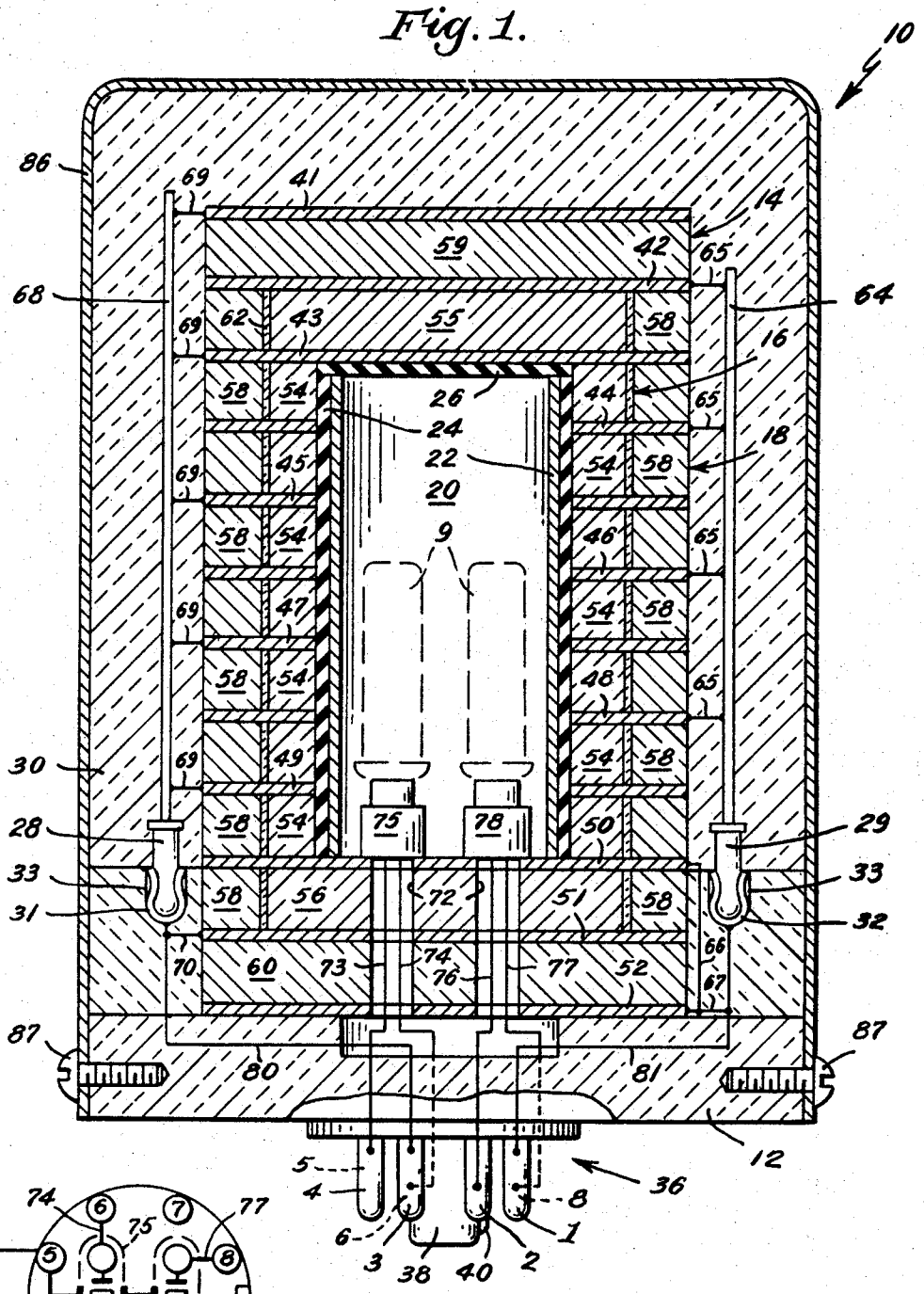
Dec. 3, 1968 C. D. FLANAGAN ETAL 3,414,706

SELF-REGULATING HEATING DEVICE

Filed Jan. 3, 1966

Fig. 1.



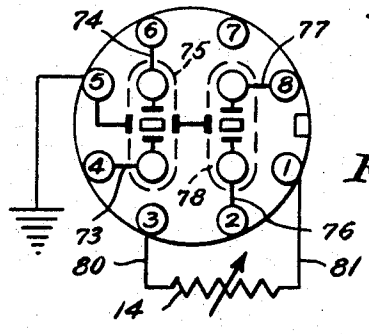


Fig. 2.

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SELF-REGULATING HEATING DEVICE

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ABSTRACT OF THE DISCLOSURE

Method and means for providing a relatively constant ambient temperature for temperature sensitive devices in which a plurality of heater elements composed of material having a positive-temperature coefficient of resistance (hereinafter referred to as PTC) are placed adjacent one another in ascending order of PTC anomaly temperatures resulting in a temperature control gain in the direction of the higher PTC anomaly temperatures. One embodiment shows a first set of stacked annular PTC discs placed within a second set of stacked annular PTC discs and electrically connected in parallel thereto. The constant ambient temperature is thus provided in the center of the inner set. More than two sets of discs may be employed as well as configurations other than annular.

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 the result of the characteristics of the thermostat—from a maximum to a minimum back to a maximum and so on. Also, since there is a 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 requirements 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. In copending and coassigned applications Ser. No. 435,166, filed Feb. 25, 1965, and Ser. No. 435,165, filed Feb. 25, 1965, devices were disclosed and claimed which provide such a constant ambient utilizing self-regulating heating elements. It is an object of this invention to provide an improved self-regulating heating device, especially of the type contained in the first mentioned application.

It is an object of the invention to provide an oven which is simple, highly reliable, long lasting, mechanically and electrically silent in operation and displays a closely controlled, relatively constant oven temperature.

It is another 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 temperature nature.

It is another object of the invention to provide an improved self-regulating 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.

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 appended claims.

In the accompanying drawings in which one of the various possible embodiments of the invention is illustrated:

FIG. 1 is a vertical partial cross sectional view through one embodiment of the invention; and

FIG. 2 is a schematic wiring diagram of the oven of FIG. 1.

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 purposes of clarity of illustration.

Referring now to the drawings, numeral **10** relates to the device or oven generally. It comprises a disc-shaped base **12** which may be formed of a conventional moldable phenolic resin or other suitable electrically insulating material and which mounts a heater assembly **14** composed of two sets of generally annular discs, **16** and **18** which will be further described infra. Heater assembly **14** is formed with a cavity **20** therein in which temperature sensitive components **9** are mounted. Although it is not essential, a thermally conductive liner **22**, e.g., aluminum, may be placed in cavity **20** to even out any temperature gradients which might exist in an axial direction. Electrical insulation **24** and **26** is used to prevent any short circuiting of the heater current. Quick disconnect pins **28** and **29** are mounted in a conventional potting compound **30** which is of an electrical as well as a heat insulating material conventional in the art. Insulation **30** will keep heat losses of the oven to a minimum. Pins **28** and **29** protrude from potting material **30** as shown in FIG. 1 and are received in mating clips **31** and **32** respectively which in turn are contained in bores **33** formed in base **12**. A conventional mounting assembly **36** is attached to the bottom of base **12** which includes shank **38** formed with key **40** which serves to properly orientate the oven for insertion in a receiving means (not shown). The mounting assembly **36** mounts pins **1–8** as shown, the number of which is a matter of choice. The heater, self-regulator assembly **14**, is composed of sets **16** and **18** of discs made of material having a steep positive sloped, resistivity-temperature curve at temperatures above the anomaly point (hereinafter referred to as PTC material). A layer of silver or other electrically conductive material is attached by conventional means to the two faces of each of the discs, the layers shown in FIG. 1 number from **41–52**.

Set **16** is composed of annular discs **54** sandwiched between discs **55** and **56**. Set **18** is composed of annular discs **58** sandwiched between discs **59** and **60**. It will be seen that set **16** is telescopically received within the coaxial recess formed within set **18**. Although it is not essential a thermal insulation layer **62** is shown separating the two sets from another (this provides a thermal gradient which will be explained in greater detail infra).

The even numbered layers **42–48** are electrically con-

nected to conductor **64** by conductors **65**. Conductor **64** is electrically connected to pin **29**. Layers **50** and **52** are electrically connected to clip **32** by conductor **66** and **67** respectively. Odd numbered layers **41–49** are connected to conductor **68** by conductors **69**. Conductor **68** is electrically connected to quick disconnect pin **28**. Layer **51** is electrically connected to clip **31** by conductor **70**.

It will be seen that this provides two stacks of discs, one within the other, connected in parallel. It will also be obvious that the particular number of discs employed is a matter of choice.

Bottom discs **56** and **60** are provided with bores **72** to provide space for leads **73**, **74** and **76**, **77** of sockets **75**, **78** respectively.

FIG. 2 shows a schematic wiring diagram indicating the internal electrical connections of pins **1–8**. Conductors **80** and **81** connect clips **31** and **32** and hence the PTC discs to pins **3** and **1**. Leads **73** and **74** are connected to pins **4** and **6** respectively and leads **76** and **77** are connected to pins **2** and **8** respectively. Pin **5** is grounded and pin **7** is not used. Metal cap **86** encloses oven **10** and is attached to base **12** by any conventional means, such as screws **87** shown.

Heating and regulating current (AC or DC) is applied through the PTC sets **14** and **16** from pin **1** to conductors **81**, clip **32**, pin **29**, conductors **64–67**, even numbered layers **42–52**, PTC elements **54–56** and, **58–60**, odd numbered layers **41–51**, conductors **69**, **70** through conductor **68**, pin **28**, clip **31**, conductor **80** and pin **3**. The PTC discs act as a heater and also as their own temperature regulator. The current passing through the PTC material causes heat to be generated thereby heating up the oven cavity **11**. Once the oven is warmed up, very little temperature variation occurs within cavity **20** 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 on the inside temperature of the oven.

At temperatures above the anomaly very little heating occurs since resistivity of the PTC material 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. If heat demand is increased tending to lower the temperature there is a relatively great drop in resistance with a concomitant increase in current ($E=IR$) and likewise generated heat ($P=I^2R$) until the material again attains a balance with heat dissipation equal to heat generated. Because of the steep slope of the PTC material very little temperature fluctuation occurs during such changes in resistance. The inner surface temperature variation of set **18** therefore, will be slight thereby providing a relatively stable temperature for the outer surface temperatuer of set **16** which in turn results in a very stable or constant temperature for the inside surface of set **16** and hence cavity **20**.

For the successful operation of the oven within the purview of the invention, the self-regulating heating element assembly **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 the so called break-point range is very large, for example from 15 to 150% per degree centigrade. This break-point range occurs near the Curie point of the material in the case of ceramic like material such as lanthanum doped barium titanate $Ba_{.997}La_{.003}TiO_3$, disclosed in the above-mentioned copending applications and in the case of materials disclosed in copending and coassigned application Ser. No. 472,108, filed July 15, 1965, at the anomaly point. For a further explanation of the self-regulating characteristic of the PTC material reference may be had to these applications.

Closer temperature control is achieved in this device by using two sets of discs **14**, **16** one placed within the other. The PTC anomaly temperature of set **14** has a lower value than that of the inner set **16**. We have found that in a case of a single set of discs a control gain of about 30 can be had (a 30° variation in outside ambient temperature will result in a 1° variation in internal oven temperature) but by use of a double set of discs one within another a control gain of approximately 900 is achieved (a 300° variation in outside ambient temperature resulting in a ⅓° inside variation).

Effective temperature control is realized through the use of a controlled temperature gradient existing between the two sets of PTC discs **14**, **16**. By using material having two different anomaly temperatures such a controlled gradient is effected. This gradient can be further maintained by using insulating layer **62** between sets **14**, **16** if desired.

The outside surface of set **18** is subjected to a relatively wide fluctuation in temperature (dependent upon outside ambient conditions). The inner surface of set **18** has a narrower range of fluctuations or temperature gradient due to the heating characteristics of the PTC material. This is referred to as control gain. The temperature range of the inner surface of set **18** is effectively the same for the outer surface of set **16**. Again a narrower temperature gradient results at the inner surface of set **16** and hence cavity **20** due to the same control gain characteristics of the PTC material.

It will be obvious that a greater control gain can be achieved by using a greater number of PTC sets, each set having an ascending anomaly temperature, in the direction of the control gain (cavity **20**).

Instead of defining a cavity with the PTC layers it is within the purview of the invention to effect the control gain by employing a plurality of layers of any geometry, e.g., sheets, each layer having a higher anomaly temperature in the direction of the control gain. Thermal insulation can be used to minimize heat loss in the environs of the area to be controlled.

The PTC material is chosen so that the oven operates inherently in the range which includes the anomaly point. One such material is lanthanum doped barium titanate the preparation of which is described in application Ser. No. 435,166 and Ser. No. 435,165. The anomaly point is controlled by the kind and amount of doping employed. Another such material is the carbon black filled cross-linked polyethylene in application Ser. No. 472,108. The anomaly temperature in the latter material may be modified by the amount of carbon present, the amount of closs linking, etc. to provide the different operating characteristics used in the two sets **14**, **16**.

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.

Instead of employing conductive layers **41–52** metal tabs may be inserted between the PTC discs to provide the electrical connections therefor. 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 view of the above it will be seen that the several objects of the invention are achieved and other advantageous results attained.

It is to be understood that the invention is not limited in its application to the details of construction, methods and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also, it is to tbe understood that the phraseology

or terminology employed herein is for the purpose of description and not of limitation.

As many changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense, and it is also intended that the appended claims shall cover all such equivalent variations as come within the true spirit and scope of the invention.

We claim:

1. A self-regulating heating device comprising:
(a) a first steep-sloped PTC element having at least two spaced portions and a cavity defined therein;
(b) a second steep-sloped PTC element having at least two spaced portions and a cavity defined therein received in the cavity of said first PTC element; and
(c) means to apply voltage across the two spaced portions of said first and second PTC elements whereby the resulting current will cause the element to heat up and an equilibrium will be reached so that the temperature of the surface defining the cavity of said second PTC element as well as the temperature within the cavity will be approximately constant regardless of change in heat demand.

2. A self-regulating heating device according to claim 1 in which the PTC elements are hollow cylinders and the means to apply voltage across the spaced portions includes an electrically conductive layer electrically connected to each spaced portion.

3. A self-regulating heating device according to claim 1 in which the PTC material is lanthanum doped barium titanate.

4. A self-regulating heating device according to claim 3 in which the lanthanum doped barium titanate is $Ba_{.997}La_{.003}TiO_3$.

5. A self-regulating heating device according to claim 1 in which the anomaly temperature of the first PTC element is lower than the anomaly temperature of the second PTC element.

6. A self-regulating heating device according to claim 1 in which the PTC element includes a plurality of annular discs made of PTC material stacked one on top of the other to form hollow cylinders, an electrically conductive layer electrically connected to each face of the discs and the discs connected in parallel.

7. An oven for maintaining a relatively constant ambient temperature for temperature sensitive devices regardless of changes in heat demand comprising:
(a) a first set of generally annular discs formed of PTC material stacked one on top of another to form a cylinder with a cavity therein;
(b) a second set of generally annular discs formed of PTC material stacked one on top of another to form a cylinder with a cavity therein, said second set of discs telescopically received and closely fitting in the cavity of said first set of discs;
(c) an electrically conductive layer attached to each face of the discs;
(d) two disconnect pins;
(e) leads connecting the pins to the layers so that the discs are connected in parallel;
(f) electrically insulating potting compound encasing the leads, part of each pin and all but one end of the sets of PTC discs;
(g) electrical connecting means mounted in the base to receive and removably hold the pins;
(h) a base of electrical insulation material which supports the encased PTC discs;
(i) a socket mounted on the base for mounting a temperature sensitive device and adapted to be received within the cavity of said second set of discs;
(j) oven mounting means attached to the base and providing electrical connections for the socket and pins through the pin receiving and holding means; and
(k) a cover enclosing the sets of PTC discs and releasably attached to the base.

8. An oven according to claim 7 further including:
(l) thermal and electrical insulation separating the said sets of PTC discs; and
(m) a cylindrical thermally conductive liner telescopically received within the cavity of said second set of discs; and
(n) electrical insulation separating the liner from the said second set of discs.

9. An oven according to claim 7 in which the anomaly temperature of the first set of PTC discs is lower than the anomaly temperature of the second set of PTC discs.

10. An oven according to claim 7 in which the PTC discs are composed of $Ba_{.997}La_{.003}TiO_3$.

11. An oven according to claim 1 in which the PTC elements are discs composed of carbon black filled, cross-linked polyethylene.

12. The method of providing a relatively constant ambient temperature for temperature sensitive devices comprising the steps of defining a temperature controlled area; taking a plurality of PTC material layers having different anomaly temperatures; placing the layers adjacent one another in ascending order of PTC anomaly temperatures with the layer having the highest anomaly temperature closest to the temperature controlled area; and applying a voltage across spaced portions of each PTC layer to effect a control gain in temperature in the direction of the higher PTC anomaly temperature.

13. The method according to claim 12 further comprising the steps of forming the PTC layers of annular discs stacked one on top of another and electrically connecting the discs in each element in parallel.

References Cited

UNITED STATES PATENTS

2,892,988	6/1959	Schusterius	338—9
2,953,759	9/1960	Lehovec	338—8
3,038,056	6/1962	Wolfskill	219—210
3,295,087	12/1966	Landis et al.	338—28

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