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TEMPERATURE CONTROL OF ELECTROVIBRATORY SYSTEMS

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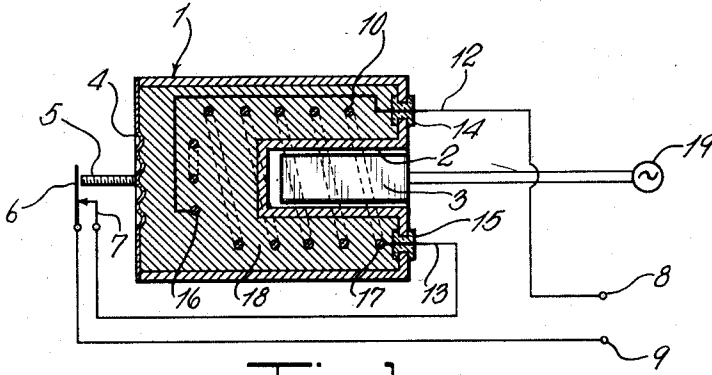


Fig. 1.

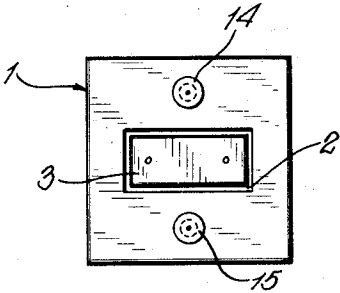


Fig. 2.

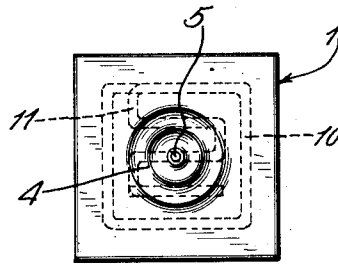


Fig. 3.

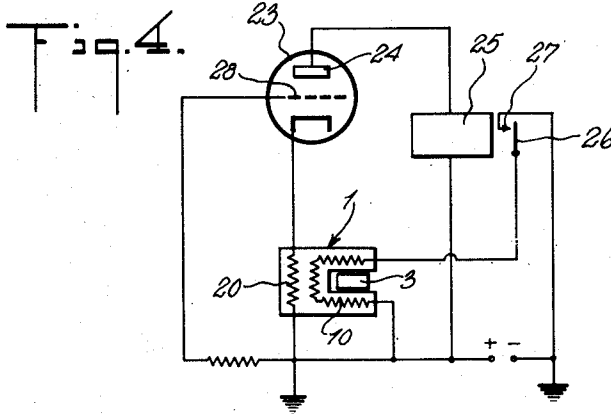
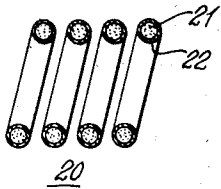


Fig. 5.



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TEMPERATURE CONTROL OF ELECTRO-VIBRATORY SYSTEMS

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12 Claims. (Cl. 219—19)

1

This invention relates to temperature control arrangements and more especially to temperature control of electro-vibratory systems.

In certain fields, it is highly important to maintain the temperature surrounding an electric device such as piezo crystal, tuning fork, etc., within very close limits, in order to take full advantage of the inherent frequency stability of such a device. In present day high frequency signaling or control systems, the utmost in frequency stability is desirable, particularly where crystal controlled oscillators are employed. While the conventional quartz crystal has excellent inherent frequency stability, this stability is dependent upon the ambient temperature around the crystal unit. In those applications wherein extreme constancy of frequency output is required, the usual thermostat control methods of maintaining the crystal at a uniform temperature are not entirely feasible.

Accordingly, it is one of the principal objects of this invention to provide an improved temperature stabilizing arrangement for use with piezo crystals and similar electro-vibratory elements.

Another principal object is to provide a novel form of heat stabilizing enclosure for piezo crystals and the like, and incorporating a heat conserving and releasing material which is capable of assuming a solid or molten condition. In accordance with this object, the transition from the solid to the molten or semi-molten state is utilized in controlling the desired temperature stability of the crystal.

Another object is to provide a heat stabilizing enclosure for electro-vibratory elements such as piezo crystals and the like, which enclosure is capable of surrounding the vibratory element with a meltable material of high latent heat characteristics.

A feature of the invention relates to a temperature stabilizing oven for piezo crystals and the like and incorporating a filling of a special low melting point alloy which surrounds the crystal.

Another feature relates to a temperature stabilizing receptacle for piezo crystals and the like and having one chamber to receive the crystal and another chamber surrounding the first chamber, the latter chamber having a filling of a specially chosen temperature stabilizing alloy whose expansion also serves to control the current supply to an electric heater for the oven.

A further feature relates to an improved crystal oven having a closed chamber containing a special temperature-stabilizing low melting point alloy, one wall of the chamber being closed by a

2

flexible diaphragm or the like whereby the expansion and contraction of said alloy controls a pair of contacts in the heating current supply circuit for the oven.

Another feature relates to an improved heating control circuit arrangement employing a special low melting point alloy which undergoes a marked change in resistance when passing from the solid to the molten or semi-molten state; in conjunction with a heating current control device such as a grid-controlled electron tube which is triggered "on" and "off" in accordance with the state of said alloy.

A still further feature relates to the novel organization, arrangement and relative location and interconnection of parts which cooperate to produce an improved temperature stabilizing unit.

Fig. 1 is a sectional view of a temperature stabilizing oven and control circuit therefor according to the invention.

Fig. 2 is a right end view of Fig. 1.

Fig. 3 is a left end view of the oven of Fig. 1.

Fig. 4 is a temperature stabilizing circuit arrangement embodying the resistance element of Fig. 5.

Fig. 5 is a view of a novel resistance element according to one phase of the invention.

Referring to Figs. 1 to 3, there is shown a chamber or oven 1, which may be of any desired cross-sectional shape and is formed from rigid sheet metal or the like. The right-hand end of oven 1 is provided with a reentrant cavity 2 to receive the piezo electric crystal unit 3 of any well-known construction. Preferably, cavity 2 is of such dimensions as to enable the unit 3 to be easily placed therein, while providing a minimum of practical clearance therearound. If desired, a hinged heat insulating cover (not shown) may be mounted at the open end of cavity 2 so as to completely enclose the crystal unit, it being understood that this cover is provided with suitable openings to permit the conductors which are connected to the crystal electrodes to pass there-through.

The left-hand end of the oven is sealed by means of a plate 4, which has substantial flexibility at least at its central region. For example, plate 4 may be made from relatively thin sheet metal having a circularly corrugated central region, the flat marginal region of this plate being welded or otherwise fastened to the end of the oven. It will be understood of course that any other well-known form of flexible metal diaphragm may be used for the plate 4. Rigidly fastened to the center of plate 4 is an insulating

3

rod 5, whose free end is adapted to engage the movable contact spring 6, which cooperates with an associated fixed contact spring 7. In the normal condition of plate 4, contact springs 6 and 7 are in engagement, whereby there is completed a heating current supply circuit from the electric power terminals 8, 9, through the resistance heating coil 10 which is suitably supported within the cavity of the oven. Preferably, the heater coil 10 not only surrounds the crystal receiving cavity 2, but also has its end portion 11 zig-zagged so as to supply the proper amount of heat to the region between the end of cavity 2 and the plate 4. Suitable insulated lead-in wires 12 and 13 pass through sealing-in bushings 14, 15, and are connected to the ends 16, 17, of the heater coil 10. In order to prevent short-circuiting of the turns of heater coil 10, they are provided with suitable insulation (not shown) which is capable of withstanding the maximum operating temperatures at which the oven is operated. Likewise, the lead-in wires 12, 13, are suitably insulated throughout their respective lengths.

In accordance with one phase of the invention, the entire oven cavity is filled with a specially chosen low melting point alloy 18 having a high latent heat characteristic, such for example as Woods metal. Other examples of alloys that may be used are Rose metal and Cerro Matrix. We have found that when the device 3 is a quartz crystal for use in controlling a high frequency electron tube oscillator, the alloy 18 should preferably have a melting point below 150° C.

If desired, the entire oven unit can be further enclosed in a larger box with the space between the oven and the box walls provided with any well-known filling of heat insulating packing or material.

In order to explain the functioning of the oven, it should be understood that when a material changes from a solid to a molten state, a comparatively large amount of heat is absorbed, while a considerable amount of heat is given off when the material changes from the molten to the solid state. As a result of these characteristics, such a material when used in an oven intended to be maintained at a fixed temperature near the melting point of the alloy, this alloy material has a kind of "fly-wheel" action in maintaining the temperature constant. We have found that the best results are obtained when the heating coil and current supply are designed so as normally to maintain the alloy material in a semi-molten state.

In order to control the current through coil 10, the heating current supply circuit is controlled also by the volume expansion of the alloy material 18. If this alloy rises above the selected normal temperature of the oven, the alloy undergoes thermal expansion and forces the plate 4 to the left (Fig. 1), thus opening contact springs 6 and 7. This arrangement is to be distinguished from the conventional thermostatic control of a heating supply, because with conventional thermostat control switches the limits of change in temperature required by certain high frequency equipment are too small to enable the conventional thermostat to function properly. We have found that the change in volume which occurs when the alloy filling 18 passes from a molten to a solid state or vice versa, can be readily employed to actuate contacts 6 and 7, so as to add heat at the proper instant. Thus, when the alloy filling solidifies, as a result of a drop in the normal temperature of the oven, it contracts and allows arm

4

5 to move to the right (Fig. 1) closing contacts 6 and 7, thus supplying heating current to the coil 10 and causing the filling 18 to remelt. Under these conditions, the temperature of crystal unit 3 is maintained at an optimum steady value thus maintaining its associated high frequency oscillator 19 at its correct operating frequency.

While the embodiment of Figs. 1 to 3 employs the expansion characteristics of the alloy filling to control the heating control supply circuit, there is shown in Figs. 4 and 5 an arrangement wherein the change in resistance of the alloy filling is used for this purpose. A marked change in resistivity takes place when a metal passes from the solid to the molten state. In accordance with one phase of the invention, this marked change in resistance can be utilized to control the triggering "on" and "off" of the heating control supply circuit. Thus, as shown in Fig. 5, the resistance 20 comprises an alloy filling 21 in a suitable refractory sheath or tube 22. As shown in Fig. 4, the resistance 20 may be connected in the cathode biasing circuit of a grid-controlled electron tube 23, whose plate or anode 24 is supplied with positive D. C. potential through the operating winding of a suitable electromagnetic switch 25. The contacts 26 and 27 of this switch are connected in circuit with the heating coil 10 of an oven similar to that of Fig. 1, which is adapted to receive the crystal unit 3. If desired, the resistance 20 may also be located within the oven so as to be maintained at a temperature close to the melting temperature of the alloy filling 21. When the oven 1 is at the predetermined uniform temperature, the resistance of element 20 is such as to bias the control grid 28 to plate current cutoff so that contacts 26 and 27 remain open. If the temperature of the oven 1 drops below the predetermined temperature sufficient to cause the filling 21 to solidify, the resistance 20 then assumes a value whereby the cutoff bias on grid 28 is reduced, thus allowing plate current to flow through switch 25 and reclosing the circuit through the heating coil 10. It will be understood of course, that the arrangement shown in Fig. 4 is merely illustrative and that any other well-known method of triggering a grid-controlled tube by means of the pronounced variation in resistance of resistance 20, can be employed.

Various changes and modifications may be made in the disclosed embodiment without departing from the spirit and scope of the invention.

What is claimed is:

1. The method of stabilizing the temperature of an electro-vibratory element such as a piezo crystal and the like, which comprises locating the crystal in heat transfer relation with a quantity of material which is chosen so as to have a melting point which bears a predetermined relation to the maximum working temperature of said element, heating the said material, and employing the latent heat of said material and its mechanical expansion to control the amount of heat applied thereto.

2. A temperature stabilizing arrangement for an electro-vibratory unit such as a piezo crystal and the like, comprising an oven receptacle for said unit, said receptacle having a filling of an alloy with a melting point not substantially higher than 150° C., means to heat said filling close to its melting point, and means responsive to the volume expansion of said filling for auto-

5

matically controlling the amount of heat supplied thereto.

3. A temperature stabilizing arrangement according to claim 2 in which the last-mentioned means normally maintains said filling in a semi-molten condition.

4. A temperature stabilizing arrangement according to claim 2 in which said receptacle has a flexible wall portion which moves in response to the volume expansion of said filling, and a heating current supply circuit for said heating means, said circuit being controlled by the said movement of said flexible wall portion.

5. A piezo crystal temperature stabilizing oven, comprising in combination a closed chamber having a filling of low-melting-point alloy, said oven having a cavity separate from said chamber to receive a piezo crystal for operation at a desired steady temperature, and means to maintain said crystal at said temperature and including a heater to heat said filling to maintain the latter normally in a substantially semi-molten state.

6. A piezo crystal temperature stabilizing oven comprising a chamber having rigid walls and with one wall provided with an expansible surface portion, a filling of low melting point alloy in said chamber, said chamber having a portion arranged to receive a crystal unit, and means to heat said filling normally to approximately its melting temperature.

7. A piezo crystal temperature stabilizing oven comprising a container having a filling of a low melting point alloy, one wall of said container being reentrant to provide a crystal receiving cavity, another wall having at least a portion thereof in the form of an expansible diaphragm, a heater coil within said filling, and heating current supply contacts controlled by the movement of said diaphragm in response to volume expansion and contraction of said filling.

8. A piezo crystal oven according to claim 7 in which said filling is of Woods metal.

9. Apparatus for heating and temperature stabilizing a temperature sensitive device, comprising in combination a resistance in the form of an enclosed low-melting-point alloy said alloy being in heat transfer relation with said device, an electric heating circuit for heating said alloy to maintain it normally close to its melting temperature, a relay for controlling said heating circuit, and another device connected in circuit with said alloy resistance and said relay to control the operation of said relay in accordance with the variation of the alloy resistance as it passes from a molten to a solid state.

6

10. Apparatus according to claim 9 in which said relay is in the form of a grid-controlled electron tube, and said resistance is connected to said tube so as to control the plate current cutoff bias thereof.

11. Apparatus for heating and temperature stabilizing a temperature sensitive device, comprising in combination an enclosed filling of a low-melting-point alloy arranged in heat transfer relation with said device, a heating element to maintain said alloy close to its melting point, an electric circuit for said heating element said circuit including a pair of switch contacts and a heating current source, electrically-controlled means for opening and closing said switch contacts, and a triggering relay connected in electrical circuit with said filling and with said electrically-controlled means to cause said contacts to be operated in accordance with the electrical resistance changes in said filling.

12. The method of stabilizing the temperature of an electro-vibratory element such as a piezo crystal and the like for operation at a predetermined maximum working temperature, which comprises locating the said element in heat transfer relation with a quantity of material having a low melting point which melting point is correlated with said maximum working temperature, heating said material to maintain it normally in a substantially semi-molten state, and utilizing the variations of resistance of said material to control said heating.

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