprising an evacuated bulb, rigid conductive lead-in wires sealed into and extending within said bulb, a piezoelectric crystal plate, conductive coatings formed integral with said plate, and a plurality of non-linear

spring wires electrically and mechanically connected to said conductive coatings and said lead-in wires and constituting substantially the sole weight bearing support of said crystal plate.

2. In combination a piezoelectric plate, a metallic coating formed integral with each of two opposite surfaces of said plate in the region of the nodal zone, a pair of spring wires having one end of each attached to one of said coatings by metallic fusion, and means for fixedly mounting the other end of each spring wire, said spring wires being bent at predetermined points in order to substantially increase their compliance as compared to their compliance if straight and constituting substantially the sole weight bearing support of said piezoelectric plate.

3. In combination a piezoelectric plate, a metallic coating formed integral with each of two opposite surfaces of said plate in the region of the nodal zone, a pair of conductive spring wires having one end of each attached to one of said coatings by metallic fusion, and means for fixedly mounting the other end of each spring wire, said spring wires being curved in order to substantially increase their compliance as compared to their compliance if straight and constituting substantially the sole weight bearing support of said piezoelectric plate.

4. In combination a piezoelectric plate, a metallic coating on each of two opposite surfaces of said plate in the region of the nodal zone, a pair of conductive spring wires having one end of each attached to one of said coatings by metallic fusion, and a pair of rigid conductive support wires, the other end of each of said spring wires being attached to one of said rigid wires, said spring wires following curved paths from the point of attachment to said coatings to the point of attachment to said rigid wires whereby the compliance of said spring wires is substantially increased as compared to their compliance if a straight path from said points of attachment were followed, said spring wires supporting said plate with respect both to lateral and vertical displacement.

5. A piezoelectric unit comprising an evacuated chamber, a piezoelectric plate within said chamber, a metallic coating on each of two opposite surfaces of said plate in the region of the nodal zone, a pair of rigid conductive support wires in said chamber, and a pair of conductive spring wires having one end of each attached to one of said coatings by metallic fusion and the other end of each attached to one of said rigid supports, each of said spring wires being so bent at two points that it follows, first, a relative short path perpendicular to a major surface of said plate, then a substantially longer path parallel to said surface and finally a relatively short path perpendicular to said surface.

6. A piezoelectric unit comprising an evacuated chamber, a piezoelectric plate within said chamber, a metallic coating on each of two opposite surfaces of said plate in the region of the nodal zone, a pair of rigid conductive support wires in said chamber, and a pair of conductive spring wires having one end of each attached to one of said coatings by metallic fusion and the other end of each attached to one of said rigid supports, each of said spring wires being so bent at three points that it follows, first a relatively short path perpendicular to a major surface of said plate, second, a substantially longer path parallel to said surface, third, a path parallel to said first path and finally, a path parallel to said second

path, said third and said last paths being substantially equal in length.

7. A piezoelectric unit comprising an evacuated chamber, a piezoelectric plate within said chamber, a metallic coating on each of two opposite surfaces of said plate in the region of the nodal zone, a pair of rigid conductive support wires in said chamber, a pair of conductive spring wires having one end of each attached to one of said coatings by metallic fusion and the other end of each attached to one of said rigid support wires and a mechanical stop within said chamber adjacent to said plate for preventing undue departure of said plate from the normal operating position thereof, said spring wires being curved in order to substantially increase their compliance as compared to their compliance if straight and constituting the sole weight bearing support of said plate so long as said plate is in its normal operating position.

8. A piezoelectric unit comprising an evacuated chamber, a piezoelectric plate within said chamber, a metallic coating on each of two opposite surfaces of said plate in the region of the nodal zone, a pair of rigid conductive support wires in said chamber, a pair of conductive spring wires having one end of each attached to one of said coatings by metallic fusion and the other end of each attached to one of said rigid support wires and a pair of mechanical stops within said chamber for preventing undue departure of said plate from the normal operating position thereof, said stops comprising rectangular frames disposed about two diagonally opposite corners of said plate.

9. A piezoelectric unit comprising an evacuated chamber, a piezoelectric plate within said chamber, a metallic coating on each of two opposite surfaces of said plate in the region of the nodal zone, a pair of rigid conductive support wires in said chamber, a pair of conductive spring wires having one end of each attached to one of said coatings by metallic fusion and the other end of each attached to one of said rigid support wires, and a pair of rectangular frame members, said frame members being so positioned with respect to two diagonally disposed corners of said plate that a slight clearance prevails between said plate and said frames when said plate is in normal position and that undue departure of said plate from said normal position results in positive engagement of one of said frames and said plate.

10. A piezoelectric unit comprising an enclosing vessel, a piezoelectric crystal plate within said vessel, a plurality of conductive spring wires for resiliently supporting said plate, a plurality of mechanical stop members for preventing undue vertical movement of said plate from its normal position and a plurality of additional mechanical stop members for preventing undue lateral movement of said plate from its normal position.

11. A piezoelectric unit comprising an enclosing vessel, a piezoelectric crystal plate within said vessel, a plurality of conductive spring wires for resiliently supporting said plate and a plurality of mechanical stop members for preventing undue vertical movement of said plate from its normal position, each of said stop members comprising a disc, one of said discs being positioned above said plate in said vessel and the other of said discs being positioned below said plate in said vessel, the relative position of said discs and said plate being such that when said plate is in

normal operating position there is a small clearance between the upper end of said plate and the first disc and a similar clearance between the lower end of said plate and the second disc.

12. A piezoelectric unit comprising an enclosing vessel, a piezoelectric crystal plate within said vessel, a plurality of spring wires for resiliently supporting said plate, a plurality of mechanical stop members for preventing undue vertical movement of said plate from its normal position and a plurality of additional mechanical stop members for preventing undue lateral movement of said plate from its normal position, each of said first-mentioned stop members comprising a disc, one of said discs being positioned above said plate in said vessel and the other of said discs being positioned below said plate in said vessel, the relative position of said discs and said plate being such that when said plate is in normal operating position there is a small clearance between the upper end of said plate and the first disc and a similar clearance between the lower end of said plate and the second disc, each of said second-mentioned stop members comprising a rigidly supported arm terminating in a hook, said hook being adjacent to a vertical edge of said plate but out of contact therewith when said plate is in normal operating position.

13. A piezoelectric unit comprising an enclosing vessel, a piezoelectric crystal plate, a plurality of spring wires for resiliently supporting said plate within said vessel, a stop member within said vessel for preventing undue lateral movement of said plate from its normal position, said stop member comprising a disc having a rectangular slot therein, the dimensions of said slot being slightly greater than the corresponding dimensions of said plate, and means for so supporting said disc with respect to said plate that an end of said plate projects through the slot therein, all surfaces of said plate being free of engagement with the defining walls of the slot when said plate is in normal operating position.

14. A piezoelectric unit comprising an enclosing vessel, a piezoelectric crystal plate within said vessel, a plurality of spring wires for resiliently supporting said plate, a plurality of mechanical stop members for preventing undue vertical movement of said plate from its normal position and a plurality of additional mechanical stop members for preventing undue lateral movement of said plate from its normal position, each of said lateral movement preventing stop members comprising a disc having a rectangular slot therein, the dimensions of said slot being slightly greater than the corresponding dimensions of said plate, and means for so supporting said disc with respect to said plate that an end of said plate projects through the slot therein, all surfaces of said plate being free of engagement with the defining walls of the slot when said plate is in normal operating position and each of said vertical movement preventing stop member comprising an arm rigidly mounted on a respective one of said discs and extending across the projecting end of said plate, the projecting end of said plate being free of engagement with said arm when said plate is in normal operating position.

15. A piezoelectric unit comprising an enclosing vessel, a piezoelectric crystal plate within said

vessel, a plurality of spring wires for resiliently supporting said plate, a plurality of mechanical stop members for preventing undue vertical movement of said plate from its normal position and a plurality of additional mechanical stop members for preventing undue lateral movement of said plate from its normal position, each of said first-mentioned stop members comprising a disc, one of said discs being positioned above said plate in said vessel and the other of said discs being positioned below said plate in said vessel, the relative position of said discs and said plate being such that when said plate is in normal operating position there is a small clearance between the upper end of said plate and the first disc and a similar clearance between the lower end of said plate and the second disc and each of said second-mentioned stop members comprising an additional disc having a rectangular slot therein, the dimensions of said slot being slightly greater than the corresponding dimensions of said plate, and means for so supporting said additional disc with respect to said plate that an end of said plate projects through the slot therein, all surfaces of said plate being free of engagement with the defining walls of the slot when said plate is in normal operating position.

16. In combination, a piezoelectric plate, a metallic coating on each of two opposite surfaces of the plate in the region of the nodal zone for vibrations of a desired type, a pair of spring members of electrically conducting material having an end of each attached to one of the coatings by metallic fusion and means for fixedly mounting the other ends of the spring members, the spring members having such a compliance along the direction between their points of attachment to the coatings and their fixed mounting as to substantially free the piezoelectric plate from shocks to which the mounting means may be subjected, whereby the spring members may serve simultaneously as the entire support and the current lead-in wires for the piezoelectric plate.

17. A piezoelectric unit comprising a containing vessel, a piezoelectric plate within said vessel, a metallic coating on each of two opposite surfaces of said plate in the region of the nodal zone, a pair of rigid support wires in said vessel, a pair of spring wires having one end of each attached to one of said coatings by metallic fusion and the other end of each attached to one of said rigid support wires and a plurality of mechanical stops within said vessel for preventing undue departure of said plate from the normal operating position thereof, said stops comprising rectangular frames disposed about two of the corners of said plate.

18. In combination a piezoelectric crystal plate, a metallic coating formed integral with each of two opposite surfaces of said plate in the region of the nodal zone, a pair of bent conductive supporting spring wires having one end of each attached to one of said coatings by metallic fusion, means for fixedly mounting the other end of each spring wire, and a mechanical stop spaced from said plate for preventing undue departure of said plate from the normal operating position thereof, said spring wires constituting the sole weight bearing support of said plate so long as said plate is in its normal operating position.

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