United States Patent [19]

Fuller et al.

[11] **3,898,422**

[45] **Aug. 5, 1975**

[54] **PTC HEATER ASSEMBLY BONDING**

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[22] Filed: **Dec. 26, 1973**

[21] Appl. No.: **428,180**

[52] **U.S. Cl.** .... **219/201;** 123/119 F; 156/329; 156/331; 219/202; 252/511; 252/514; 338/328

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

[58] **Field of Search** .... 219/200–202, 219/207, 209–210, 336, 338, 385, 426, 458, 463, 465; 338/223–224, 228; 156/325, 329, 331; 261/39 E, 39 A, 23 A; 123/119 F; 252/511, 512, 514

[56] **References Cited**

UNITED STATES PATENTS

3,056,750	10/1962	Pass	252/511
3,576,387	4/1971	Derby	252/511 X
3,636,311	1/1972	Steger	252/511 X
3,645,509	2/1972	Eckert et al.	261/39 A
3,673,121	6/1972	Meyer	252/511
3,699,937	10/1972	Petris	123/119 F
3,740,040	6/1973	Brown et al.	261/23 A
3,752,133	8/1973	Irish	261/39 E

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[57] **ABSTRACT**

An assembly comprising a PTC heater, a body to be heated thereby, and a bonding layer interposed therebetween. The heater is formed from a ceramic type PTC electrical resistance material which will generate heat in response to the flow of electric current therethrough. It has a surface portion through which heat is to be transferred and through which electrical current will flow. The body to be heated has a thermally and electrically conductive surface portion of a shape which substantially matches that of the heater surface portion. The body has a thermal coefficient of expansion differing from that of the heater resistance material. The layer of bonding material is electrically and thermally conductive and is interposed between these surface portions for the transfer of heat and conduction of electric current therethrough. It comprises a mixture of small electrically and thermally conductive particles dispersed throughout a flexible, elastic and creep-resistant high temperature resin material stable at temperatures on the order of at least 150°C. and free of components which tend to degrade the PTC material.

2 Claims, 3 Drawing Figures

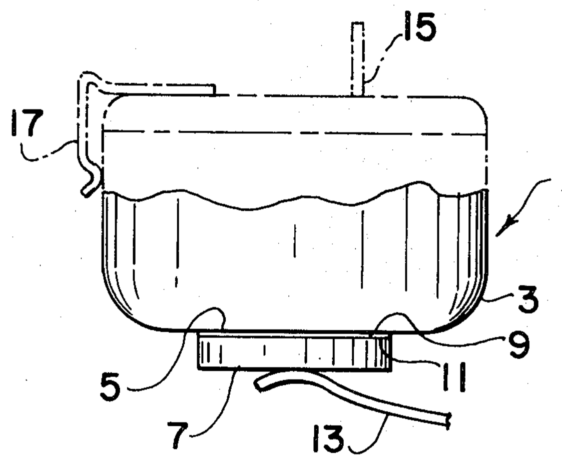


FIG. 1

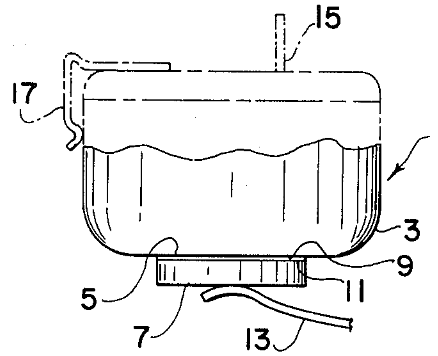


FIG. 2

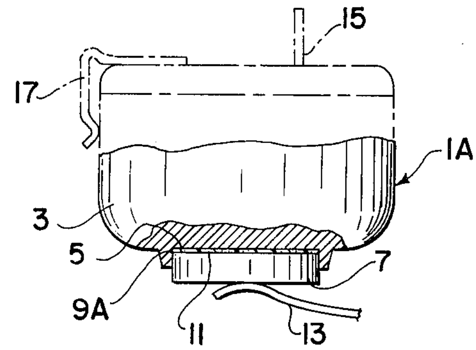
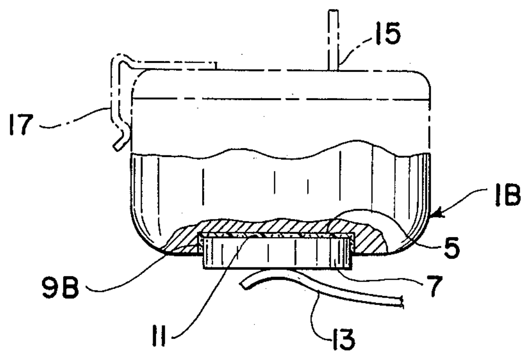


FIG. 3



PTC HEATER ASSEMBLY BONDING

BACKGROUND OF THE INVENTION

This invention relates to PTC heater assembly bonding and more particularly to such assemblies in which ceramic-type PTC heaters are bonded to bodies to be heated to elevated temperatures.

Positive temperature coefficient (PTC) resistance materials are widely utilized as heaters in thermal relays, time-delay relays and other thermally responsive devices and apparatus. Ceramic-type PTC material is commonly used for fabrication of such heaters. Typical of these are barium titanate and related divalent titanates and zirconates which undergo solid phase changes at particular temperatures. Associated with these phase changes are abrupt and large changes in the resistivity of the materials. These ceramic PTC materials generally include dopants such as rare earth metal, antimony or bismuth, or other elements to provide desired characteristics. For example, lead and strontium may be employed to increase or decrease the anomaly temperature range of these materials.

Such heaters are fixed to a body to be heated so as to be in close heat-exchange relationship therewith and usually also to provide an electrically conductive path because the electrical circuit supplying power to the heater desirably includes or utilizes the usually electrically conductive body in the circuit. In order to provide the good thermal and electrical conductivity across the interface between the PTC heater and the body to which it is held fixed in the overall assembly, epoxy-based resin materials carrying conductive particles interspersed therethrough have generally been used. This interposed layer of epoxy-conductive particle material forms a good thermal and electrical bond between the PTC heater face and the face of the body to be heated. However, the bond is a relatively rigid bond and has certain disadvantages. There is a substantial difference in the thermal expansions of this epoxy-based bonding material and the PTC. During heat cycling this causes disruptions of the conducting mechanism in the epoxy-conductive material bonding layer. This behavior is especially important when the entire system is rigidly bonded, i.e, where the forces are well coupled so as to cause displacement of the conductive particles in the epoxy from their equilibrium positions in the highly conducting mode. This momentary particle displacement can cause arc gaps and electrical as well as mechanical degradation of the interface material.

Also, the epoxy and its curing agent tend to degrade the PTC anomaly by causing a chemical reaction within the bulk of the PTC ceramic. A decrease in PTC resistance at the operating temperature may cause electrical "run-away" and lead to catastrophic breakdown.

Epoxies and related organic synthetic resins belong to a family of materials that have a rated prolonged lifetime at temperatures around 150°C. At higher temperatures, these organic materials undergo kinetically controlled thermal degradation. Since these resin materials are used as host matrices for the conducting particles, such thermal degradation will cause destructive effects on the electrical and thermal properties of the interface per se.

SUMMARY OF THE INVENTION

Among the several objects of this invention may be noted the provision of PTC heater assemblies in which the bonding layer is not subject to significant electrical and mechanical degradation even at elevated operating temperatures in the order of 150°–180°C. and even higher; the provision of PTC heater assemblies in which no significant degradation of the PTC anomaly takes place even after prolonged operation at such elevated temperatures; and the provision of such PTC heater assemblies which are convenient and economical to fabricate and reliable in use. Other objects and features will be in part apparent and in part pointed out hereinafter.

Briefly, an assembly of the present invention comprises a heater formed from a ceramic-type PTC electrical resistance maerial which will generate heat in response to the flow of electric current therethrough. The heater has a surface portion through which heat is to be transferred and through which electrical current will flow. The assembly includes a body which is to be heated and which has a thermally and electrically conductive surface portion of a shape which substantially matches that of the heater surface portion and to which heat is to be transferred from the heater. The body has a thermal coefficient of expansion differing from that of the heater resistance material. The assembly also has a layer of electrically and thermally conductive bonding material interposed between the surface portions for the transfer of heat and conduction of electric current therethrough. This layer comprises a mixture of small electrically and thermally conductive particles dispersed throughout a flexible, elastic and creep-resistant high temperature resin material stable at temperatures on the order of at least 150°C. and free of components which tend to degrade the PTC material.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevation of a heater assembly of the present invention on an enlarged scale; and

FIGS. 2 and 3 are similar elevations of alternate embodiments of the present invention.

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

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and more particularly to FIG. **1**, a thermal relay is generally indicated at **1.** This relay has a conductive metal, e.g., copper or aluminum, housing or body **3** having a thermally and electrically conductive substantially flat surface portion **5** to which heat is to be transferred and which serves as an electrode or terminal to carry electrical current to a generally flat cylindrical or pill-shaped PTC heater **7.** A layer of electrically and thermally conductive bonding material **9** is interposed between body surface portion **5** and inner surface **11** of heater **7.** The bottom is substantially flat or otherwise substantially matches the shape of body portion **5.** A resilient electrically conductive spring **13** (secured to a conventional case — not shown) for relay **1** bears against the outer surface of pill **7** thereby providing an electrical connection thereto and applying a mechanical force to bias heater **7** against body **3.** The top portion of relay **1** is shown in phantom to include at least one relay terminal **15** and an electrical terminal **17** contacting body **3** for connection to an electrical circuit to supply power to heater **7.**

Layer 9 is relatively thin (e.g., 3–4 mils thick) and formed of a flexible, elastic and creep-resistant high temperature resin material stable at temperatures on the order of at least 150°C. and free of components which tend to degrade the ceramic PTC material. This resin has a major portion by weight of conductive particles, such as silver, silver-copper alloys, graphite, etc., interspersed therethrough. For example, about 60–85 percent or more by weight of conductive metal particles of an average size of about 1 micron is employed in a silicone or polyimide resin. Typical silicone resins are those obtainable under the trade designations 525, SR-155, SR-520, SR-527 and SR-585 from General Electric. Polyamic acid-solvent mixtures available under the trade designation "Pyre-ML" from E. I. DuPont de Nemours and Company and which heat-cure to polyimide resins are also excellent high temperature resins for formation of layer **9**. Another high temperature resin for this purpose is that obtainable under the trade designation AI-10 from Amoco Chemicals Corp. Other high temperature resin materials, i.e., those useful at temperatures in the order of about 500°F. include benzophenone, polyamide-imide, polybenzimidazoles, polybenzothiazoles, polyethyleneimines, phosphonitrilic and polyester resins.

Bonding layers **9**, as above described, form an effective interface between PTC heaters and the thermal relay body, etc., to which it is affixed. They are sufficiently flexible and elastic to accommodate the differential expansion of the heater and body, e.g., in the order of 1 percent, as they undergo heat cycling and at elevated temperatures of 150°–180°C. or more. They have sufficient adhesion, e.g., a peel strength of not less than 5 pounds, and are creep resistant, i.e., they do not significantly permanently deform when subjected to the conditions of usage of these assemblies. Further, with the high loading of conductive particles they are also highly thermally conductive and have excellent electrical conductivity, e.g., in the order of 0.1 ohm/square/mil. They may be applied by silk screening or other conventional application procedures, or preformed as will be discussed hereinafter and applied in sheet or other configurations.

Bonding layer **9** thus permits relative movement and differential expansion of the heater and the body during heat cycling without loss of thermal and electrical contact therebetween. The relatively loose or weak mechanical coupling between the substrate or body and the heater assures that the equilibrium positions of the conducting particles are minimally disturbed and this avoids particle-particle separation which leads to arcing and degradation of the layer. The electrical switching characteristics of layer **9** are as good as those of epoxy resin materials. Chemical additives that avoid making the layer rigid and do not effect degradation of the PTC anomaly (amine curing agents are undesirable because of this) may be used, if desired, but are not essential.

Referring now to FIG. **2** a heater assembly bonding, similar to that of FIG. **1**, is illustrated at **1A** except the body surface portion **5** is defined by a projecting ridge and a preformed layer **9A** in sheet form is employed. Such a sheet of silver-particle loaded silicone resin is available under the trade designation "850-Consil" from Technical Wire Products Inc. The assembly of FIG. **2** allows the PTC pill to expand axially, limited only by the spring force of **13**, while the ridge somewhat limits movement laterally.

FIG. **3** illustrates still another embodiment **1B** of the present invention, quite similar to that of FIG. **2**, wherein the body surface portion **5** is recessed and a layer **9B** is a sheet of high temperature resin-conductive particles formed to fit within the recess, thus improving heat transfer between the PTC pill and body **3** due to larger surface area in contact with the PTC ceramic. In this and the other embodiments the spring **13** may be utilized to provide sufficient force to maintain the heater in its equilibrium position.

Typical applications of the assemblies of this invention are in time-delay relays where the PTC heater actuates a bimetal plate, and an automatic choke control where the PTC ceramic heater is used to actuate a bimetal spring that adjusts the fuel/air ratio.

An assembly of this invention utilizing as a bonding layer **9** a silicone resin heavily loaded (approximately 85 percent) with silver particles was successfully tested under operating temperatures of about 190°C. for 1 year.

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 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.

What is claimed is:

1. An assembly comprising:

a heater formed from a ceramic titanate PTC electrical resistance material which will generate heat in response to the flow of electric current therethrough, said heater having a surface portion through which heat is to be transferred and through which electrical current will flow;

a metal body which is to be heated and which has a thermally and electrically conductive surface portion substantially matching in shape with that of the heater surface portion and to which heat is to be transferred from said heater, said body having a thermal coefficient of expansion differing from that of the heater resistance material; and

a layer of electrically and thermally conductive material interposed between said surface portions for securing said heater and body to each other and for the transfer of heat and conduction of electric current therethrough between said heater and body, said layer comprising a mixture of small electrically and thermally conductive particles selected from the group of silver, silver-copper alloys and graphite materials dispersed throughout a material selected from the group consisting of silicone resin, polyimide resin, benzophenone resin, polyamide-imide resins, polybenzimidazole resins, polybenzothiazole resins, polyethyleneimine resins, phosphonitrilic resins and polyester resins so that said layer is flexible, elastic and creep-resistant and stable at temperatures on the order of at least 150°C. and free of components which tend to degrade the PTC heater material.

2. An assembly as set forth in claim **1** wherein said resin material is selected from the group consisting of silicone resin and polyimide resin and wherein said conductive particles comprise from 60 to 85 percent of the weight of said bonding layer and have an average particle size of about 1 micron.

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