United States Patent [19]

Cartier et al.

[11] **3,727,164**

[45] **Apr. 10, 1973**

[54] **TEMPERATURE-RESPONSIVE ELECTRICAL SWITCH**

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[73] Assignee: **Minnesota Mining and Manufacturing Company,** St. Paul, Minn.

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[21] Appl. No.: **271,745**

[52] **U.S. Cl.**.....**337/405,** 337/409

[51] **Int. Cl.**.....**H01h 37/76**

[58] **Field of Search**.....337/407, 405, 406, 337/408, 409, 401; 116/114.5

[56] **References Cited**

UNITED STATES PATENTS

3,519,972	7/1970	Merrill	337/407
3,518,961	7/1970	Kovac	116/114.5
3,054,378	9/1962	Bienfait	116/114.5

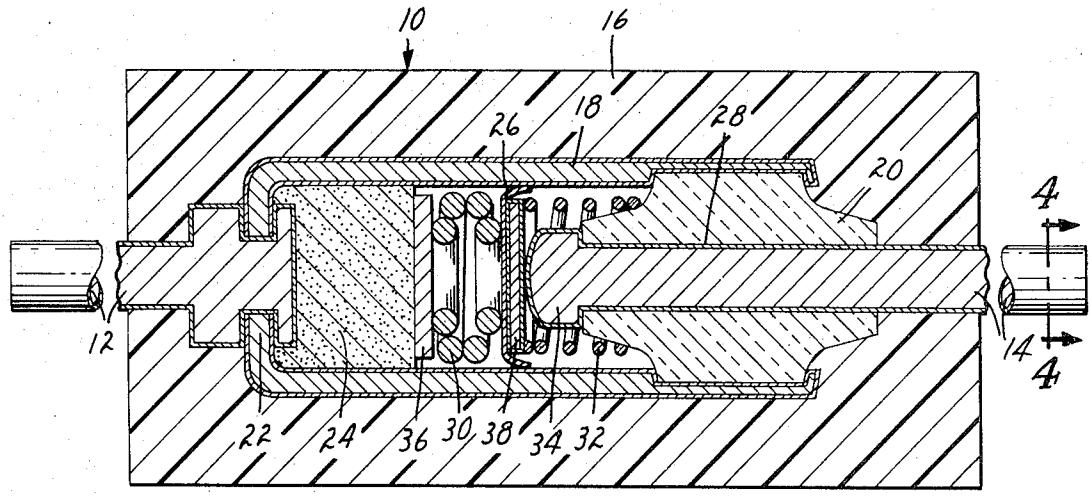
Primary Examiner—Harold Broome

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[57] **ABSTRACT**

An improved, temperature-responsive electrical switch is provided which is actuated at temperatures above 250° C., the switch utilizing fusible pellets prepared from imide or substituted melamine compounds.

7 Claims, 4 Drawing Figures



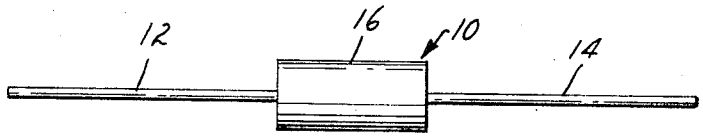


FIG. 1

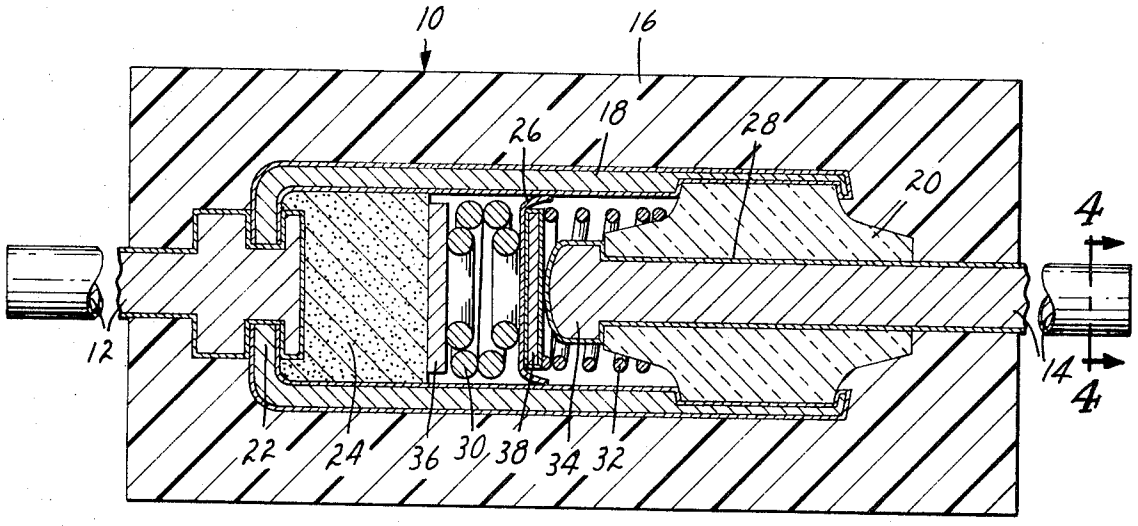


FIG. 2

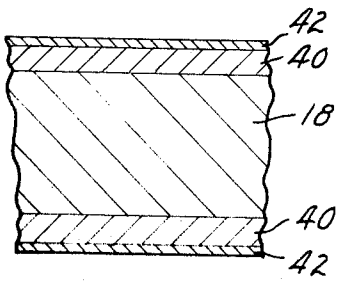


FIG. 3

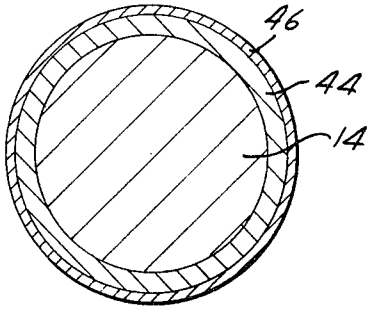


FIG. 4

TEMPERATURE-RESPONSIVE ELECTRICAL SWITCH

This invention relates to electrical switches, and more particularly, to electrical switches of the type which are temperature responsive.

Electrical switches of various types are well known, including electrical switches of the type which are temperature responsive. These temperature-responsive switches are used in a variety of applications, e.g., fire alarms, household appliances, warning systems, etc. These switches may be of the type which conduct electrical current therethrough until a predetermined temperature is reached or of the type which do not conduct electrical current therethrough until a predetermined temperature is reached.

Typical of such temperature-responsive switches are those described, e.g., in Merrill, U.S. Pat. No. 3,519,972; Merrill, U.S. Pat. No. 3,505,630; Merrill, U.S. Pat. No. 3,291,945; Merrill, U.S. Pat. No. 3,180,958; Massar, U.S. Pat. No. 2,934,628; Weese, U.S. Pat. No. 3,313,312; Bahr, U.S. Pat. No. 2,247,902; Ebensteiner, U.S. Pat. No. 3,281,559; Milton, U.S. Pat. No. 2,955,179; Denton, U.S. Pat. No. 3,155,800; Delaney, U.S. Pat. No. 1,368,230; Spracher, U.S. Pat. No. 2,442,830; Derby et al., U.S. Pat. No. 2,516,964; Pierce, U.S. Pat. No. 968,406; Thomas, U.S. Pat. No. 2,996,591; Chabala, U.S. Pat. No. 3,118,992; and Fister, U.S. Pat. No. 3,281,557.

Each type of temperature-responsive switch typically contains means movable between a first position and a second position to either open or close an electrical path within the switch. Such means is ordinarily actuated by the collapse of a normally solid, fusible pellet, as described in the aforementioned patents.

Fusible pellets for use in these temperature-responsive electrical switches have been made from a variety of materials. For example, they have been made from metallic alloys e.g., bismuth, lead, tin or antimony alloys), waxes, powdered ceramic material mixed with fusible binder, etc.

In spite of the wide variety of temperature-responsive switches available, and in spite of the existence of a wide variety of fusible pellets, there has not heretofore been provided a suitable temperature-responsive electrical switch which will operate reliably above temperatures on the order of 250° C. or more. The present invention provides such a temperature-responsive electrical switch.

The invention will be described in more detail hereinafter with reference to the drawings wherein like reference characters refer to the same part throughout the several views and in which:

FIG. 1 is an elevation of one completed switch of this invention;

FIG. 2 is a longitudinal, cross-sectional view of a typical temperature-responsive electrical switch of the invention;

FIG. 3 is a cross-sectional view of the portion of the casing of the switch shown in FIG. 2; and

FIG. 4 is a cross-sectional view of a portion of one of the leads of the switch of FIG. 2.

FIG. 1 shows a temperature-responsive electrical switch **10** made in accordance with the invention and having conductive leads **12** and **14** extending into the casing of the switch which is encapsulated in electrically insulative resin **16**.

In FIG. 2 there is shown a longitudinal cross-sectional view of a temperature-responsive electrical switch **10** of the general type described in U.S. Pat. No. 3,519,972, the switch comprising a cylindrical, tubular, electrically and thermally conductive casing **18** having closures **20** and **22** at the ends thereof. Closure **20** is an electrically nonconductive closure.

A first conductor **12** conductively contacts the casing **18** at the integral closure **22**. A second conductor **14** extends into the casing **18** through the electrically nonconductive closure **20**. A normally solid fusible pellet **24** is spring-biased to exert outward pressure against one of the closures, such as the closure **22**.

An electrically conductive member **26** is slidably mounted within the casing **18** and has a slidable, resilient, peripheral conductive engagement with the conductive casing **18**, such as by outwardly resilient integral teeth which outwardly press against the inner surface of the casing **18**. Member **26** also has a conductive central portion in electrical contact with the second conductor **14** via conductive disc **38** in one position of member **26** and out of electrical contact with said second conductor **14** in another position of said member **26**.

A compression spring construction inside casing **18** serves as means to change the electric flow condition between the casing and conductor **14** upon collapse of the pellet **24**, such as by leftward movement of conductive member **26** away from electrical contact with conductor **14**.

The nonconductive closure **20** may have a central opening **28** surrounding the second conductor **14**, and the closure **20** may be secured in the conductive casing **18** as shown in the drawing.

The compression spring construction may include a relatively strong compression spring **30** between the pellet **24** and the electrically conductive member **26**. Such compression spring construction also may have a relatively weak compression spring **32** between the closure **20** and the electrically conductive member **26**. As long as the pellet **24** does not collapse, the stronger spring **30** holds the slidable, conductive member **26** against disc **38** and head **34** of second conductor **14** so that electrical current may pass through first conductor **12**, casing **18**, conductive member **26**, disc **38** and then second conductor **14**. However, when the pellet **24** reaches a temperature above 250° C. (depending on the particular type of compound used in making the pellet), the material of pellet **24** becomes fluid almost instantaneously and flows around disc **36** and thus allows the stronger spring **30** to expand towards closure **14** so that its spring load becomes less than the spring load of the weaker spring **32**. This permits spring **32** to move the conductive member **26** and the disc **38** away from head **34**. Consequently, the conductive member **26** is moved out of electrical contact with head **34** of second conductor **14** and thus breaks the electrical flow condition between the first conductor **12** and the second conductor **14** to stop the flow of current through switch **10**.

In order to make the conventional copper or brass casing normally used in electrical switches more temperature-resistant, they must be overcoated with thin layers of various other metals. As shown in FIG. 3, the casing **18** can be overcoated with a thin layer **40**, e.g.,

nickel, followed by a thin overcoating **42** of another metal such as silver or gold. These thin overcoatings may vary from about 2.5 microns to about 50 microns in thickness, and they have been shown to reduce or retard oxidation of the conventional copper or brass casings at temperatures above 250° C.

In order to prevent the sticking or welding at high temperatures and pressures of disc **38** and second conductor **14**, these parts are coated or treated with overlayers of metal of a type which is harder than silver. Thus, in FIG. **4** there is a cross-sectional view of second conductor **14** having a first thin overcoating **44** and a second thin overcoating **46**. It has been found that thin overcoatings of first nickel and then rhodium are quite suitable for use in the switches of this invention. It has also been found that platinum or palladium may be used in place of rhodium as the second thin overcoating. Typical thickness for the nickel overcoatings ranges from about 2.5 microns to about 7.5 microns. Typical thickness for the rhodium, platinum or palladium overcoatings ranges from about 0.25 microns to about 1.5 microns, although thicker overcoatings can also be used.

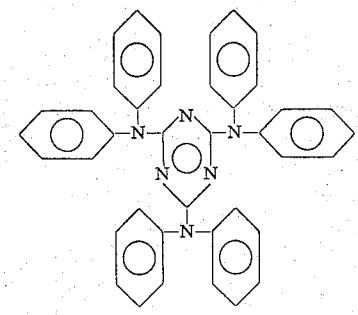
The thin nickel overcoatings are normally applied using well-known techniques of electroless plating or electroplating using commercially available plating solutions. The rhodium, platinum, or palladium overcoatings are normally applied using well-known electroplating techniques and commercially available plating solutions.

The encapsulating resin **16** which surrounds the electrical switch is thermally resistant and it retards the entry of air and moisture into the temperature-responsive electrical switch and also assists in anchoring the first and second conductors **12** and **14**. Resin **16** is preferably tough and exhibits a high heat-distortion temperature as well as permitting rapid heat transfer therethrough. Preferably, resin **16** is a silicone molding compound which may be filled with glass fibers or fused silica or both. Typical examples of such resins are those commercially available from Dow Corning in their "300" series which are filled with both short glass fibers and fused silica. Another typical silicone resin is General Electric MC–710, a thermosetting silicone resin filled with silica glass fibers (typical cure being 4–24 hours at 200° C.). Those polyimide and phenolic resins which are quite thermally resistant and tough can also be used.

Resin **16** is normally formed around the switch by either compression or transfer molding. Typical conditions for transfer molding, e.g., the Dow Corning "306" resin are a temperature of 150°–180° C., a dwell of 1–5 minutes, and a molding pressure of about 25–30 kilograms per square centimeter, followed by a post-cure of 2 hours at 200° C.

Resin **16** normally extends about one millimeter or more beyond the casing of the switch. Generally, the thickness of the resin **16** must be sufficiently thick to be an adequate dielectric barrier and to provide sufficient strength to resist cracking during molding and during subsequent thermal cycling and aging and yet be sufficiently thin to permit relatively rapid heat transfer therethrough. When using, e.g., the Dow Corning "306"resin, the minimum resin thickness is about 0.3 millimeters but it may be as thick as 0.8 millimeters or more.

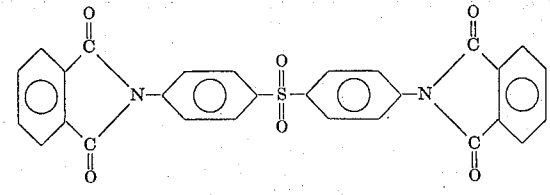
Fusible pellets which are useful in the temperature-responsive electrical switches of the present invention are those which are stable (i.e., do not melt, significantly sublime or degrade) at temperatures up to at least 250° C. over extended periods of time. The pellets are made from organic compounds having no reactive groups (e.g., acid, hydroxy, acid chloride, halogen, etc.) and having relatively low vapor pressures. Although several classes of compounds are known which have melting points above 250° C., there have only been found two classes of compounds which meet the requirements for use in fusible pellets for high temperature-responsive electrical switches. These classes are the imide compounds and substituted melamine compounds. Exemplary of the substituted melamine compounds is hexaphenyl melamine which melts at 304° C. and which has the following structure:



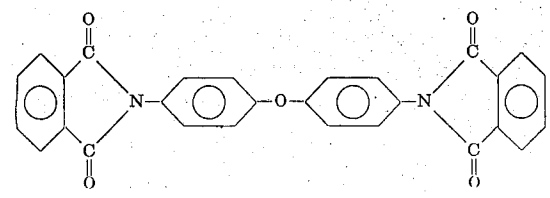
Other substituted melamine compounds melting above 250° C. are also useful. Melamine compounds having aromatic substituents are preferred over those having aliphatic substituents. Substituted melamine compounds can be prepared in accordance with the methods described in "The Relative Thermal Stability of Polymer Model Compounds," D. Sheenan, A. P. Bentz, J. C. Petropoulos, J. Applied Polymer Science, 6 (19), 47 (1962).

Exemplary of useful high-melting imide compounds are the following:

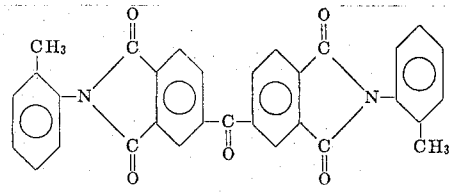
Diphthalimidodiphenylsulfone, having the structure



and having a melting point of 324°–325° C.; diphthalimidodiphenyl ether, having the structure



and having a melting point of 289° C.; and imide of benzophenone dianhydride and o-toluidine, having the structure



and having a melting point of 279° C.

Methods for preparing imides are well known, e.g., as described in U.S. Pat. Nos. 3,179,630 and 3,179,632 and in various other references.

Fusible pellets are made from the above-described compounds by compressing the powdered compound in a cylindrical cavity. The force applied and the amount of material in the cavity is adjusted in such a manner that about 30–35 fusible pellets are obtained per gram of powdered compound. The fusible pellets (typically having a diameter of 3.2 mm.) should able to sustain an axial load of at least about 4.5 kilograms (measured with a Stokes Tablet Hardness Tester). For some compounds (for example, hexaphenylmelamine), it is difficult or impossible to obtain a pellet having sufficient strength for use in the temperature-responsive switch. Consequently, a binder material is ordinarily added to such compounds to increase the internal strength of pellets made therefrom. A binder level of about 3–5 percent by weight has been found sufficient for this purpose. Suitable binders which have been used include Scotchcast 265, a thermosetting epoxy resin powder commercially available from the 3M Company; Dow Corning 901 Varnish, a thermosetting silicone resin dissolved in a solvent; and General Electric SR–350, a powdered thermosetting silicone resin. The powdered binder resins are dispersed in the finely divided compound used for the pellet by any method of dry blending. The compound with added binder is then compressed and heated to melt and cure the binder. For example, pellets made using an epoxy resin as a binder may be heated for about 40 minutes at 180° C.

When using silicone resin as the binder material, it is dissolved in a suitable solvent along with the catalyst therefor, after which the finely divided pellet material is added thereto. The resulting dispersion is heated to drive off the solvent and the resulting solid is ground to a powder, pressed into pellets, and then cured with heat (e.g., 2 hours at 200° C.).

The following nonlimiting examples serve to further illustrate the present invention:

EXAMPLE 1

Hexaphenylmelamine is prepared using the following ingredients:

Cyanuric chloride	92 grams
Diphenyl amine	169 grams

These materials are charged to a flask fitted with an acid scrubbing tower and nitrogen gas atmosphere. The flask contents are then heated slowly to 200° C. and held until no more hydrogen chloride gas evolution is observed. The solid product is washed in chloroform and then purified by sublimation at a pressure of 50–100 microns Hg and a temperature just below the melting point of the product.

EXAMPLE 2

Diphthalimidodiphenyl sulfone is prepared using the following ingredients:

Diaminodiphenylsulfone	24.8 grams
Phthalic anhydride	29.6 grams

After dissolving the phthalic anhydride in 300 ml. of acetone and the diaminodiphenyl sulfone in 100 ml. of acetone, the two solutions are mixed together and warmed for 30 minutes at about 40° C. The precipitated amide acid is then filtered out and recrystallized from 500 ml. of tetrahydrofuran.

The amide acid is then dissolved in 300 ml. of tetrahydrofuran, warmed to about 50° C. and 25 ml. of pyridine and 25 ml. of acetic anhydride are added thereto. The resulting solution is then warmed for 30 minutes at 50° C., cooled to room temperature, and the precipitated imide product is recovered, filtered, and dried.

EXAMPLE 3

A fusible pellet is prepared by first dispersing 0.97 gram of hexaphenylmelamine in 10 ml. of toluene containing 0.06 gram of Dow Corning "901" silicone varnish (55 percent solids) and 0.000216 gram lead octoate (24 percent lead by weight). The resulting dispersion is dried for 1 hour at 120° F.

Pellets were formed from the dry residue using 1,000 pounds axial pressure. Approximately 0.03 grams of material were used for each pellet. The pellets were cured for 30 minutes at 155° C. after which they could withstand an axial force of 10.5 kilograms.

What is claimed is:

1. In a temperature-responsive electrical switch of the type comprising:
   a. an electrically and thermally conductive casing having a closure at each end thereof, one of said closures being electrically nonconductive;
   b. a first conductor in electrical contact with said casing;
   c. a second conductor extending into said casing through said electrically nonconductive closure;
   d. a normally solid fusible pellet contained in said casing; and
   e. means contained in said casing for permitting electrical flow through said switch via said first conductor, said casing and said second conductor when said means is in one position and not permitting electrical flow through said switch when said means is in another position; said means being actuated by the collapse of said fusible pellet;

the improvement which comprises a temperature-resistant casing, a normally solid, fusible pellet comprising an imide compound or a substituted melamine compound having a melting temperature of at least 250° C., and a second conductor whose surface bears a first thin overcoating of nickel and a second thin overcoating of rhodium, platinum or palladium, said switch being encapsulated in a thermally resistant resin.

2. The improvement of claim 1 wherein said temperature-resistant casing comprises a copper or brass shell bearing a first thin overcoating of nickel and a second thin overcoating of silver or gold.

3. The improvement of claim 2 wherein said casing comprises a brass shell bearing a first thin overcoating of nickel and a second thin overcoating of silver.

4. The improvement of claim 1 wherein said fusible pellet comprises hexaphenylmelamine.

5. The improvement of claim 1 wherein said fusible pellet is prepared from a compound selected from the group consisting of diphthalimidodiphenylsulfone, diphthalimidodiphenyl ether, and the imide prepared from benzophenonedianhydride and o-toluidine.

6. The improvement of claim 1 wherein said resin comprises a cured silicone resin.

7. The improvement of claim 1 wherein said surface of said second conductor bears a first thin overcoating of nickel and a second thin overcoating of rhodium.

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