April 26, 1938. L. F. KOERNER 2,115,145

PIEZOELECTRIC CRYSTAL HOLDER

Filed Aug. 16, 1935 3 Sheets-Sheet 1

FIG. 1

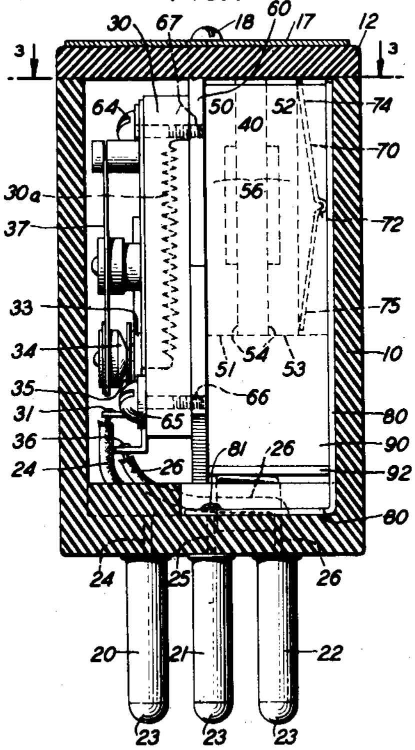


FIG. 2

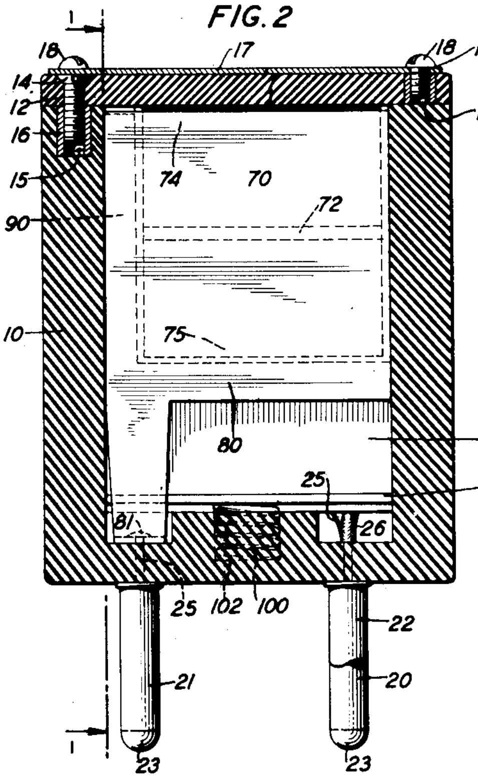


FIG. 3

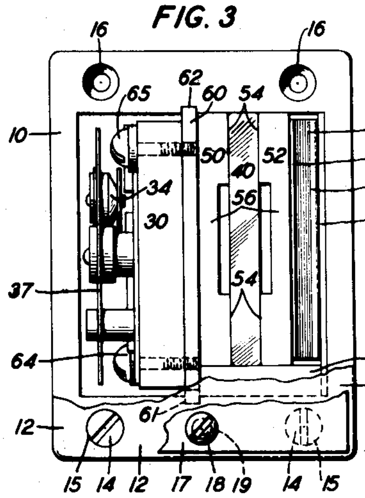
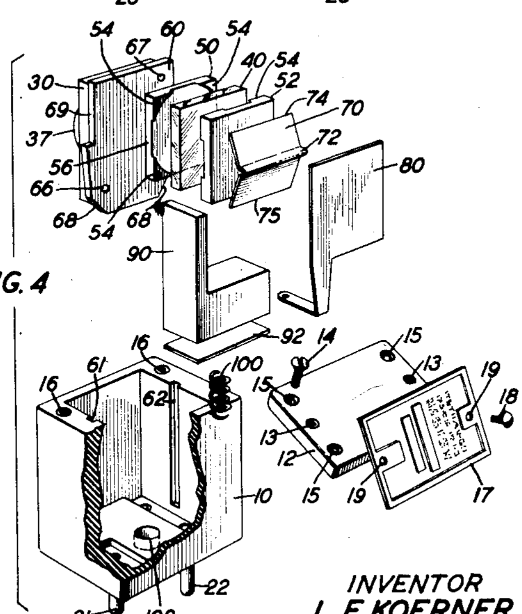


FIG. 4



INVENTOR
L. F. KOERNER

BY W. J. O'Neill

ATTORNEY

PIEZOELECTRIC CRYSTAL HOLDER

Filed Aug. 16, 1935 3 Sheets-Sheet 2

FIG. 5

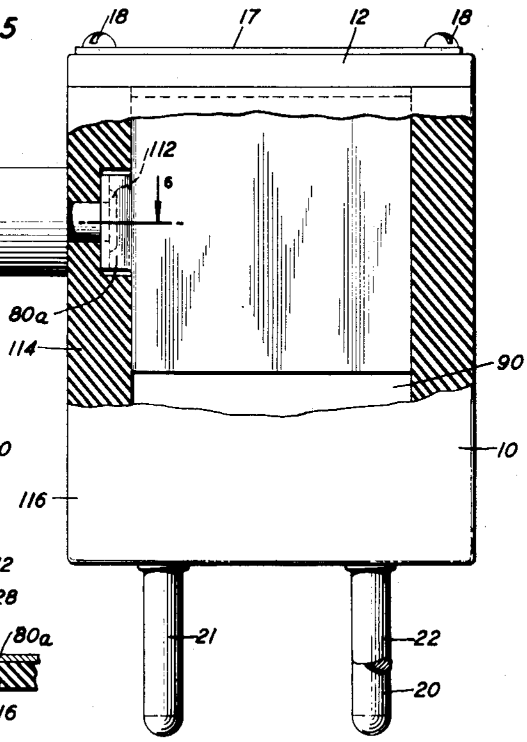


FIG. 6

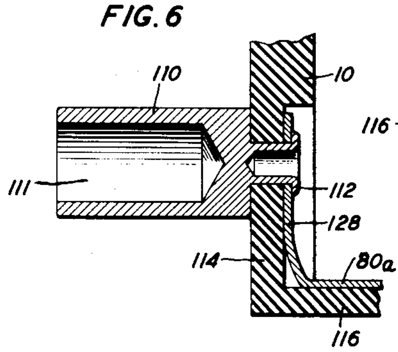


FIG. 7

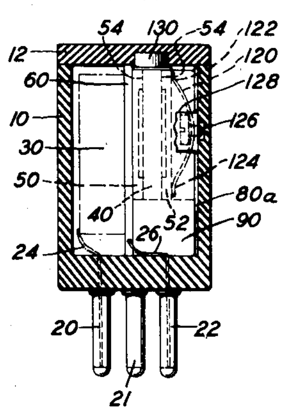
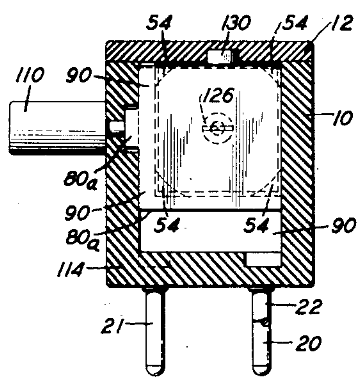


FIG. 8



INVENTOR
L. F. KOERNER
BY W. J. O'Neill
ATTORNEY

April 26, 1938. L. F. KOERNER 2,115,145

PIEZOELECTRIC CRYSTAL HOLDER

Filed Aug. 16, 1935 3 Sheets-Sheet 3

FIG. 9

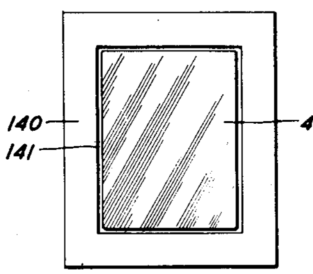


FIG. 10

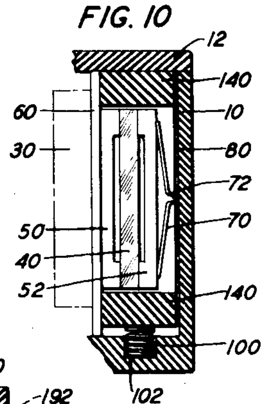


FIG. 11

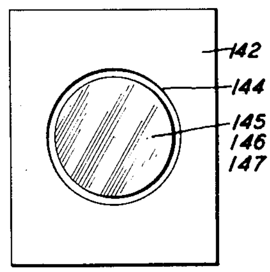


FIG. 14

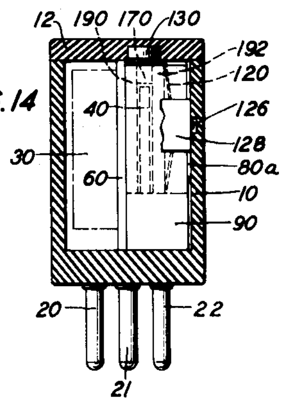


FIG. 15

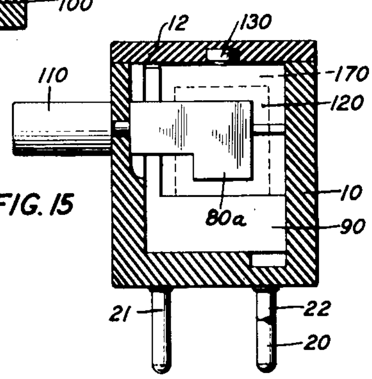


FIG. 16

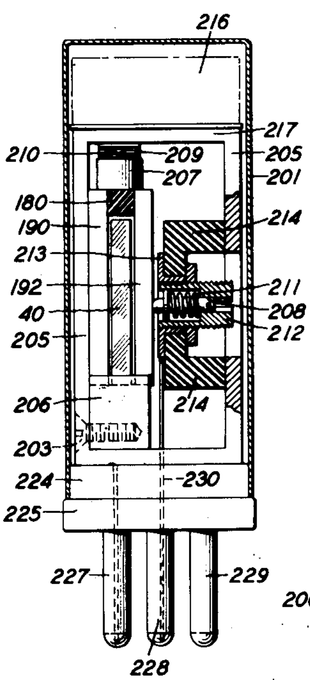


FIG. 12

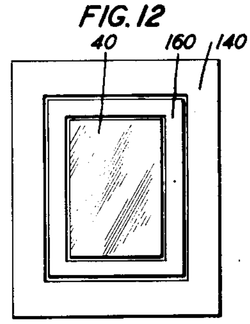
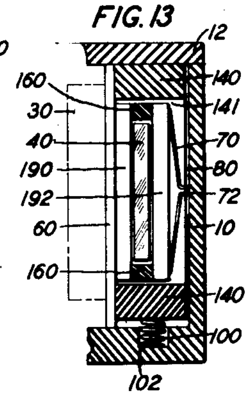


FIG. 13



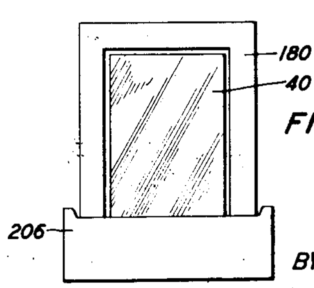


FIG. 17

INVENTOR
L. F. KOERNER
BY
W. J. O'Neill
ATTORNEY

Patented Apr. 26, 1938 2,115,145

UNITED STATES PATENT OFFICE

2,115,145

PIEZOELECTRIC CRYSTAL HOLDER

Lawrence F. Koerner, Summit, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application August 16, 1935, Serial No. 36,467

19 Claims. (Cl. 171—327)

This invention relates to piezoelectric apparatus and particularly to piezoelectric crystal holders.

One of the objects of this invention is to provide a piezoelectric crystal holder which may be small in height and compact in size.

Another object of this invention is to provide a piezoelectric crystal holder suitable for use on non-stationary radio equipment such as, for example, on aircraft.

Another object of this invention is to reduce the capacity effect in a piezoelectric crystal holder.

Another object of this invention is to provide a holder suitable for use with various sizes and shapes of piezoelectric elements and the electrodes therefor.

Another object of this invention is to control pressure upon the surfaces of piezoelectric elements and upon the electrodes therefor.

Another object of this invention is to decrease the weight of electrodes for a piezoelectric element.

The particular forms of piezoelectric quartz crystal holders herein disclosed by way of example to illustrate the invention may be complete units ready for removable insertion in the oscillator circuit of a radio transmitter or receiver, for example, to control or maintain the frequency of oscillations at a desired value in accordance with the frequency characteristic of a suitable piezoelectric quartz crystal, for example.

The holder may consist of a molded Bakelite casing or container of cubical shape, for example, and a cover of the same material removably fastened thereto by screws.

Terminals, including mechanically supporting pins or prongs, may be secured to the outside of the container and provide connections with a thermostatically-controlled heating element and a removable piezoelectric crystal and electrode assembly disposed inside the container. A metal plate or partition disposed inside the container casing may divide the container into two compartments. On one side of the partition plate, the thermostat and its corresponding heater may be mounted. On the opposite side of the partition plate, there may be provided an assembly consisting of a piezoelectric crystal, two electrodes, a removable insulating spacer surrounding at least a part of the periphery or edges of the electrodes and the crystal, and a plurality of resilient means including springs exerting suitable pressures on the spacer and also on the electrodes to hold the removable assembly in place within the container.

A name-plate may be removably secured to the cover of the enclosing case in such manner that the name-plate covers the screws securing the cover to the case thereby to render the contents of the case accessible only upon removal of the name-plate as well as the cover.

Reduction in capacity losses may be obtained by utilizing dielectric materials as extensively as possible and by disposing metallic parts in such manner with respect to the electrodes as not to produce a short-circuiting capacitative connection therebetween. To reduce energy losses at high frequencies, the container casing and its cover may be formed of low-loss dielectric material.

In order to adapt the same holder to hold electrodes and crystals of various sizes and of various configurations, such as circular-shaped or square-shaped crystals and electrodes, for example, removable inserts or spacers of dielectric material having dimensions suitable for the electrodes, the crystals and the container compartment may be provided. Where the crystal and its electrodes are square-shaped, an L-shaped removable insert or spacer may be utilized to contact with two edges of each electrode.

Where unclamped operation of the crystal is desired, another insulating spacer partly or wholly surrounding the peripheral edges of the crystal may have such slightly greater thickness with respect to the thickness of the crystal as to separate the two electrodes so that when this spacer is clamped between the two electrodes, the piezoelectric element itself is mechanically free to vibrate in unclamped position between the two electrodes and the spacer.

Resilient means in the form of a spring, for example, may be utilized to yieldably press one of the removable spacers, or the electrodes against the container or container cover. The spring may be in the form of a metallic spiral or coil spring, preferably of small diameter relative to the spacing of the electrodes, to avoid the introduction of an electrical capacity effect with respect to the edges of the metal electrodes of the crystal.

Another spring of suitable tension value may be provided to resiliently press the electrodes and crystal together in clamped relation and also to press one of the electrodes in contact with the metallic heat-conducting partition which may be disposed in heat-conducting contact with the heating element. Such spring may be in the form of a V-shaped or bow-shaped leaf spring and may have a centrally disposed transverse corrugation or rib to permit the spring to be readily bent and adjusted by hand to the desired pressure to suit the crystal which may be clamped between the electrodes.

Where clamping of the piezoelectric element between the electrodes is utilized, the metal electrodes may have a suitable number of projections, as three or four clamping projections, adapted to nodally contact with the piezoelectric body and to provide a spacing of approximately 0.001 inch between the depressed portion of the electrodes and the piezoelectric body. The spring referred to in the preceding paragraph may be of approximately the same area as the crystal electrodes and may have bosses or projections located to register with the clamping projections of the electrodes. Where the pressure points of the spring so coincide with the contact points between the electrode and the piezoelectric element, the electrodes may be of thin lightweight material since substantially no bending movements will be exerted on the electrodes.

The depressed portion of each crystal electrode may be formed by photo-etching to very accurately control the depth and uniformity of depth of the depression with respect to the projections and the spacing of the depression with respect to the crystal with which the projections may be in contact. The very uniform depth of electrode depression that may be obtained by etching results in such advantages as securing high frequency stability, avoiding arcing between the crystal and the electrode, and avoiding damping of crystal vibrations due to lack of uniformity in spacing between the electrode and crystal. The electrode having the etched depression permits the use of such desirable metals as stainless steel without grinding and subsequent heat treating thereof.

Where temperature control of the piezoelectric crystal element is desired as, for example, to stabilize the frequency of associated radio equipment, the holder unit may contain its own thermostat and heater within the casing of the unit. The thermostat may be of the bimetallic dish-shaped snap action type of relatively large current capacity and may be connected in series with and directly control the supply of energy to the heater from a circuit including the prongs or pins secured to the exterior of the casing and spaced to fit corresponding sockets associated with the radio equipment to be controlled. Where the thermostat directly controls the supply of energy to the heater, an external heater relay may be dispensed with to thereby eliminate the expense of and servicing of such additional relay.

This type of thermostat may be conveniently used to maintain properly the frequency of the associated radio equipment where the piezoelectric element has a zero or low temperature coefficient of frequency in a region above a certain critical temperature such as, for example +32° F. and where the ambient temperature remains within a range from about −40° F. to about +140° F. for example. In this instance, the thermostat may be adapted to connect the heater to the power supply at a temperature not less than a predetermined value such as, for example, about +41° F., and to disconnect the power at some temperature appreciably higher. This operating range is selected that the quartz crystal unit may always be maintained above the temperature of +32° F. mentioned though the ambient temperature may drop to −40° F. for example. This method of operation is made possible by using a quartz crystal element of low temperature coefficient of frequency in a region above +32° F. for example, and is of considerable advantage since no power is consumed by the heater except during periods when the temperature drops below the +32° F. in the example mentioned.

The crystal holder herein disclosed may also be utilized as a non-temperature controlled unit where, for example, the ambient temperature will remain within the range suitable for the crystal element that is employed. In this case, the prong or pin connected with the heating element may be electrically disconnected from the source of power and the remaining prongs connected with the crystal element may be electrically connected, through sockets spaced to fit the prongs, with the electrodes of a suitable space discharge device.

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 an enlarged view partly in section of a piezoelectric crystal holder taken on the line 1—1 of Fig. 2;

Fig. 2 is another view, partly in section, of the piezoelectric crystal holder shown in Fig. 1;

Fig. 3 is a view of the piezoelectric crystal holder shown in Figs. 1 and 2 taken on the line 3—3 of Fig. 1;

Fig. 4 is an exploded view of the piezoelectric crystal holder shown in Figs. 1 to 3;

Fig. 5 is a view partly in section of a modification of the holder shown in Figs. 1 to 4;

Fig. 6 is a sectional view of the side terminal shown in Fig. 5 taken on the line 6—6 of Fig. 5;

Fig. 7 is a sectional view approximately to size of another modification of piezoelectric crystal holder;

Fig. 8 is another sectional view of the holder shown in Fig. 7;

Fig. 9 is a view of a modified form of removable insulating spacer;

Fig. 10 is another view of the spacer shown in Fig. 9;

Fig. 11 is a view of another modification of removable insulating spacer;

Fig. 12 is a view of another electrode assembly showing two removable insulating spacers;

Fig. 13 is a sectional view of the assembly shown in Fig. 12;

Figs. 14 and 15 are views of another modification of the invention;

Fig. 16 is a sectional view of still another modification of crystal holder; and

Fig. 17 is another view of the U-shaped spacer and insulating support shown in Fig. 16.

The several piezoelectric crystal holders shown in these figures may be small in height, compact in size, suitable for use on non-stationary radio equipment such as, for example, on aircraft, and suitable for use with various sizes and shapes of piezoelectric crystals and crystal electrodes. They are complete units ready for removable insertion in the oscillator circuit of a radio transmitter or receiver, for example, to control or maintain the frequency of oscillations at a desired value in accordance with the frequency characteristic of a suitable piezoelectric element such as a quartz crystal.

Referring to Figs. 1 to 4, the holder may consist of a molded Bakelite casing or container 10 of substantially cubical shape and a cover 12 of the same material removably fastened thereto by four screws 14 insertable through four circular openings 15 in the cover 12 and engaging four internally tapped brass inserts 16 embedded in the phenol product casing 10. A name-plate 17 may be removably secured to the cover 12 of the enclosing case 10 by two screws 18 insertable through two openings 19 in the name-plate 17 and engaging two internally tapped brass inserts 13 embedded in the cover 12. The name-plate 17 covers the screws 14 securing the cover 12 to the case 10 thereby to render the contents of the case 10 accessible only upon removal of the name-plate 17 as well as the cover 12. To reduce energy losses at high frequencies, the container 10 and its cover 12 may be formed of a low energy loss type of Bakelite or phenol formaldehyde condensation product.

Terminals, including three mechanically supporting hollow tubular metal pins or prongs 20, 21 and 22 each having rounded tips 23 may be secured to the outside of the container 10 and provide connections, by wires 24, 25 and 26 disposed centrally within and soldered to the tips 23 of studs 20, 21 and 22 respectively, with a thermostatically controlled heating element 30 and a piezoelectric crystal assembly including a piezoelectric crystal 40 and electrodes 50 and 52 all disposed inside the container 10.

Where temperature control of the piezoelectric crystal element 40 is desired as, for example, to stabilize the frequency of associated radio equipment (not shown), the heat source metallic casing 30 may be provided and may include therein any suitable heating resistance element 30a having one terminal soldered to the casing 30 and the other soldered to a contact 33, which, when the thermostat 37 is operated, is connected by the switch 34 to a contact 35, which is joined to a terminal 31, the latter being connected by the wire 24 to the pin 20. The side of the resistance element 30a connected to the frame 30 of the heat source is also connected to the plate 60 by means of the metal mounting screws 64 and 65. The plate 60 is connected to the pin 22 by the wire 26 which may be soldered to the plate 60 or to the terminal 36.

The bimetallic dish-shaped snap action disc 37 is supported by the heater casing 30 and, in response to selected temperature values, controls the switch 34. The switch 34 and its cooperating contacts 33 and 35 may be of relatively large current capacity and in closed position are connected in series with and directly control the supply of heating energy to the heater 30a from a circuit including the connection pins 20 and 22 secured to the exterior of the casing 10. Since the thermostat 34, 37 directly controls the supply of energy to the heater 30, an external heater relay may be dispensed with to thereby eliminate the expense and servicing of such relay. This type of thermostat shown in Figs. 1 to 4 may be conveniently used, for example, to maintain properly the frequency of the associated radio equipment (not shown) where the piezoelectric element 40 has a relatively small temperature coefficient of frequency above a critical temperature as about +32° F. for example, and the ambient temperature remains within a range from about −40° F. to about +140° F. for example. The thermostat 34, 37 may be adapted to connect the heater 30a to the power supply at a temperature of about +41° F. for example, and to disconnect the power at some temperature appreciably higher. This operating range is selected that the quartz element 40 may always be maintained above about +32° F. for example, though the ambient temperature may drop to about −40° F. for example. This method of operation is made possible by using a quartz element 40 having a zero or low temperature coefficient of frequency above +32° F. and is of considerable advantage since no power is consumed by the heater 30 except during periods when the temperature drops below a predetermined value. It will be understood that the crystal holders herein disclosed may also be utilized as a non-temperature controlled unit where, for example, the ambient temperature will remain within any range suitable for the crystal element 40, which may be, for example, a crystal adapted to function at temperatures below +32° F.

Each of the metal electrodes 50 and 52 for the crystal 40 has four flat-surfaced corner projecting portions 54 which are adapted to contact the four corners of the crystal element 40 and a central depressed portion 56 the surface of which is adapted to be uniformly spaced about 0.001 inch or less from the surface of the crystal element 40. The depressed central portion 56 of the electrodes 50 and 52 may be formed by photo-etching, for example, to very accurately control the depth and uniformity of the depression 56 with respect to the projections 54 and the spacing of the depression 56 with respect to the crystal 40 with which the projections 54 are in contact. The purpose of the uniform depth of depression formed by the depressed portions 56 of the electrodes 50 and 52 is to secure frequency stability, to avoid arcing between the crystal element 40 and the electrodes 50 and 52 and to avoid damping of vibrations of the crystal element 40 due to lack of uniformity in spacing between the depressed portions 56 of the electrodes 50 and 52 and the crystal 40 which is clamped between the four projections 54 of the electrodes 50 and 52. The electrodes 50 and 52 may be formed of stainless steel, for example.

A metal plate or partition 60 slidable in oppositely disposed grooves 61 and 62 in the interior walls of the container 10 mechanically divides the container 10 into two compartments. On one side of the brass partition plate 60 in heat conducting relation therewith the thermostat-controlled heater casing 30 may be mounted by the two screws 64 and 65 engaging two tapped openings 66 and 67 in the brass mounting plate 60. The screws 64 and 65 extend only part way into the plate 60 to permit the electrode 50 to have a flat surface contact relation with the plate 60. On the opposite side of the partition plate 60 there may be provided an assembly consisting of the metal electrode 50 disposed in heat conductive and in electrical conductive relation with the plate 60, the piezoelectric crystal 40, the metal electrode 52, a phosphor bronze leaf spring 70, a brass connector plate 80 disposed in contact with an interior wall of the Bakelite casing 10, an L-shaped removable insulating spacer 90 disposed in slidably fitting relation between the metal plates 60 and 80 and surrounding a part of the periphery or edges of the electrodes 50 and 52, a phenol fibre strip 92, and a coil spring 100 disposed in a pocket 102 in the bottom of the container 10 and exerting suitable pressure on the insulating strip 92, the insulating spacer 90 and also on the edges of the electrodes 50 and 52 to hold the assembly in place against the cover 12 of the container 10.

The container 10 may interchangeably hold electrodes and crystals of various sizes and of various shapes such as, for example, the circular-shaped crystal and electrodes of Fig. 11 or the square-shaped crystals and electrodes shown in the remaining figures. For this purpose, removable inserts or spacers of dielectric material having external dimensions suited to the dimensions of the compartment between the parallel spaced plates 60 and 80 and having internal configurations suitable for the edges of the electrodes may be provided. Where the crystal and its electrodes are square-shaped, an L-shaped removable insert or spacer 90 as shown in Figs. 1 to 4 may be utilized.

The coil spring 100 yieldably presses the L-shaped spacer 90 against the lower edges 51 and 53 of the electrodes 50 and 52 and also presses the opposite edges of the same electrodes against the container cover 12. Sufficient pressure is applied by the spring 100 to the edges of the electrodes 50 and 52 to prevent vibration thereof when in service. The spring 100 is in the form of a metallic spiral or coil spring and may be of small diameter relative to the spacing of the electrodes 50 and 52 to reduce to a minimum its electrical capacity effect with respect to the two edges 51 and 53 of the metallic electrodes 50 and 52.

The spring 70 resiliently presses together in clamped relation the electrodes 50 and 52 and the crystal 40 and also presses electrode 50 in contact with the metallic heat conducting plate 60 which is disposed in contact with the heat source casing 30. The spring 70 is in the form of a V-shaped leaf spring and may have a centrally disposed integral transverse corrugation or rib 72 extending across its entire width to permit the spring to be readily bent at the corrugated portion 72 and adjusted by hand to the desired and somewhat critical pressure to suit the crystal 40 which may be clamped between the electrodes 50 and 52. In a particular instance, the pressure exerted by the spring 70 was of the order of about five pounds.

The spring 70 has approximately the same projected area as the area of the major surfaces of the electrodes 50 and 52. The upper and lower ends 74 and 75 respectively, of the spring 70 register with the four flat pads or projections 54 of the electrodes 50 and 52. Where the pressure points 74 and 75 of the spring 70 so coincide with the contact points 54 between the electrodes 50 and 52 and the piezoelectric element 40, the electrodes 50 and 52 may be of relatively thin lightweight material since substantially no bending movements will be then exerted on the electrodes 50 and 52.

Electrical connections for the crystal holder shown in Figs. 1 to 4 are as follows: The connection pin 21 is connected with the high voltage side of the piezoelectric crystal element 40 by a circuit which includes the wire 25 soldered to the tip 23 of the hollow tubular pin 21, the brass connector plate 80 disposed along the internal walls of the insulating container 10 and soldered at 81 to the wire 25, the corrugated portion 72 of the spring 70, and the crystal electrode 52. The connection pin 22 may be connected with the electrode 50 by a direct or indirect circuit which includes the wire 26 soldered to the tip 23 of the hollow pin 22. The insulated terminal 31 of the heater 30 is connected with the connection pin 20 by the insulated wire 24 which is soldered to the tip 23 of the pin 20. The two lower corners of the partition plate 60 are removed at 68 as shown in Fig. 4 to permit the insulated wire 26, for example, the pass from one side of the plate 60 to the other side thereof. A portion of the upper half of the brass plate 60 may be removed as shown at 69 in Fig. 4 to permit a connector plate 80a as shown in Fig. 6 to pass from one side of the plate 60 to the other side thereof and without contact therewith when a connection to the electrode 52 is made from a side terminal 110 as shown in Figs. 5 and 6 instead of from a pin terminal 21 as shown in Figs. 1 to 4.

Through sockets corresponding to the spacing and dimensions of the pins 20, 21 and 22, the pin 21 may be connected to a control grid, for example, of a space discharge device, the pin 22 may be connected with a grounded cathode of the space discharge device and also with one terminal of a suitable source of energy for the heater 30, the pin 20 being connected with the other terminal of such heat energy source.

Figs. 5 and 6 show a modification of the crystal holder illustrated in Figs. 1 to 4. In Figs. 5 and 6, a brass side terminal 110 having an opening 111 is secured to the container 10 and is spun over and soldered at 112 to a brass connector plate 80a which is disposed on two internal walls 114 and 116 of the container 10 and which makes contact with the corrugation 72 of the spring 70 in the same manner as the connector plate 80 shown and described in connection with Figs. 1 to 4. In the modification shown in Figs. 5 and 6, there is no electrical connection with the pin 21, the connection with the side terminal 110 by means of the connector plate 80a being substituted. Otherwise, the device shown in Figs. 5 and 6 is of the same construction as that shown in Figs. 1 to 4.

In Figs. 7 and 8, a metallic leaf spring 120 of substantially the same area as the area of the electrodes 50 and 52 may have end portions 122 and 124 located so as to register with the projections 54 of the electrodes 50 and 52 between which the piezoelectric crystal element 40 is clamped with a spacing of approximately 0.001 inch or less between the central depressed portion of each electrode 50 and 52 and the quartz element 40. The electrodes 50 and 52 may be constructed from a sheet of stainless steel or iron suitably plated with chromium, for example. Where the pressure points 122 and 124 for example, of the spring 120 coincide with the contact points 54 between the electrodes 50 and 52 and the quartz element 40, the electrodes may be made of relatively light material since substantially no bending movements will be exerted. An adjusting screw 126 engaging a support 128 is adapted to adjust the pressure of the spring 120 to a value suitable for the electrodes 50 and 52, and the piezoelectric element 40. The spring 120 exerting a maximum pressure of about five pounds may be utilized, for example, when the electrodes 50 and 52 have a thickness of about one-sixteenth of an inch and the width and length dimensions of the piezoelectric element 40 are of the order of about 28 and 38 millimeters, respectively. When a quartz element 40 of smaller dimensions is used, the pressure exerted by the spring 120 may be reduced. It will be understood that in all cases, the pressure of the spring 120 will be adjusted to suit the particular crystal and electrode assembly that may be interchangeably used with the crystal holder 10 by reason of the removable assembly including the removable L-shaped insulating spacer 90 disposed between the metallic plates 60 and 80a and contacting the lower edges of the electrodes 50 and 52.

In the cover 12, a resilient device 130 which may be in the form of a yieldable rubber plug or a coil spring like the spring 100 of Figs. 1 to 4 exerts a suitable pressure on the upper edges of the electrodes 50 and 52 to keep the electrode assembly from shifting its position. The resilient device 130 may be in the form of a coil spring such as the coil spring 100 shown in Figs. 1 to 4, or in the form of a small leaf spring, for example, suitably fastened to the cover 12 and having at its free end or part, an insulating member in contact with the upper edges of the electrodes 50 and 52 to prevent short-circuiting of the electrodes.

The remaining parts of the device shown in Figs. 7 and 8 are of the same construction and arrangement as those shown of like reference numerals in Figs. 1 to 6. It will be noted that the terminal 110 is connected to the high voltage side of the crystal element 40 by a circuit including the connector plate 80a connected with the side terminal 110, the adjusting screw 126, the spring 120 and the electrode 52. The pin 22 is connected with the low voltage side of the crystal 40 through the metal partition plate 60 and the electrode 50. The metal plate 60 supports the thermostat-controlled heater 30, forms a heat conducting path between the heater 30 and the electrode 50, and forms part of the electrical connection between the electrode 50 and the pin 22.

Figs. 9 and 10 show a removable insulating spacer 140 having an opening 141 therein of rectangular shape. The spacer 140 is similar to the L-shaped spacer 90 of Figs. 1 to 8 but surrounds in slidably fitting relation all of the edges of the electrodes 50 and 52 instead of only two adjacent edges of each electrode 50 and 52 as shown in Figs. 1 to 8. The coil spring 100 holds the removable spacer 140 in position against the cover 12 of the container 10. The leaf spring 70 holds the crystal 40 and the electrodes 50 and 52 in position. Electrical connections with the electrodes 50 and 52 are made as hereinbefore described through the spring 70 and metal plate 80 and through the metal partition plate 60.

Fig. 11 shows a removable Bakelite spacer 142 like the spacer 140 of Figs. 9 and 10 but having an opening 144 therein of circular form adapted to hold a crystal 145 of circular shape and a pair of equal diameter electrodes 146 and 147 of the same configuration. The spacer 142 being of the same external dimensions as the spacer 140 may be substituted for the spacer 140 and removably arranged in the crystal holder 10 as shown in Fig. 10. It will be understood that a suitable spring similar to the spring 70 of Fig. 10 may be utilized to hold the circular-shaped equal diameter crystal 145 and electrodes 146 and 147 of Fig. 11 in clamped position against the metal partition 60 of Fig. 10.

Referring to Figs. 12 to 17, where unclamped operation of the piezoelectric crystal 40 is desired, an additional insulating spacer of Bakelite, such as the spacer 160 of Figs. 12 and 13 wholly surrounding the edges of the crystal 40 or the U-shaped spacers 170 of Figs. 14 and 15 and 180 of Figs. 16 and 17 partly surrounding the peripheral edges of the crystal 40 may have such slightly greater thickness with respect to the thickness of the crystal 40 as to separate the two flat-surfaced electrodes 190 and 192 such distance that when the spacers 160, 170 or 180 are clamped between the two electrodes 190 and 192, the piezoelectric element 40 itself is mechanically free to vibrate in unclamped position between the two electrodes 190 and 192 and the corresponding spacer 160, 170 or 180.

In Figs. 12 and 13, the assembly comprises the piezoelectric crystal 40, the spacer 160 and the electrodes 190 and 192 all disposed within the rectangular opening 141 of the spacer 140 and held in position and electrically connected by the spring 70 and the plate 80 in the manner shown in Fig. 10.

In Figs. 14 and 15, the U-shaped spacer 170 surrounds three edges of the quartz element 40 and has a thickness sufficiently greater than the thickness of the piezoelectric element 40 to allow free movement of the element 40 between the electrodes 190 and 192 which are held in position by the leaf spring 120, the L-shaped spacer 90, and the resilient device 130 according to the construction shown in Figs. 7 and 8. It will be understood that the assembly comprising the crystal 40, the electrodes 190 and 192, the U-shaped spacer 170 and the L-shaped spacer 90 may be held in position and connected by such constructions as coil spring 100 and leaf spring 70 of Figs. 1 to 6 in place of that shown in Figs. 14 and 15. In Figs. 14 and 15, connections are made to the electrode 192 through the connector plate 80a and the side terminal 110 but it will be understood that they may also be made if desired from the pin 21 through the metal plate 80 as shown in Figs. 1 to 4.

In Figs. 16 and 17, a casing 201 in which the piezoelectric apparatus is enclosed, may be composed, for example, of aluminum or of molded resin consisting of phenol formaldehyde condensation product. A suitable quartz piezoelectric element 40 which may have a zero or low temperature coefficient of frequency is supported in unclamped position between the two flat-surfaced metal electrodes 190 and 192 and the insulating U-shaped spacer 180. The electrodes 190 and 192 are held in position by an aluminum frame 205, a fixed insulating support 206 composed, for example, of phenol fibre and attached to the frame 205 by a screw 203, a resilient insulated support 207 and a metal pin 208. The electrodes 190 and 192 have flat surfaces adjacent the piezoelectric element 40. The U-shaped spacer 180 surrounds three edges of the crystal 40 and is spaced therefrom a suitable distance such as, for example, about one millimeter to allow free unclamped vibration of the crystal 40. The thickness of the U-shaped spacer 180 is slightly greater than the thickness of the piezoelectric quartz crystal 40 to allow unclamped vibration of the crystal 40. The electrodes 190 and 192 and the spacer 180 fit into a groove in the fixed support 206. A small metal leaf spring 209 preferably of narrow width relative to the spacing of the electrodes 190 and 192 is attached at its center to the support 207. Two screws 210 passing through two holes in the ends of the metal leaf spring 209, secure the spring 209 to the frame 205. The spring 209 resiliently presses the insulating support 207 against the upper edges of the electrodes 190 and 192 to hold the assembly in position.

The pin or plunger 208 exerts a suitable pressure on the electrode 192 by means of a coil spring 211, the convolutions of which surround the plunger 208. This pressure insures constant contact between the electrodes 190 and 192 and the U-shaped spacer 180. Both the plunger 208 and the spring 211 are contained within a screw member 212. The screw member 212 is inserted in a metallic bushing 213. The bushing 213 is secured to an insulating support 214 which may be composed of phenol fibre. The phenol fibre support 214 is, in turn, fixedly attached to the frame 205.

When temperature control of the piezoelectric crystal 40 is desired, a thermostat-controlled heater 30 as shown in Figs. 1 to 4, for example, may be mounted in the space 216 and secured by screws 64 and 65 (Fig. 1) to the frame 205 at 217. As shown in Figs. 1 to 4, the thermostat may comprise a bimetallic cupped disc 37 having a contact switch 34 fixedly attached thereto which, when the cup-shaped disc 37 assumes a convex configuration in response to a predetermined temperature, engages two suitable metallic contacts to supply energy to the heater 30. The bimetallic cupped disc 37 may be, for example, of the type disclosed in U. S. Patent 1,448,240 granted to J. A. Spencer. The heating unit 30 may comprise any suitable heating coil wound on a mica card, for example.

The frame 205 may be suitably attached as by bolts (not shown) to a base composed, for example, of laminated phenol fibre sections 224 and 225. The base 224 fits into the casing 201 and may be secured thereto by suitable screws (not shown). Three spaced prongs 227, 228 and 229, corresponding to prongs 20, 21 and 22 of Figs. 1 to 4, provide connections to the piezoelectric crystal 40 and to the heating unit if utilized. The prong 228 is connected to the bushing 213 by a wire 230. The prong 229 may be connected by a wire (not shown) to the thermostat. The prong 227 may be connected to the frame 205. Since the metal electrode 190 is disposed in contact with the metal frame 205, current may pass from the prong 228 to the prong 227 by a circuit including the wire 230, metallic bushing 213, screw member 212, plunger 208, electrode 192, quartz element 40, electrode 190, and frame 205. The heating circuit, if utilized, may be completed from the prong 229 through the switch of the thermostat, the heating coil and the frame 205 to prong 227. The three prongs 227, 228 and 229 are insertable in suitably spaced sockets (not shown). Heating current may be applied to the prongs 227 and 229, while the leads from the oscillator or other apparatus to be associated with the piezoelectric element 40 may be connected to the prongs 227 and 228.

If the replacement of one piezoelectric element 40 by another is desired, the casing 201 may be disengaged from the frame 224 and the screw member 212 rotated in such manner that the plunger 208 is separated from the electrode 192 with which the plunger 208 is normally in contact as shown in Fig. 16. By pressing the resilient support 207 in an upward direction, the electrodes 190 and 192, the spacer 180 and the quartz crystal 40 are easily removed from the frame 205. To place the electrode assembly in the frame 205, the resilient support 207 is pressed in an upward direction and the electrodes 190 and 192, the quartz crystal 40 and the spacer 180 placed in normal position in the apparatus. The screw member 212 is then rotated until sufficient pressure is exerted by the plunger 208 on the electrode 192 to hold the assembly in place.

As a modified arrangement, the two electrodes 50 and 52 each having the four clamping projections 54 for clamping the marginal corners of the piezoelectric quartz crystal 40 as illustrated in connection with Figs. 1 to 10, may be replaced by two electrodes of suitable dimensions each having two flat major surfaces without projections 54 such as the electrodes 190 and 192 of Figs. 13, 14, and 16 and an insulating spacer, such as the U-shaped spacer 170 of Fig. 14 or 180 of Fig. 16, clamped therebetween for permitting unclamped vibration of a piezoelectric crystal such as the crystal 40. The U-shaped spacer such as the spacer 170 of Figs. 14 and 15 may be arranged in any of the holders of Figs. 1 to 10 in the position as shown in Figs. 14 and 15 or may be inverted from such position shown in Figs. 14 and 15 so that the opening between the sides thereof will be at the top of the holder adjacent the cover end 12 of the holders of Figs. 1 to 15 thereby to allow removal and replacement of the crystal plate 40 through such opening in the U-shaped spacer upon removal of the cover 12 without disassembling the electrodes such as the pair of electrodes 190 and 192 and the springs 70 or 120 of Figs. 1 to 15. With such inverted arrangement of the U-shaped spacer, the same arrangement of the L-shaped spacer 90 and the springs 100 or 130 may be used as illustrated in the crystal holders shown in Figs. 1 to 4 and in Figs. 14 and 15 for example.

As another modified arrangement, where it is desired to have a single holder contain two piezoelectric elements of the same or different frequencies instead of only one element as illustrated in the several figures herein, the additional piezoelectric element may be disposed in the space designated for the thermostat and heater in the same manner that the piezoelectric element 40 is disposed as shown in the drawings. The additional piezoelectric element may be connected between the ground prong and the prong that is normally connected with the heater terminal where a heater is used or that is normally disconnected when no heater is used. For example, in the modification shown in Fig. 1, the additional piezoelectric element may be symmetrically assembled and connected in the space at the left of the partition plate 60 in exactly the same manner as the crystal 40 is assembled and connected in the space at the right of the partition plate 60, the high voltage side of the additional crystal being connected with the prong 20 in the same manner that the high voltage side of the crystal 40 is connected with the prong 21, and the low voltage side of both crystals being connected by the partition plate 60 and the flexible wire 26 with the common or ground prong 22.

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. Piezoelectric apparatus comprising a piezoelectric crystal, a plurality of metallic electrodes for said crystal, a thermostat-controlled heat source, an insulating container enclosing said crystal, electrodes and heat source, said container having a removable insulating cover, a plurality of metallic connection terminals including a plurality of spaced pins or prongs secured externally to said container, a removable metallic heat con-

ducting partition disposed within said container in contact with said heat source and in contact with one of said electrodes, a metallic connector plate disposed in contact with an internal wall of said container, means connecting said partition with one of said terminals, means connecting said connector plate with another of said terminals, a removable L-shaped insulating spacer disposed between said partition and said connector plate and disposed in contact with the edges of said plurality of electrodes, means including a removable spring resiliently exerting pressure on said spacer and on said edges of said electrodes to prevent shifting of said spacer and said electrodes, and means comprising a removable leaf spring disposed in contact with said connector plate and in contact with a surface of one of said electrodes for resiliently exerting pressure on said electrodes and on said crystal.

2. Piezoelectric apparatus comprising a piezoelectric crystal, a plurality of removable electrodes for said crystal, a thermostat-controlled heating element, an insulating container enclosing said crystal, electrodes and heating element, a plurality of metallic terminals including a plurality of pins or prongs secured externally to said container, a removable metallic heat conducting partition disposed within said container in contact with said heating element and in contact with one of said electrodes, a metallic connector plate disposed in contact with an internal wall of said container, means connecting said partition with one of said terminals, means connecting said connector plate with another of said terminals, a removable insulating spacer disposed between said partition and said connector plate and disposed in contact with the edges of said plurality of electrodes, means resiliently exerting pressure on said spacer, and means resiliently exerting pressure on said electrodes.

3. Piezoelectric apparatus comprising a piezoelectric crystal, a plurality of removable electrodes for said crystal, a thermostat-controlled heating element, an insulating container enclosing said crystal, electrodes and heating element, said container having a removable insulating cover, a plurality of metallic terminals including a plurality of pins or prongs secured externally to said container, a removable metallic heat conducting partition disposed within said container in contact with said heating element and in contact with one of said electrodes, a metallic connector plate disposed in contact with an internal wall of said container, means connecting said partition with one of said terminals, means connecting said connector plate with another of said terminals, and means including a removable insulating spacer and a plurality of resilient devices positioning and interconnecting said electrodes and crystal between said partition and said connector plate.

4. Piezoelectric apparatus comprising a piezoelectric crystal, a plurality of removable electrodes for said crystal, an insulating container enclosing said crystal and said electrodes, a plurality of metallic terminals including a plurality of prongs secured externally to said container, a plurality of metallic connector plates disposed in spaced parallel relation within said container, means connecting one of said plates with one of said terminals, means connecting another of said plates with another of said terminals, a removable L-shaped insulating spacer disposed in contact with the edges of said plurality of electrodes, means including a spring resiliently exerting pressure on said spacer and on said edges of said plurality of electrodes, and means including a leaf spring connected with one of said plates and resiliently exerting pressure on a surface of one of said electrodes and pressing another of said electrodes against another of said plates.

5. Piezoelectric apparatus comprising a piezoelectric crystal, a plurality of removable electrodes for said crystal, an insulating container enclosing said crystal and electrodes, a plurality of metallic terminals including a plurality of prongs secured externally to said container, a plurality of metallic connector plates disposed in spaced parallel relation within said container, means connecting one of said plates with one of said terminals, means connecting another of said plates with another of said terminals, a removable insulating spacer disposed in contact with the edges of said plurality of electrodes, means resiliently exerting pressure on said spacer and on said edges of said plurality of electrodes, and means connected with one of said plates and resiliently exerting pressure on a surface of one of said electrodes and pressing another of said electrodes against another of said plates.

6. Piezoelectric apparatus comprising a piezoelectric crystal, a plurality of electrodes for said crystal, an insulating container enclosing said crystal and electrodes, a plurality of metallic connector plates disposed in spaced parallel relation within said container, a removable L-shaped insulating spacer disposed in contact with the edges of said plurality of electrodes, means including a spring resiliently exerting pressure on said spacer and on said edges of said plurality of electrodes, and means including a leaf spring connected with one of said plates and resiliently exerting pressure on a surface of one of said electrodes and pressing another of said electrodes against another of said plates.

7. Piezoelectric apparatus comprising a piezoelectric crystal, a plurality of electrodes for said crystal, an insulating container enclosing said crystal and electrodes, a plurality of metallic conductor plates disposed in spaced parallel relation within said container, a removable insulating spacer disposed in contact with the edges of said plurality of electrodes, means resiliently exerting pressure on said spacer and on said edges of said plurality of electrodes, and means connected with one of said plates and resiliently exerting pressure on a surface of one of said electrodes and pressing another of said electrodes against another of said plates.

8. Piezoelectric apparatus including a piezoelectric element, a plurality of electrodes for said element, an enclosing container for said element and said electrodes, and means for removably and resiliently positioning said electrodes within said container including a rigid insulating retaining member disposed in contact with a plurality of the edge faces of each of said plurality of electrodes and a spring exerting compression on said insulating member and on the edges of said plurality of electrodes.

9. Piezoelectric apparatus including a piezoelectric element, a plurality of electrodes for said element, an enclosing container for said element and said electrodes, and means for removably and resiliently positioning said electrodes within said container, said positioning means including a rigid insulating body disposed in contact with adjacent edges of said plurality of electrodes, and a spring exerting compression on said insulating body.

10. Piezoelectric crystal apparatus including a piezoelectric crystal, a plurality of electrodes for said crystal, a housing for said crystal and said electrodes, and means locating said electrodes within said housing including removable retaining means contacting the adjacent outer edges of said plurality of electrodes and a spring exerting compression on said retaining means.

11. Piezoelectric crystal apparatus including a piezoelectric crystal, a plurality of electrodes for said crystal, a housing for said crystal and said electrodes, and means locating said electrodes within said housing including removable L-shaped retaining means contacting two of the outer edges of each of said plurality of electrodes.

12. In a piezoelectric crystal holder, a container, a piezoelectric crystal, electrodes for said crystal, and means resiliently positioning said electrodes and said crystal within said container including removable spacing means contacting at least a part of the outer edges of said electrodes and having a thickness greater than the thickness of said crystal.

13. Piezoelectric apparatus including a plurality of electrodes, a piezoelectric crystal disposed between said electrodes, means detachably disposed between said electrodes for spacing said electrodes a distance greater than the thickness of said crystal, means detachably disposed in contact with at least a part of the outer edges of said electrodes for positioning said electrodes, and means resiliently holding said spacing means and said electrodes.

14. Piezoelectric apparatus including a plurality of electrodes, a piezoelectric crystal disposed between said electrodes, an insulating spacer detachably disposed between said electrodes and having a thickness greater than the thickness of said crystal and surrounding at least a part of the whole peripheral edge of said crystal, and means resiliently holding said spacer and said electrodes comprising a rigid insulating body disposed in contact with the edge faces of said plurality of electrodes, a spring exerting compression on said body, and a spring exerting pressure on a major surface of one of said electrodes.

15. Piezoelectric apparatus including a plurality of electrodes, a piezoelectric crystal disposed between said electrodes, a spacer disposed between said electrodes and having a thickness greater than the thickness of said crystal and surrounding at least a part of the whole peripheral edge of said crystal, a spacer having a thickness greater than the thickness of said first mentioned spacer and surrounding at least a part of the peripheral edges of said electrodes, and means positioning said spacer and said electrodes.

16. Piezoelectric apparatus including a pair of spaced parallel metal plates, a piezoelectric element, a pair of electrodes each having a flat surface, a U-shaped insulating spacer surrounding three edges of said element and having a thickness greater than the thickness of said element, means including a spring for clamping said U-shaped spacer between said flat surfaces of said pair of electrodes and for holding said electrodes and connecting said electrodes with said plates, an L-shaped insulating spacer surrounding two edges of each of said electrodes and having a thickness substantially equal to the spacing between said pair of plates, and means including a resilient device for exerting pressure on said L-shaped spacer.

17. Piezoelectric apparatus including a piezoelectric crystal, a plurality of electrodes for said crystal, an enclosing container for said crystal and said electrodes, a removable insulating spacer disposed in contact with the edge faces of said plurality of electrodes, means supported by said container and resiliently exerting pressure on said spacer and on said edge faces of said electrodes, and means supported by said container and resiliently exerting pressure on a major surface of at least one of said electrodes.

18. Piezoelectric apparatus including a piezoelectric crystal, a plurality of electrodes for said crystal, an insulating spacer disposed in contact with the edge faces of said plurality of electrodes, means including a resilient device for exerting pressure on said spacer in a direction substantially parallel to the major surfaces of said electrodes, and means including another resilient device for exerting pressure on said electrodes in a direction substantially perpendicular to the major surfaces of said electrodes.

19. Piezoelectric crystal apparatus including a plurality of crystal electrodes, means including a resilient device for exerting clamping pressure on the major surface of said electrodes, and means disposed in contact with adjacent edge surfaces of said plurality of electrodes and including another resilient device for exerting clamping pressure on said edge surfaces.

LAWRENCE F. KOERNER.