United States Patent [19]

Marcoux

[11] **3,878,357**

[45] **Apr. 15, 1975**

[54] **COMPONENT OVEN**

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[73] Assignee: **Texas Instruments Incorporated,** Dallas, Tex.

[22] Filed: **Nov. 29, 1968**

[21] Appl. No.: **779,839**

Related U.S. Application Data

[60] Division of Ser. No. 508,643, Oct. 24, 1965, which is a continuation-in-part of Ser. No. 435,166, Feb. 25, 1965, abandoned.

[52] **U.S. Cl.** **219/209;** 219/505

[51] **Int. Cl.** **H05b 1/00**

[58] **Field of Search** 219/209, 210, 510, 505

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[57] **ABSTRACT**

Method and means for providing a relatively constant ambient for temperature sensitive devices is disclosed. The method includes the steps of forming an enclosure, in which the controlled ambient will lbe effected, at least partially, of a positive temperature coefficient of resistance (hereinafter referred to as PTC) material and applying a voltage to the PTC material. The material acts as a heater and also as its own temperature regulator. The enclosure is formed, at least partially, by various structures or means including a single hollow cylindrical element, a stack of annular discs and two or more pieces of PTC material. Another embodiment discloses a design particularly useful with transistor-type devices while yet another is particularly useful with diode-type devices.

Several materials are disclosed which exhibit a PTC characteristic.

4 Claims, 12 Drawing Figures

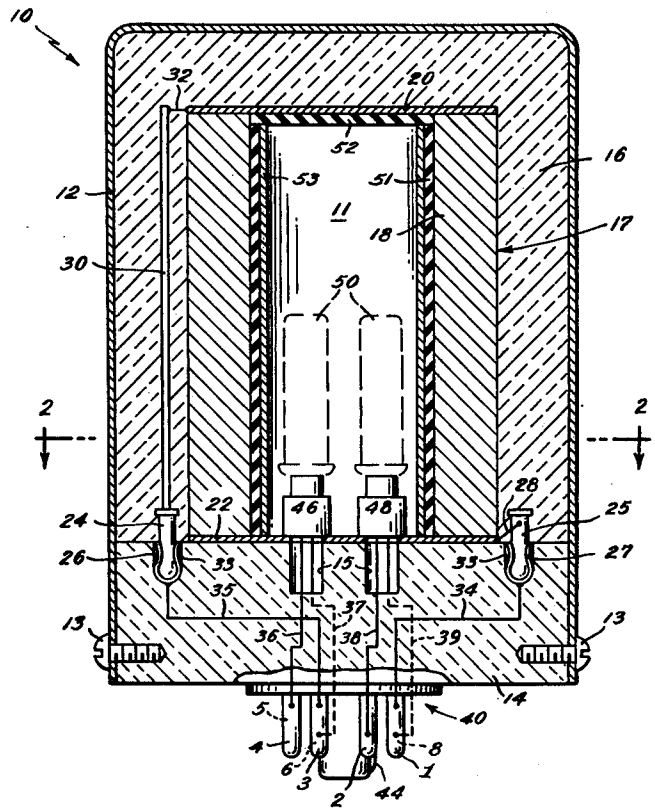


Fig. 1.

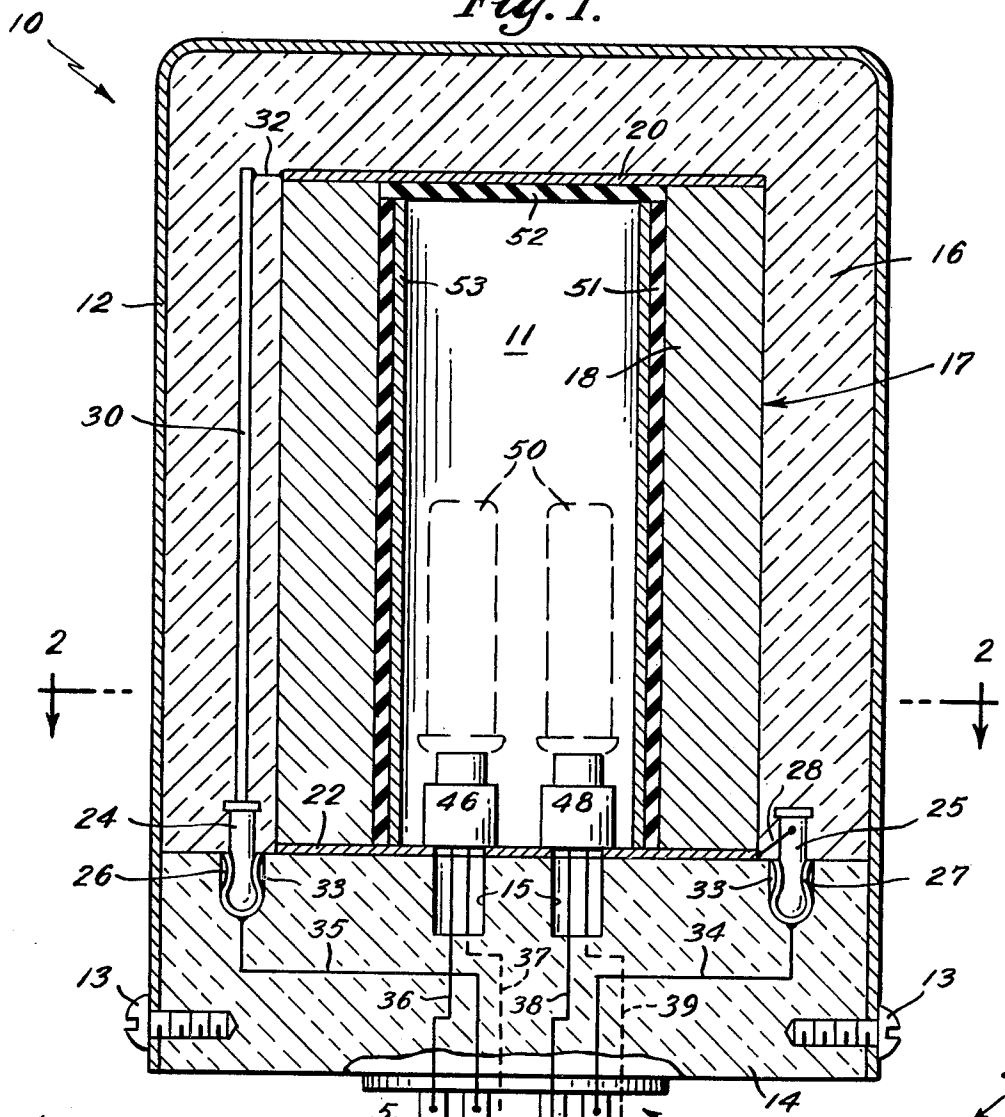
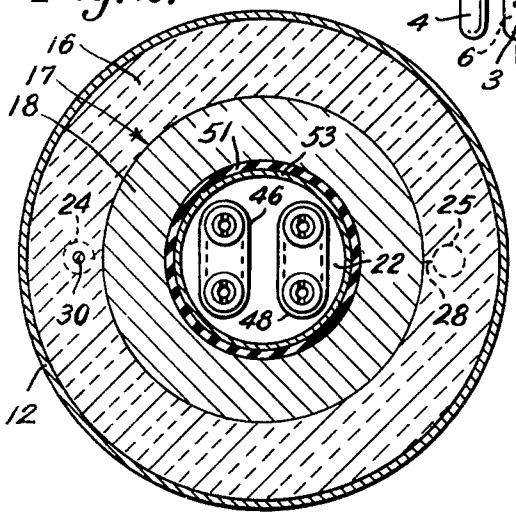


Fig. 2.



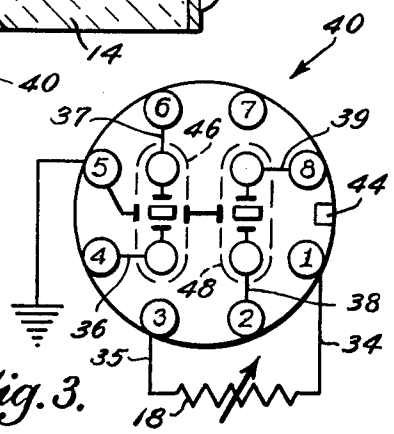
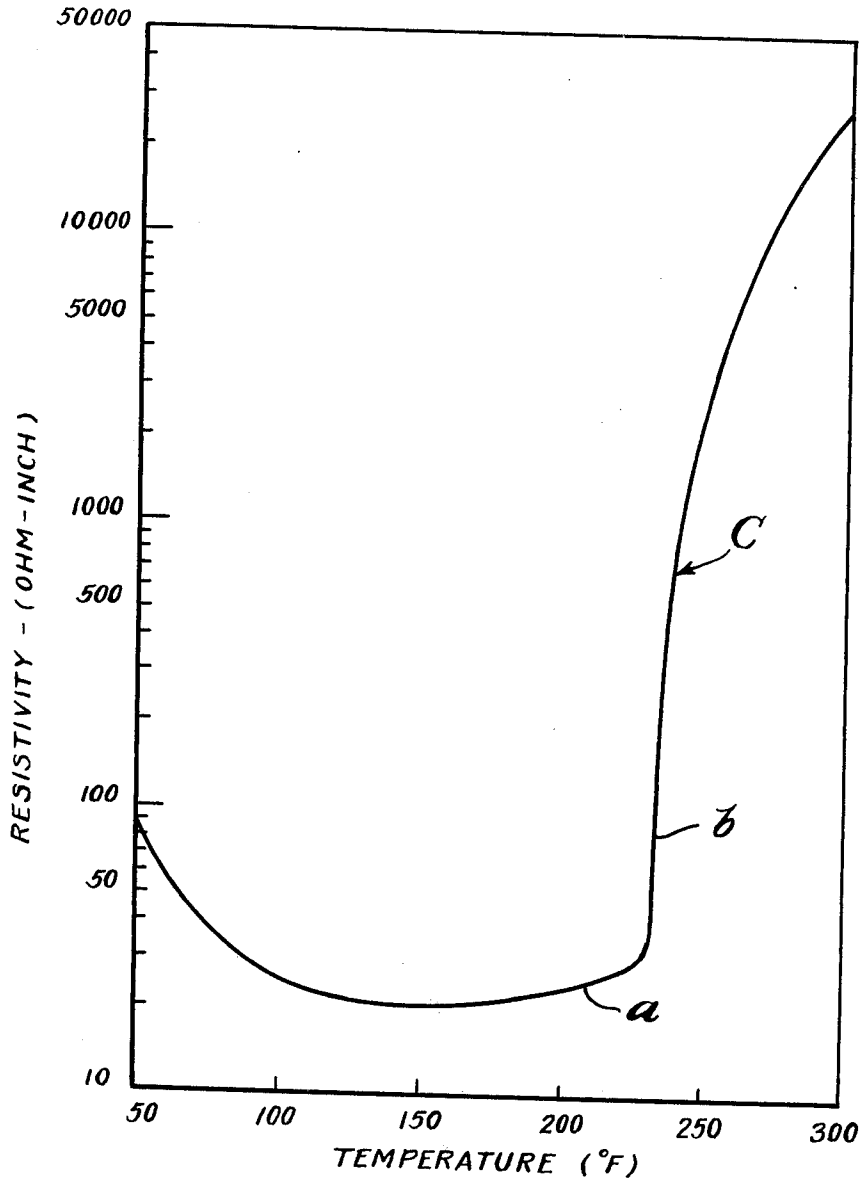


Fig. 3.

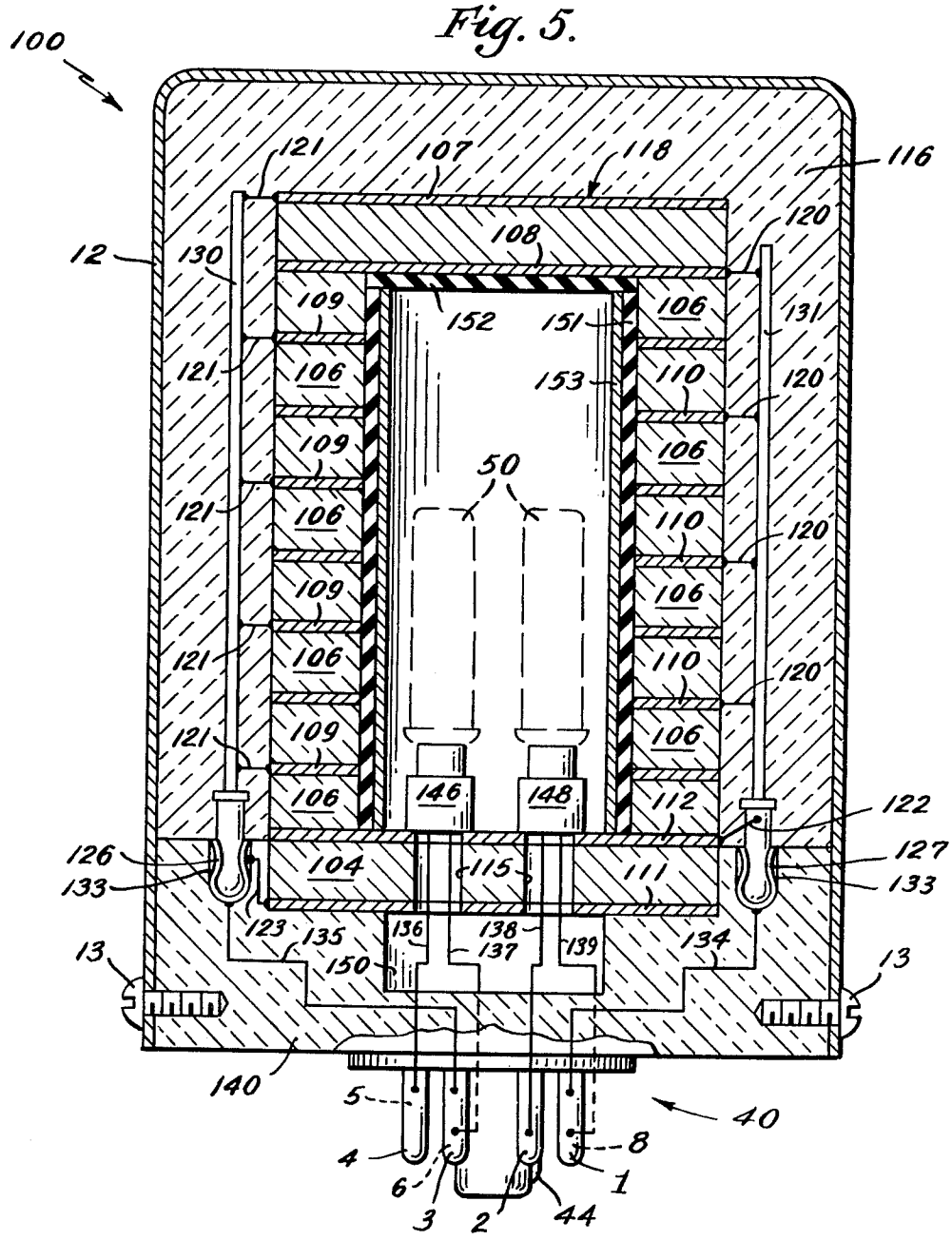
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Fig. 4.



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Fig. 5.



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Fig. 7.

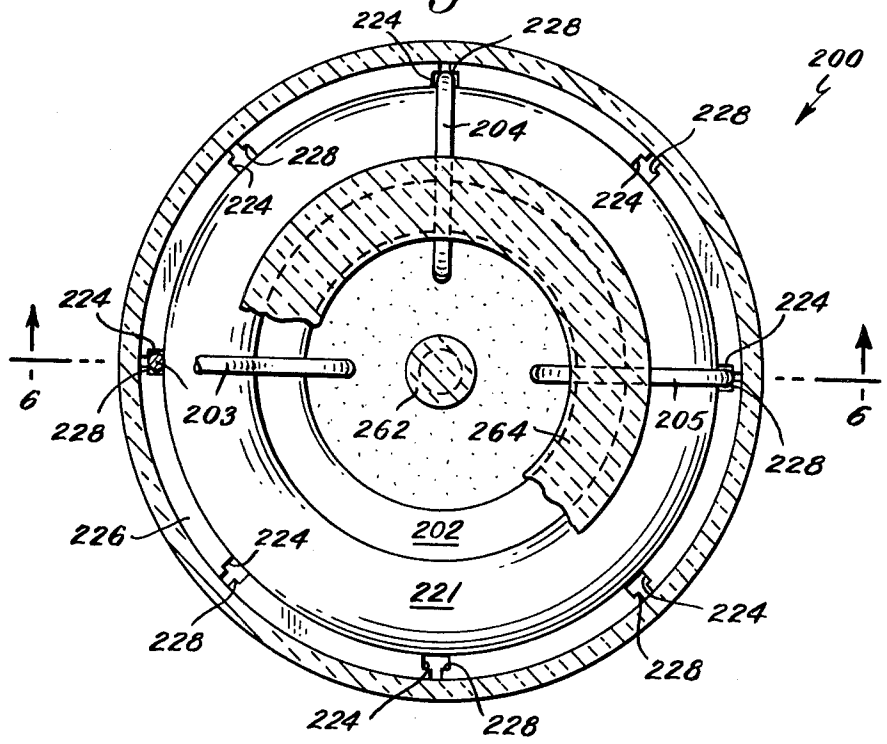
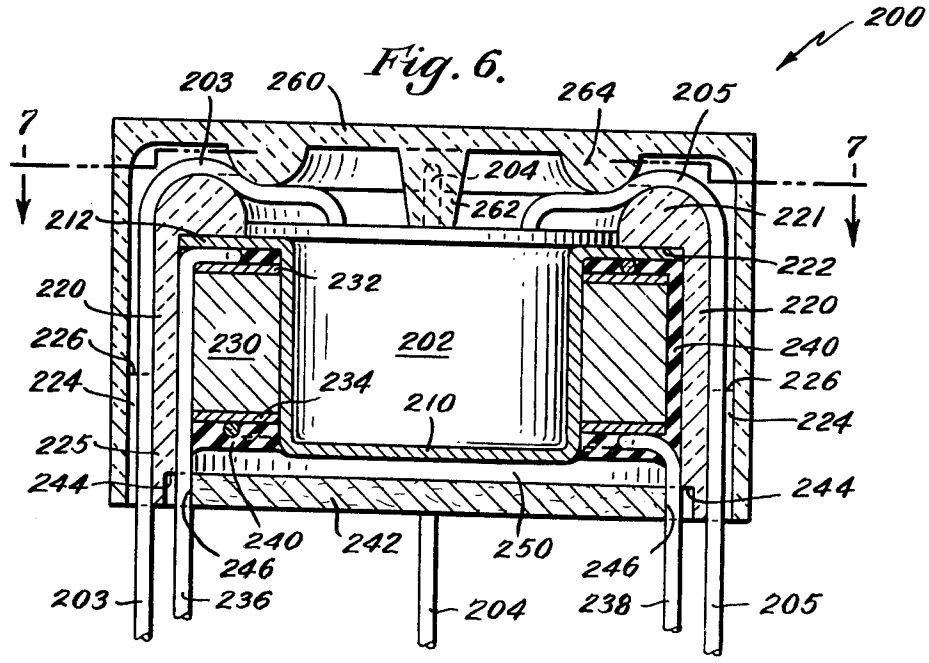


Fig. 6.



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Fig. 8.

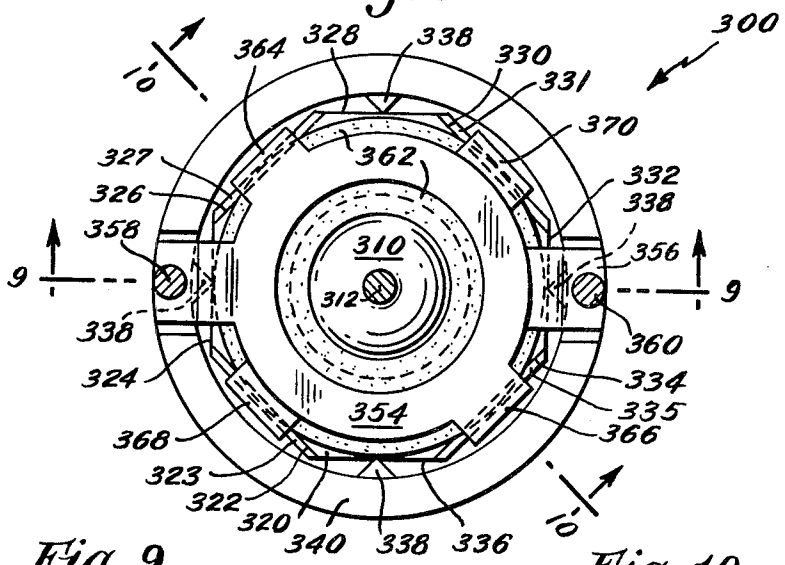


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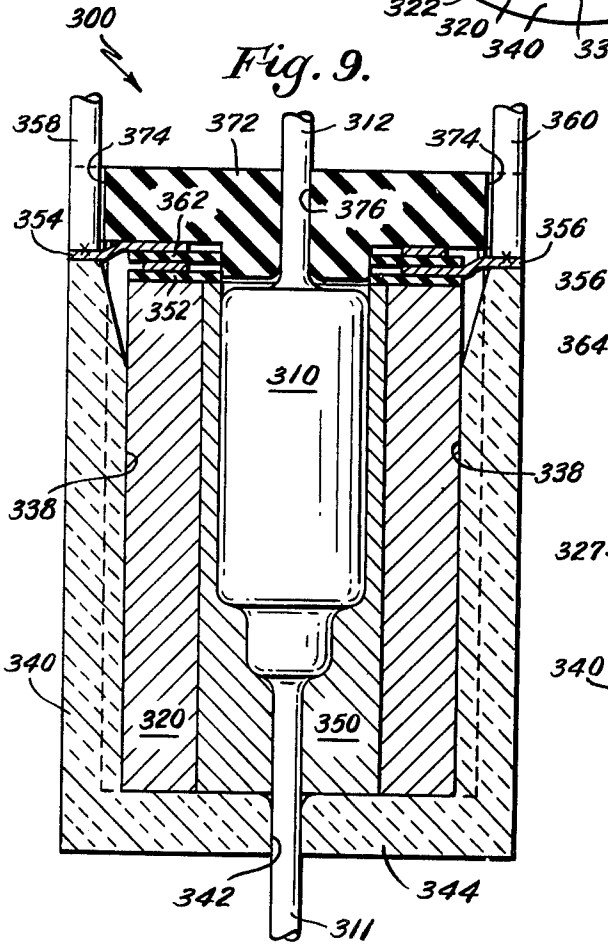
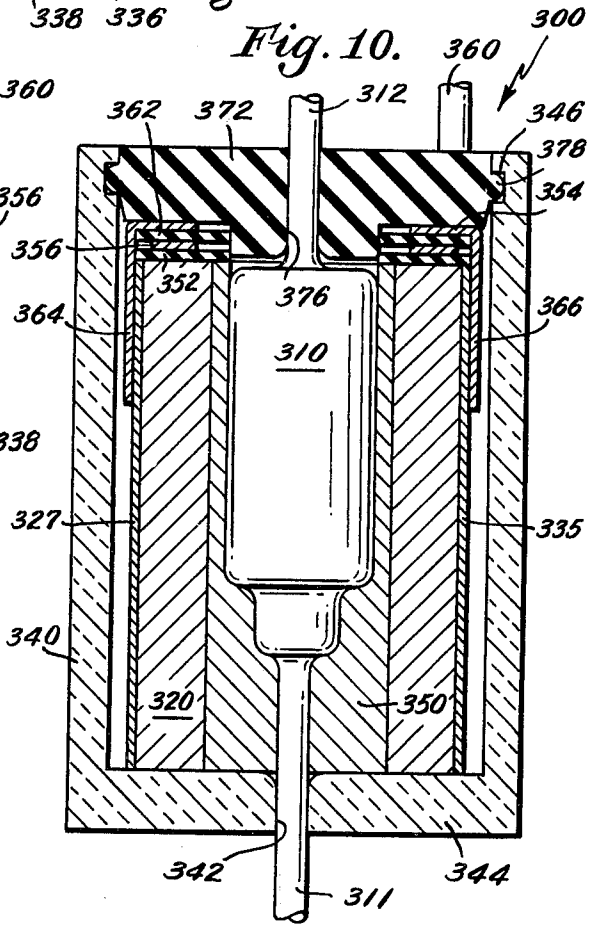


Fig. 10.



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Fig. 11.

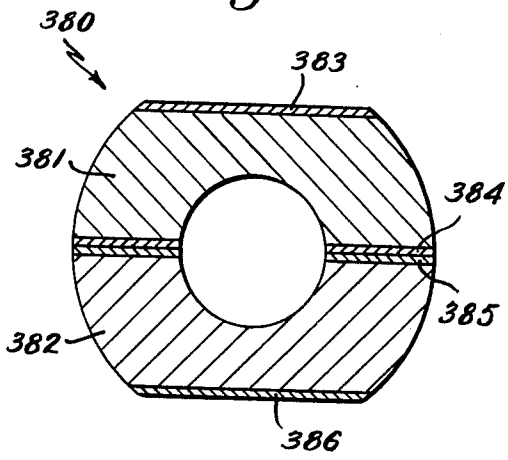
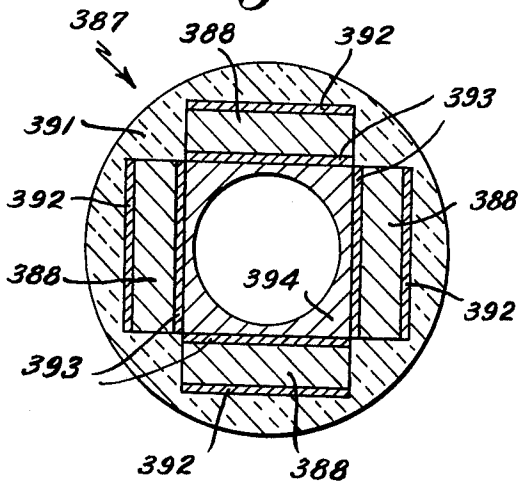


Fig. 12.



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COMPONENT OVEN

This is a division of application Ser. No. 508,643, filed Oct. 24, 1965 which in turn is a continuation-in-part of Ser. No. 435,166, filed Feb. 25, 1965, now abandoned.

This invention relates to heating elements, and particularly to ovens used to provide a constant temperature for temperature sensitive devices located therein. There are many electronic components which must be contained in a constant ambient for effective operation in certain applications. Examples of such components are crystals, diodes, transistors and so on.

It is known to provide ovens as described above which utilize a heater and a thermostat. The thermostat keeps the inside oven temperature within a certain range by turning on and off the heater current by use of movable contacts. This type of oven has certain inherent disadvantages, viz., the temperature varies as a result of the characteristics of the thermostat—from a maximum to a minimum back to a maximum and so on. Also, since there is mechanical movement, the longevity of the device is limited.

Another approach has been what is commonly known as proportional control whereby relatively complex electrical circuits serve to limit the power input to the heater to equal the heat loss from the oven. This is done, for example, by providing a bridge containing a temperature-sensing device which is used to balance a circuit containing the heater. This type of control eliminates the on/off moving contacts and therefore provides more precise temperature control with no overshoot or thermal cycling, more constant power requirement and no noise due to mechanical operation although many devices of this description do emit electrical noise. Also, the device is relatively complex and expensive.

It is an object of the invention to provide an oven which is simple, highly reliable, inexpensive, long lasting, of minimal size, mechanically and electrically silent operating, relatively insensitive to voltage variations and displays a closely controlled, relatively constant oven temperature.

It is an object of the invention to provide a heating element which has a self-regulated temperature.

It is a further object to provide an oven which is characterized by being of a self-regulating and self-limiting temperature nature.

It is another object of the invention to provide an oven which will maintain a relatively constant inside temperature for temperature-sensitive devices contained therein regardless of change in heat demand which is simple, reliable, long lasting, silent operating and has no moving parts.

It is another object of the invention to provide a component oven which employs solid state control with no moving parts.

The invention accordingly comprises the elements and combinations of elements, steps and sequence of steps, features of construction and manipulation and arrangements of parts, all of which will be exemplified in the structures and methods hereinafter described, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which several of the various possible embodiments of the invention are illustrated:

FIG. 1 is a vertical partial cross section through one embodiment of the invention;

FIG. 2 is a cross section along 2—2 of FIG. 1;

FIG. 3 is a schematic wiring diagram of the embodiments of FIGS. 1 and 5;

FIG. 4 is a chart plotting logarithms of resistivity against temperature of a steep sloped PTC material usable in accordance with the invention;

FIG. 5 is a vertical partial cross section through a second embodiment of the invention;

FIG. 6 is a vertical cross section through a third embodiment of the invention taken on line 6—6 of FIG. 7;

FIG. 7 is a cross section along line 7—7 of FIG. 6 with parts broken away for clarity;

FIG. 8 is a plan view of a fourth embodiment of the invention with the cover removed;

FIG. 9 is a vertical cross section taken along line 9—9 of FIG. 8;

FIG. 10 is a vertical cross section taken along line 10—10 of FIG. 8; and

FIGS. 11 and 12 are cross sections of two alternate heating elements usable in the FIG. 8–10 embodiment.

Similar reference characters indicate corresponding parts throughout the several views of the drawings.

Dimensions of certain of the parts as shown in the drawings may have been modified and/or exaggerated for the purpose of clarity of illustration.

Referring now to FIGS. 1–3, the first embodiment is shown as a single PTC element oven or chamber 10 which comprises a disc-shaped base 14 which may be formed of a conventional moldable phenolic resin or other suitable electrical insulation material, which mounts a cylindrically-shaped element 18 made of a steep sloped PTC material such as, for example, $Ba_{0.997}La_{0.003}TiO_3$. The cylinder forms a cavity 11 in which the components are mounted as explained infra. Layers 20 and 22 of silver or other conductive material are attached to the ends of cylinder 18 by any known process such as firing or ultrasonic soldering. This provides a good electrical connection with the PTC element 18. A metal liner 53 may be placed in the oven cavity 11 which serves to even-out any temperature gradients. Electrical insulation 51 and 52 are used to prevent any short circuiting of the heater current. Conductors 30 and 32 connect layer 20 to a quick-disconnect pin 24 and conductor 28 connects layer 22 to quick-disconnect pin 25. Pins 24 and 25 are mounted in a conventional potting compound 16 which is of an electrical as well as a heat insulation material conventional in the art. The insulation 16 will keep heat losses of the oven to a minimum. The pins 24 and 25 protrude from potting material 16 as shown in FIG. 1 and are received in mating clips 26 and 27 respectively. The clips 26 and 27 are contained in bores 33 formed in base 14. A conventional mounting assembly 40 is attached to the bottom of the base 14 which includes shank 42 formed with key 44 which serves to properly orientate the oven for insertion in a receiving means (not shown). The mounting assembly 40 mounts pins 1–8. FIG. 3 shows a schematic wiring diagram indicating the internal electrical connections of pins 1–8. Conductor 34 joins pin 1 to clip 27 and hence the bottom of PTC element 18 via pin 25, conductor 28 and layer 22. Conductor 35 joins pin 3 to clip 26 and hence the top of PTC element 18 via pin 24, conductors 30 and 32 and layer 20. The components 50 (crystals, diodes, etc.) which are to be

mounted in the oven cavity **11** are mounted in supports or sockets **46** and **48** (the number of supports or sockets provided is optional, two are shown for convenience). Pins **4** and **6** of the mounting assembly **40** are connected to socket **46** by conductors **36** and **37** respectively. Pins **2** and **8** are connected to socket **48** by conductors **38** and **39** respectively. Pin **5** is grounded and pin **7** is not used. Metal cap **12** encloses the oven **10** and is attached to base **14** by any conventional means, such as screws **13.**

Heating and regulating current (ac or dc) is applied through the PTC element **18** from pin **1** to conductors **34,** clip **27,** pin **25,** conductor **28,** layer **22,** through PTC element **18,** layer **20,** conductors **32** and **30,** pin **24,** clip **26,** conductor **35** to pin **3.** Element **18** acts as a heater and also as its own temperature regulator. The current passing through the PTC material causes heat to be generated thereby heating the oven cavity **11.** Once the oven is warmed up, it is noted that very little temperature variation occurs within the cavity **11** regardless of ambient temperature fluctuations outside the oven, i.e., changes in heat demand, or appreciable fluctuations in the applied voltage. A relatively constant ambient is provided in the oven for the components contained therein and this is achieved without moving parts and without any elaborate, comparatively complex circuitry. The relatively low heat generation of components within the oven has been found to have a negligible effect in the inside temperature of the oven.

For the successful operation of the oven within the purview of the invention, the self-regulating heating element **18** must be constructed of material having as a characteristic a large positive temperature coefficient of resistance (PTC); that is, material in which the percent change in resistance per degree change in temperature in the so-called break-point range (about 230°F. on the curve of FIG. **4**) is very large as an example 150 percent per degree centigrade. This break-point range occurs near the Curie or transition point of the material and is sometimes referred to as the PTC anomaly.

FIG. **4** shows the resistivity-temperature curve C of such a material. While I do not wish to be bound by any particular theory as to why the oven operates as it does, a possible explanation is as follows: At temperatures above the anomaly near point b on curve C very little heating occurs since resistivity increases much more rapidly than temperature at temperatures above the anomaly. Therefore, heat generation, which is inversely proportional to resistivity, drops off drastically above the anomaly. Heat transferred through regions of relatively high temperature such as portions of element **18** radially removed from the surface **17,** is accordingly low with the result that the temperature gradient is also low. When the temperature in a region becomes depressed below the anomaly, section *a* of curve *c*, say by a reduction of temperature along surface **17,** the resulting drop in resistivity causes a greatly increased current flow and attendent rate of heat generation in that region along the surface and thus a sharply increased gradient in those adjoining regions that must conduct the heat away. As the surface temperature is depressed further, the anomaly temperature moves radially inward toward the longitudinal cylindrical axis creating regions of high heat generation as it passes through. Those regions at temperatures above the anomaly continue to generate heat at approximately the same low rate and thus their temperatures are hardly affected by such change in surface temperature.

In the embodiment of FIG. **1,** the greater part of the heat flow is perpendicular to the current flow. The heat flows radially in element **18** while the current flows axially. If the outside temperature decreases, i.e., heat demand is increased, thereby reducing temperature of the outer surface **17,** the resistivity of that same area will also be reduced. This will cause an increase in current at the surface **17,** however, currents throughout the main body of the element **18** will remain fairly constant. Heat generation at the surface will increase, this will tend to offset the temperature reduction induced by increased heat demand. Hence, the element will generate heat at the surface **17** where it is most useful.

The oven inherently operates in the range which includes the anomaly point, this is approximately 230°F. on the curve shown in FIG. **4.** The material, which temperature-resistivity curve is shown, is lanthanum doped barium titanate, the preparation of which is described infra. Ordinarily, the barium titanate family of ceramics has an electrical resistivity of a magnitude greater than 10^{12} ohm cm, however proper doping can reduce the resistivity to less than 10^{2} ohm cm. Lanthanum doping of barium titanate produces an exceptionally steep slope of the resistivity-temperature curve at temperatures above the anomaly point combined with a relatively low base resistivity at temperatures below the anomaly point. Other doping elements may be used to modify the anomaly temperature, the base resistivity and the rate of change of resistivity with temperature above the anomaly temperature.

As an example, one self-regulating heater element **18** was made using $Ba_{0.997}La_{0.003}TiO_3$ as follows.

The raw materials used were reagent grades of barium carbonate ($BaCO_3$), lanthanum carbonate $La_2(CO_3)_3 \cdot 5H_2O$ and titanium dioxide (TiO_2). These were weighed out to an accuracy of about ± 0.25 percent to form stoichiometric mixtures, plus 0.1 mole percent excess TiO_2 in order to assure the formation of a liquid phase during final firing. These materials were mixed and a sufficient amount of distilled water was added to form a 20 percent solid mixture by weight. This mixture was ball milled and dried. The dried product was powdered and calcined in order to convert the material into the desired doped compound ($Ba_{0.997}La_{0.003}TiO_3$) by firing at approximately 1100°C. in air and cooled. The material, in the form of a porous cake, similar in texture and appearance to soft blackboard chalk, was broken up and wet milled as above, dried comminuted and sieved from ± 40 to —270 (U.S. standard Sieves). The resulting powder was again immediately dried to drive off any moisture which might have been absorbed during comminution and sieving and finally pressed into the desired cylindrical shape using conventional closed die ceramic-pressing techniques on a hydraulic press. The resulting compacted powder body was fired to the ceramic state at about 1500°C. Further details regarding the preparation of similar PTC material may be found in copending application, filed Apr. 13, 1964, Ser. No. 359,370, assigned to the assignee of the instant invention.

Any material which displays a relatively steep positive sloped resistivity-temperature curve can be used as the heat generating-self regulating element in accordance with the present invention such as the carbon black filled cross-linked polyethylene disclosed in co-

pending applications of Francis Buiting and Joseph Waseleski, Jr., Ser. No. 472,108, filed July 15, 1965, and assigned to the assignee of this invention.

FIG. 5 shows another embodiment of the invention. It is important to achieve a homogeneous heater element of constant density so that the resistivity is consistent, i.e., internal cracks or non-conducting inclusions must be avoided. The oven in FIG. 5 lends itselve to the achievement of such uniformity by employing a stacked disc configuration. The only difference between oven **10** of FIG. **1** and oven **100** of FIG. **5** is the form of the PTC heater-regulator element and electrical connection thereof. The description of the remainder of the device will, therefore, not be repeated.

The heater-self regulator assembly **118** is composed of a plurality of annular discs **106,** the number of which is a matter of choice but shown in FIG. **5** as eight, are sandwiched between discs **102** and **104.** These discs are made of PTC material having the same characteristic of a steep-positive slope resistivity-temperature curve at temperatures above the anomaly point as that material used in cylinder **18.** A conductive layer is attached by conventional means to the faces of each of these discs, the layers shown in FIG. **5** numbered from **107–112.** The even-numbered layers **108–110** are electrically connected to conductor **131** by conductors **120.** Conductor **131** is connected to pin **125.** Layer **112** is electrically connected to pin **125** by conductor **122.** Odd-numbered layers **107–109** are connected to conductor **130** by conductor **121.** Conductor **130** is electrically connected to quick-disconnect pin **124.** Bottom layer **111** is connected to clip **126** by conductor **123.** It may be seen that this provides a stack of discs, electrically connected in parallel and that the greater part of the heat flow is radial and therefore perpendicular to the current flow. This will provide even better temperature control than element **18** because it will minimize the effects of any localized areas of non-uniform density and hence will make resistivity more consistent throughout the stacked assembly **118.**

Bottom disc **104** is provided with bores **115** to provide space for conductors **136, 137** and **138, 139** which lead to sockets **146, 148** respectively. Cavity **150** may be provided in base **140,** if desired, to give still more room for the conductors. Conductors **134** and **135** connect clips **127** and **126** to pins **1** and **3** to complete the electrical connections in the same manner as described supra in reference to conductors **34, 35** in FIG. **1.**

Instead of employing conductive layer metal tabs may be inserted between the PTC discs to provide the electrical connections therefore. It should be noted that separate voltage sources could be supplied to the several discs of equal or varying magnitude to provide a desired axial temperature gradient if desired.

In FIGS. **6** and **7** is shown an oven **200** which is particularly useful with transistors. Transistor **202** is shown with three leads **203, 204** and **205,** although it is obvious that any number of leads would come within the purview of this invention. Transistor **202** is telescopically received in mounting can **210.** Can **210** is formed with an annular flange **212** of a good thermal conductor such as aluminum. An electrical insulation layer is provided on the outer surface of can **210.** Although this may be done in various ways, such as by coating with a thermoplastic resin, heat conduction should be kept at an optimum level. Employing anodized aluminum meets the above requirements. Flange **212** of can **210** abutts shoulder **222** formed in tubular casing member **220** of a thermally and electrically insulating material, such as a thermoplastic (e.g. Nylon). End **225** of casing **220** has an annular flange **226** in which are formed slots **224.** Transistor leads **203, 204** and **205** are located in slots **224** and are retained therein by shoulders **228.** These slots are shown to be rectangular in shape but could be any other convenient shape, such as eliptical. The PTC heater regulator element **230** is ring-shaped and fits closely around can **210.** Layers **232** and **234** of silver or other conductive material serve as terminal surfaces on opposite faces of element **230.** Leads **236** and **238** are electrically connected as by soldering, to layers **232, 234** respectively. The leads, as shown, contact the layers throughout approximately 360° thereby insuring uniform electrical conductivity through element **230.** Electrically and thermally insulating potting compound **240** of a conventional type is infilled around element **230.** Shoulder **244** is formed in end portion **225** of casing **220** which seats disc **242,** formed of an electrical insulating material such as a resin impregnated fiberboard. Disc **242** is provided with slots **246** to provide access for PTC heater leads **236** and **238.** Shoulder **244** is positioned to provide a predetermined air gap **250** between disc **242** and can **210** and potting material **240** thereby resulting in a desired thermal insulation. Instead of relying on air gap **250,** some other thermal insulation could be used.

A cover member **260** is positioned closely around casing **220** and can be formed of the same electrically, thermally insulating material as the casing, i.e., Nylon. Cover **260** is provided with projection **262** which serves as a component wedge to maintain transistor **202** firmly in mounting can **210.** Annular projection or wedge **264** in cover **260** contact leads **203, 204** and **205** biasing them against hub **221** of casing **220.** This construction serves to minimize heat loss through leads **203, 204** and **205.** That is, it decreases the effective size of the heat sink of the transistor leads. The transistor **202** is in close thermal relation to heater **230** resulting in more efficient control. It has been found useful to apply a coating of a heater transfer compound to the outer periphery of mounting can **210,** such as a silicon compound. This facilitates heat conductance from the PTC element **230** through mounting can **210** to transistor **202.** One such compound available is GE G641 INSULGREASE. A coating of this heat transfer compound may also be applied to the outer periphery of transistor **202,** further facilitating heat conductance from the PTC heater.

It will be noted that in this embodiment and in the ones described infra the component is in intimate thermal contact with the PTC heater-regulator element.

Oven **300,** which is particularly useful for diodes and the like, is shown in FIGS. **8–10.** A diode **310** is shown positioned in oven **300** and has two leads **311** and **312** which extend therefrom through the walls of the oven. Oven **300** comprises a hollow tubular-shaped PTC heater element **320.** Element **320** as shown is octagonal in cross section, although it is obvious that the number of faces provided is a matter of choice, providing rectangular faces **322, 324, 326, 328, 330, 332, 334** and **336.** Layers **323, 327, 331** and **335** of silver or other conductive material are attached in a conventional manner to faces **322, 326, 330** and **334** respectively. Thus, alternate faces are electrically conductive. Ribs **338** are provided in casing **340** and serve to center PTC

element by contacting the non-electrical conducting faces **324, 328, 332** and **336.** Casing **340** is generally cylindrical in shape and composed of an electrically and thermally insulating material such as a thermoplastic resin. An aperture **342** is provided in bottom wall **344** of the casing to permit passage of lead **311.** Diode seating member **350** is telescopically received in the bore of PTC element **320** and fits closely therein. Member **350** is constructed of a good thermally conducting but electrically insulating material, such as anodized aluminum. Before inserting diode **310** in seating member **350** a coating of heat transfer compound may be applied to the outer periphery of diode **310** and member **350.** As explained supra, this serves to facilitate heat conductance from the PTC heater element **320** through setting member **350** to the diode **310** and avoids hot spots and the like. An electrically insulating washer **352** overlies the outer end of PTC element **320** and also retains member **350** within casing **340.** Terminal members **354** and **356** are welded to leads **358** and **360** as best seen in FIG. **9** and are separated by electrically insulating terminal separator **362.** Terminal member **354** is provided with two downwardly depending fingers **364, 366** which are in good electrical contact as by soldering with layers **327** and **335** respectively, as best seen in FIG. **10.** Terminal member **356** is provided with downwardly depending fingers **368** and **370** which are in good electrical contact as by soldering with layers **323** and **331** respectively.

The terminal members and associated washers are covered by cap **372** which is provided with slots **374** in which leads **358, 360** are located and aperture **376** through which diode lead **312** extends. Cap **372** is also constructed of electrically and thermally insulating material, e.g. Nylon, and is provided with an annular rib **378** which is received in a mating groove **346** in casing **340.**

FIGS. **11** and **12** are cross sections of two other PTC heating elements which can be used in place of element **320.**

Referring first to FIG. **11,** PTC element **380** is composed of two halves **381, 382.** Electrically conductive layers **383** and **384** are attached in a conventional manner to opposite faces of half **381** while layers **385** and **386** are attached to opposite faces of half **382.** Lead **358** is electrically connected to layers **383** and **386** while lead **360** is electrically connected to layers **384,** 385. It will be seen that current will pass from the outer layers **383, 386** through the PTC halves **381, 382** to layers **384, 385** thereby causing the element **380** to generate heat in accordance with the present invention.

FIG. **12** shows another PTC heater assembly **387** useful in the diode oven of FIGS. **8–10.** Assembly **387** is composed of a plurality of PTC slabs **388** enclosed by electrically and thermally insulating member **391.** The PTC slabs **388** have outer electrically conductive layers **392** and inner electrically conductive layers **393** conventionally attached respectively thereto. Diode seating member **394** retains the slabs in place and is constructed of material which is thermally conductive but electrically insulating, similar to member **350,** e.g. anodized aluminum. A silicone heat transfer compound may be applied to the outer surfaces of element **394** to enhance the thermal conductivity from the heating PTC slabs **388.** Lead **358** is electrically attached to outer layers **392** and lead **360** is electrically attached to inner layers **393** to effect a passage of current from the outer layers **392** to the inner layers **393.**

It will thus be seen that the embodiments of the present invention offer numerous advantages over the prior art. Among them are for example low cost; minimal size; solid state control with no moving parts; self-regulation using no moving contacts, sensing circuits, amplification circuits, etc.; extreme simplicity; and ease of fabrication.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions and methods without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense. Also, it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

I claim:

1. An electronic assembly with built-in thermal regulation, said assembly including a thermo-sensitive device having a positive temperature coefficient and a sharp resistance variation in a regulation range located on both sides of a critical reference temperature; said device being shaped as a solid block having a plane warm face; at least one electronic component mounted on said plane face and electrically insulated therefrom, and means for applying electric power to said solid block independently of said component.

2. An electronic assembly with built-in regulation, said assembly including a thermo-sensitive device having a positive temperature coefficient and a sharp resistance variation in a regulation range located on both sides of a critical reference temperature; said device being shaped as a substantially solid block having a plane warm face; at least one electronic component mounted juxtaposed said plane face and electrically insulated therefrom, and means for applying the electric power to said solid block independently of said compound.

3. An electronic assembly with build-in thermal regulation, said assembly including a thermo-sensitive device having a positive temperature coefficient and a sharp resistance variation in a regulation range located on both sides of a critical reference temperature; said device being shaped as a substantially solid block having a plane warm face; at least one electronic component mounted in heat transfer relation to said plane face and electrically insulated therefrom, and means for applying electric power to said solid block independently of said component.

4. An electronic assembly with built-in thermal regulation, said assembly including a thermo-sensitive device having a positive temperature coefficient and a sharp resistance variation in a regulation range located on both sides of a critical reference temperature; said device being shaped as a substantially solid block having a plane warm face; at least one electric component mounted on said plane face and electrically insulated therefrom, and means for applying electric power to said solid block independently of said component.

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