

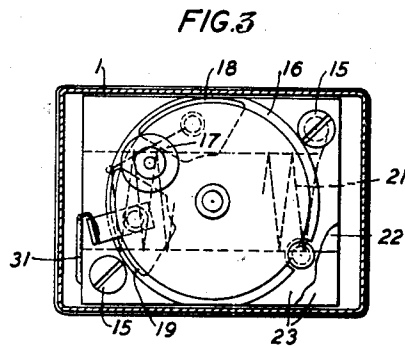
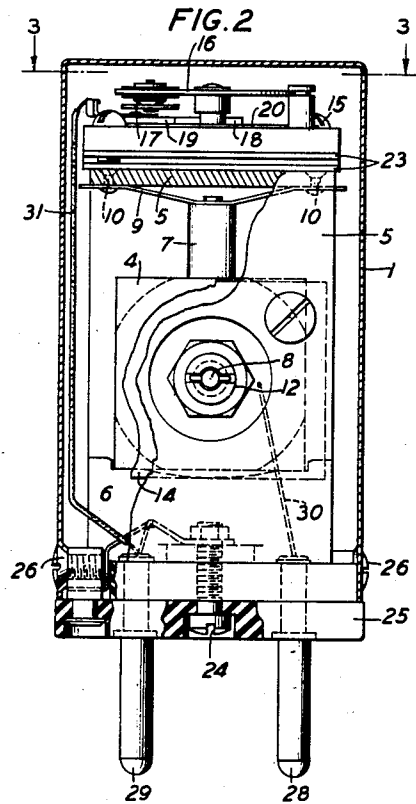
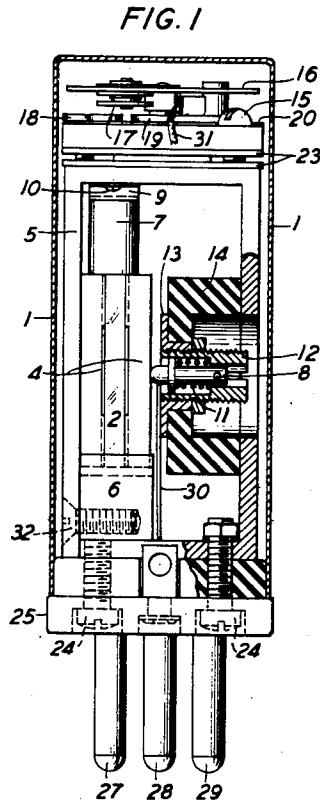
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PIEZOELECTRIC APPARATUS

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PIEZOELECTRIC APPARATUS

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9 Claims. (Cl. 171—327)

This invention relates to piezoelectric apparatus and more particularly to piezoelectric apparatus especially adapted for use in airplanes.

An object of this invention is to maintain the frequency of oscillations of a piezoelectric oscillator substantially constant.

A more particular object of this invention is to provide a compact light-weight temperature regulating equipment for piezoelectric elements having a low temperature coefficient of frequency.

If oscillations of a constant frequency are to be obtained in piezoelectric oscillators, the piezoelectric element of these oscillators must be maintained within a close range of temperature limits. Usually the apparatus for this temperature maintenance involves the use of relays and is heavy and bulky. In mobile radio equipment of airplanes, this excessive weight is decidedly undesirable.

W. P. Mason and R. A. Sykes have developed a piezoelectric element which possesses a reduced temperature coefficient of frequency. This piezoelectric element is described in their copending application Serial No. 702,334, filed December 14, 1933. Although the variations in frequency of oscillations generated by an oscillator in which these elements are employed are satisfactory for the usual temperature range to which the oscillators are subjected, the changes in frequency at the extreme low temperatures which sometimes obtains in airplanes in flight dictate the use of some means of temperature maintenance for the piezoelectric elements of oscillators employed in airplanes. Not unlike other airplane apparatus, the temperature maintenance equipment must be as light and compact as possible.

The temperature coefficient of frequency as pointed out in a copending application of F. R. Lack, G. W. Willard and I. F. Fair, Serial No. 728,640, filed June 2, 1934, is a concomitant of the various functions of the temperature coefficient of dimensions of the elements involved, the temperature coefficient of the density of the elements employed and the temperature coefficient of the elastic constants involved. The manufacturing variation from the desired angle is also a factor contributing to a deviation in the temperature coefficient of frequency. After a consideration of all these contributory causes—the maximum deviation in frequency permissible for the particular purpose for which the piezoelectric element is to be employed and the probable temperature conditions under which the piezoelectric element is to be used—the tolerated temperature range within which the element functions satisfactorily is de-

termined. With piezoelectric elements having a low or approximately zero temperature coefficient of frequency as described in the above stated copending application of Willard, Fair and Lack, this tolerated temperature range may be relatively wide.

In accordance with this invention, heating energy is supplied to these piezoelectric elements having a low or approximately zero temperature coefficient of frequency when the ambient temperature to which the apparatus containing the elements is subjected, falls below the lowest tolerated temperature for efficient control. For example, certain of these elements employed in oscillators on airplanes have an average temperature coefficient of frequency of approximately two parts per million per degree centigrade between 0° C., and +60° C. If the tolerated deviation of frequency for this particular purpose is 120 cycles per million, a temperature range of 60° C., is permissible. Since an airplane in flight is subject to a range in temperature between -40° C., and +60° C., the piezoelectric element may be manufactured to generate the desired frequencies at approximately 30° C., and heating energy supplied to the element when the ambient temperature falls below 0° C. When the element has attained a temperature slightly above 0° C., either from the heating energy supplied or from an increase in the ambient temperature the heating energy is withdrawn. Since an airplane in flight attains a temperature below 0° C., on occasions only, a marked saving in the heating energy supplied to the piezoelectric element is effected. Furthermore, no relays or heavy cumbersome apparatus is required for supplying the heating energy to the element since the thermostat may be made sufficiently rugged to handle any current required.

A more comprehensive understanding of this invention is obtained by reference to the accompanying drawing in which:

Fig. 1 is a side elevation of an embodiment of this invention;

Fig. 2 is a front elevation partly in section of the embodiment of the invention shown in Fig. 1;

Fig. 3 is a cross-sectional view of the apparatus shown in Fig. 2 along the lines 3—3 thereof.

In the drawing the numeral 1 is a casing in which piezoelectric apparatus to be hereinafter described is enclosed. The casing is preferably composed of aluminum or molded resin consisting of phenol formaldehyde condensation product. A quartz piezoelectric element 2 of the type described in the above stated copending applica-

tions of Willard-Fair-Lack or Mason-Sykes is supported by two electrodes 4. The piezoelectric element 2 may be, for example, a relatively thin quartz plate of rectangular parallelepiped shape having its major plane and its electrode surfaces disposed substantially parallel to an electric crystallographic or X axis thereof and inclined at such an acute angle as a positive angle of substantially $+35^{\circ} 20'$ or a negative angle of -49° with respect to the optic crystallographic or Z axis thereof as to produce a substantially zero temperature coefficient of frequency at a given temperature and a low temperature coefficient of frequency as approximately two cycles per million per degree Centigrade throughout a substantial temperature range as from substantially 0° C. to $+60^{\circ}$ C. when vibrated in the shear mode of motion at a frequency determined by the thin dimension as measured between the two major or electrode surfaces thereof. It will be understood that the angles of $+35^{\circ} 24'$ and -49° mentioned may be varied slightly without producing a temperature coefficient of frequency substantially in excess of two cycles per million per degree centigrade. For example, the positive angle may be substantially from $+35^{\circ}$ to $+36^{\circ}$ to produce a temperature coefficient of frequency not exceeding about three parts in a million per degree centigrade.

The positive angle and the negative angle referred to in the preceding paragraphs may be specified as follows: A quartz crystal is designated as right-hand if it rotates the plane of polarization of plane polarized light traveling along the optic or Z axis in a right-hand direction and is designated as left-hand if it rotates the plane of polarization to the left. If a compressional stress be applied to the ends of the electric or X axis of a quartz body and not removed, a charge will be developed which is positive at the positive end of the axis and negative at the negative end of the axis for either right-hand or left-hand crystals. The amplitude and sign of the charge may be measured with a vacuum tube electrometer. In specifying the orientation of the right-hand crystal, the angle which the major plane of the quartz plate Z makes with respect to the optic axis as the crystal plate is rotated about the electric axis is deemed positive when, with the positive end of the electric axis pointed toward the observer, the rotation is in a clockwise direction, and is deemed negative when the rotation is counterclockwise. Conversely, the angle of a left-hand crystal is positive when, with the positive end of the electric axis pointed toward the observer, the rotation is counterclockwise and is negative when the rotation is clockwise. The electrodes 4 are held in the apparatus by means of an aluminum frame 5, a fixed support 6 composed of phenol fiber attached to the frame 5 by means of a screw 32, a resilient insulated support 7 and a plunger 8. The electrodes 4—4 are preferably constructed so that the quartz 2 is clamped around its periphery. This construction of the electrodes is described in U. S. Patent 1,883,111, granted to G. Thurston on October 18, 1932. The electrodes 4 fit into grooves in the fixed support 6. A metal strip 9 is fixedly attached to the support 7. By means of two prongs 10, 10 of the frame 5, which engage in two holes in the metal strip 9, the support 7 is held to the frame and may be removed quickly therefrom when adjustment or change of the crystal 4 is desired.

The plunger 8 exerts a pressure on one of the

electrodes by means of a coil spring 11, the convolutions of which surround the plunger 8. This pressure insures constant contact between the electrodes 4 and the peripheries of the quartz 2. Both the plunger 8 and the spring 11 are contained within a screw member 12. Screw member 12 is inserted in a metallic bushing 13. The bushing 13 is fixedly held to a support 14 composed of phenol fiber. The phenol fiber support 14 is in turn fixedly attached to the aluminum frame 5.

A thermostat comprising a bimetallic cupped disc 16 is held rigidly to the frame by means of two screws 15, 15. A contact 17 is fixedly attached to the cup-shaped disc 16. When the cup-shaped disc 16 assumes a convex configuration the contact 17 engages two metallic strips 18 and 19. This type of thermostat has a large current carrying capacity. The bimetallic cupped disc is preferably of the type disclosed in U. S. Patent 1,448,240, March 13, 1923, granted to J. A. Spencer. The metallic strips 18 and 19 are insulated by means of a sheet of mica 20 from the frame 5.

A heating unit is contained between the thermostat and the frame 5. The heating unit comprises a heating coil 21 wound on a mica card 22. The heating coil is insulated from the thermostat and the frame 5 by means of two mica strips 23. One of the leads of the heating coil 21 is connected to the metallic strip 18, while the other lead is connected to the frame 5.

The frame 5 is fixedly attached to a base 25 composed of laminated phenol fiber by means of a pair of bolts 24. The base 25 fits into the casing 1 and is held to it by means of screws 26. Three prongs 27, 28 and 29 provide connections to the piezoelectric crystal and heating unit with other apparatus. The prong 28 is connected to the bushing 13 by means of a wire 30. The prong 29 is connected by means of a wire 31 to the metal strip 19 of the thermostat, while the prong 27 is connected to the frame 5. Since the electrode 4 adjacent to the frame 5 is in intimate contact therewith, current passes from prong 28, wire 30, bushing 13, screw member 12, plunger 8, one of the electrodes 4, quartz 2, the other electrode 4, frame 5 to prong 27. The heating circuit is completed from the prong 29, wire 31, metallic strip 19, contact 17 of the thermostat, strip 18, heating coil 21, frame 5 to prong 27. The three prongs are inserted in a socket (not shown). Heating current is applied to prongs 27 and 29, while the leads from the oscillator or other apparatus for the quartz are connected to prongs 27 and 28.

If the quartz 2 requires adjustment or if the replacement of one piezoelectric element by another is desired the casing 1 is disengaged from the frame 5 by removal of the screws 26. The screw member 12 is rotated in such manner that the plunger 8 is separated from one of the electrodes 4 with which the plunger is normally in contact. By pressing the resilient support 7 in an upward direction the electrodes 4 and quartz 2 are easily removed from the frame. To place the electrodes in the frame the resilient support is inserted in the frame, the two holes contained in the metal strip 9 being held manually in engagement with the two prongs 10, 10. The support 7 is pressed in an upward direction and the electrodes and quartz placed in normal position in the apparatus. The screw member 12 is then rotated until sufficient pressure is exerted by the plunger 8 on one of the electrodes 4.

If the ambient temperature to which the piezo-electric apparatus is subjected varies from -40° C. to $+60^{\circ}$ C. the quartz 2 is calibrated to produce the desired frequency at 30° C. Since the quartz 2 is an element prepared in accordance with the above description and has a low temperature coefficient of frequency from about 0° C. to 60° C., the temperature may be varied within a range of 60° C. without deviating from the frequency tolerated for efficient operation of radio transmitting and receiving systems. The thermostat 16 is designed to connect the heater coil 21 to the power supply at a temperature lower than $+5^{\circ}$ C. and to disconnect the power at some appreciably higher temperature. This operating temperature is selected so that the apparatus is always maintained above 0° C. Since temperature of the quartz 2 is maintained within the range of 0° C. to 60° C. the frequency does not exceed the deviation of that which can be tolerated for efficient operation of the system. Since the change in temperature of quartz, as the ambient temperature drops below 5° C., is $\frac{1}{20}$ of the ambient change, the quartz is maintained above 0° C. even if the ambient temperature drops to -40° C. This method of operation is made possible by the low temperature coefficient of the quartz employed and is of considerable advantage since no power is consumed by the heater except during periods when the temperature drops below 0° C. If the apparatus is placed in operation at temperatures below 0° C. as in the case of apparatus contained in an airplane which is in the open for a considerable period of time during the winter months, some time elapses before the crystal is brought to the operating temperature. At -40° C. it requires approximately 30 minutes to reach 0° C. and the time required for the quartz to attain the operating temperatures from higher temperatures is proportionally less than that period. For example, if the ambient temperature is approximately -10° C. it requires about $7\frac{1}{2}$ minutes to bring the quartz to 0° C. Accordingly, if the apparatus is started at a temperature lower than 0° C. a sufficient time must be allowed to permit the quartz to attain at least 0° C. before operation. When the quartz has attained a temperature of at least 0° C., however, and the power supply is continually connected to the prongs 27 and 29, the quartz is maintained at at least 0° C. even if the ambient temperature falls to -40° C.

While a preferred embodiment of this invention has been illustrated and described, various modifications therein may be made without departing from the scope of the appended claims.

What is claimed is:

1. A piezoelectric apparatus comprising an enclosing housing, a conductive metallic chassis slidably removable from said housing, a piezoelectric element having a low temperature coefficient of frequency mounted on said chassis, and means mounted on said chassis comprising a heater controlled by a thermostat having a bimetallic cupped disc responsive to an ambient temperature below that required for efficient constant frequency operation of said element, for maintaining said element substantially above said required temperature and at substantially constant frequency.

2. A piezoelectric apparatus comprising an enclosing housing, a conductive metallic chassis slidably removable from said housing, a piezoelectric crystal having a low temperature coefficient of frequency mounted on said chassis, and

means mounted on said chassis comprising a heater controlled by a thermostat having a bimetallic cupped disc responsive to a temperature of approximately zero degrees centigrade, for maintaining the temperature of said crystal substantially above approximately zero degrees centigrade and the frequency thereof substantially constant.

3. A piezo electric apparatus comprising a housing, a heat conductive chassis slidably removable from said housing, means for fixedly holding said chassis in said housing, a piezoelectric element mounted on said chassis and means mounted on said chassis comprising a thermostat having a bimetallic cupped disc and a heater controlled by said disc for maintaining said crystal above a predetermined temperature.

4. A piezoelectric crystal apparatus comprising a housing comprising aluminum, a chassis comprising aluminum slidably removable from said housing, a piezoelectric crystal mounted on said chassis aluminum, means mounted on said chassis aluminum comprising a heating coil and a bimetallic thermostat having a cupped disc for directly controlling the supply of energy to said coil for maintaining said crystal above a predetermined temperature and prongs fixedly attached to said chassis electrically connected to said crystal and said heating means and adapted for insertion into receptacles for supplying a source of energy to said heating means.

5. A piezoelectric device comprising an enclosing housing, a conductive frame slidably removable from said housing, a piezoelectric element having a low temperature coefficient of frequency, mounted on said frame, means mounted on said frame comprising heating means controlled by a thermostat having a bimetallic cupped disc for maintaining said element above a predetermined minimum tolerated temperature for efficient frequency control of said element, and terminal prongs secured to the exterior of said device, and electrically connected with said piezoelectric element and with said heating means.

6. Piezoelectric crystal apparatus comprising a piezoelectric crystal having a tolerated temperature coefficient of frequency of less than substantially two parts in a million per degree centigrade over a range in temperatures between 0 degrees and $+60$ degrees centigrade, and a desired zero temperature coefficient of frequency at substantially $+30$ degrees centigrade, a pair of removable electrodes having metallic projections for clamping said crystal therebetween, an insulating base, a plurality of spaced metallic terminal prongs secured externally to said base, a heat conductive aluminum frame secured to said base and surrounding said crystal, a heat source secured to said frame in heat conductive relation therewith and including a heating winding, a thermostat including a movable bimetallic cupped disc having a contact secured thereto and having a substantial temperature differential between the operating and non-operating positions thereof, means including said thermostat for connecting said contact directly in series circuit relation with said heating winding at a temperature lower than substantially $+5$ degrees centigrade and for disconnecting said circuit at a substantially higher temperature within said tolerated range, said heat source being disposed between said thermostat and said crystal, and being disposed adjacent said thermostat and spaced a greater distance away from said crystal than

from said thermostat, an enclosing housing detachably secured to said insulating base and wholly enclosing said frame, electrodes, crystal, heat source and thermostat, an insulating support secured to said frame and having a retaining groove disposed in contact with adjacent edge faces of said pair of electrodes, a movable insulating spacer disposed in contact with the edge faces of said pair of electrodes opposite to said mentioned adjacent edge faces, a leaf spring secured at its ends to said frame and secured intermediate said ends to said movable spacer for resiliently clamping said electrodes between the opposite edge faces thereof, a slidable conductive plunger disposed in contact with a major surface of one of said electrodes, a coil spring surrounding and engaging said plunger, means supported by said frame and including said coil spring and said plunger for resiliently clamping said crystal between said electrodes and for pressing a major surface of one of said electrodes in contact with said frame, and means connecting one of said prongs with said plunger, another of said prongs with said frame and another of said prongs with said heat source.

7. Piezoelectric apparatus including a piezoelectric body having a temperature coefficient of frequency less than substantially two parts in a million per degree centigrade over a range in temperatures not less than substantially 50 degrees centigrade, a plurality of electrodes for said body, an insulating base, a plurality of terminal prongs secured externally to said base, a heat conductive frame secured to said base and surrounding said body and electrodes, a heat source mounted on said frame, thermostat means controlling said heat source and including a bimetallic cupped disc having a substantial temperature differential between the operating and non-operating positions thereof corresponding respectively to a selected temperature equal substantially to the minimum temperature of said range and a temperature substantially higher than said minimum temperature and within said range, said heat source being disposed between said thermostat and said body and being disposed adjacent said thermostat and spaced a greater distance away from said body than from said thermostat, a plurality of insulating spacers, spring means supported by said frame for resiliently clamping the opposite edge faces of said plurality of electrodes between said spacers, spring means supported by said frame for resiliently exerting pressure on one of said electrodes and for press-

ing another of said electrodes in contact with said frame, means for electrically connecting said terminal prongs with said electrodes, thermostat and heat source, and a housing detachably secured to said insulating base and enclosing said frame, electrodes, piezoelectric body, heat source and thermostat.

8. Piezoelectric apparatus including a piezoelectric body having a temperature coefficient of frequency less than substantially two parts in a million per degree centigrade over a temperature range not less than 50 degrees centigrade, electrodes for said body, a heat conductive frame disposed in heat conductive relation with at least one of said electrodes, a heat source secured to said frame, thermostat means controlling said heat source and including a bimetallic cupped disc having a substantial temperature differential between the operating and non-operating positions thereof corresponding respectively to a selected temperature substantially equal to the minimum temperature of said range and a temperature substantially above said minimum temperature, said heat source being disposed a greater distance from said body than from said thermostat, means supporting said body from said frame, a container enclosing said frame, electrodes, piezoelectric body, heat source and thermostat, a plurality of terminal prongs secured externally to said container, and means for electrically connecting said prongs with said electrodes, thermostat and heat source.

9. Piezoelectric apparatus including an enclosing housing, a conductive frame slidably removable from said housing, a piezoelectric crystal having an average temperature coefficient of frequency not substantially in excess of two cycles per million per degree centigrade throughout a substantially 50 degrees centigrade temperature range, a heating winding for heating said crystal, a thermostat including a bimetallic cupped disc having a contact secured thereto, said crystal and heating winding being mounted on said frame, a plurality of terminal prongs secured to said frame and connected with said crystal and said heating winding, and means including said thermostat for connecting said contact directly in circuit relation with said heating winding at a minimum tolerated temperature within said temperature range and for disconnecting said contact from said circuit relation at a temperature higher than said minimum temperature.

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