(12) UK Patent Application (19) GB (11) 2 052 228 A

(21) Application No **8015417**
(22) Date of filing **9 May 1980**
(30) Priority data
(31) **7916273**
(32) **10 May 1979**
(33) **United Kingdom (GB)**
(43) Application published
21 Jan 1981
(51) **INT CL³**
H05B 3/12
(52) Domestic classification
H5H 104 111 113 120 125 126 130 144 152 154 170 176 230 233 240 251 CB
B5A 1G1 1G2 1G7A1 1G7AX 1G8C 1R158 1R214A 1R214F 1R314C1C 1R314C4 1R322 1R439E 2A1 2A2 2C T17F
H1K 1FD 2R4 2S11S 2S6 2S9 4C1M 9C2 FDB
(56) Documents cited
None
(58) Field of search
H1K
H5H

(71) Applicants
Sunbeam Corporation, 5440 West Roosevelt Road, Chicago, Illinois 60650, United States of America
(72) Inventors
George Martin Gale, David Ivan James, John van Buren Meyer
(74) Agents
Frank B. Dehn & Co.

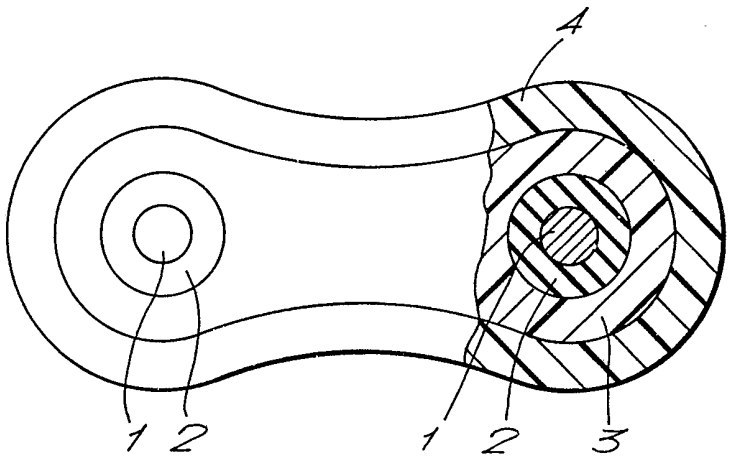
(54) **Flexible heating elements and dies and processes for the production thereof**

(57) A flexible heating element comprises two electrical conductors 1 spaced apart by a PTC material 3, an amorphous highly conductive rubber 2 compatible with the PTC material and adhered to each conductor being interposed between the PTC material and each conductor whereby in use current passes from one conductor to the other through the PTC material via the highly conductive rubber. The conductors are spaced sufficiently close to one another to ensure that when energised the PTC material heats substantially uniformly without exhibiting a significant temperature gradient between the conductors and that any abnormal temperature increase increases the temperature of all the PTC material between the conductors in the region of the abnormal temperature increase.

The arrangement is such that in use the deleterious effects of poor interface adhesion and interface breakdown are reduced by the provision of the amorphous highly conductive rubber between the PTC material and the conductors.

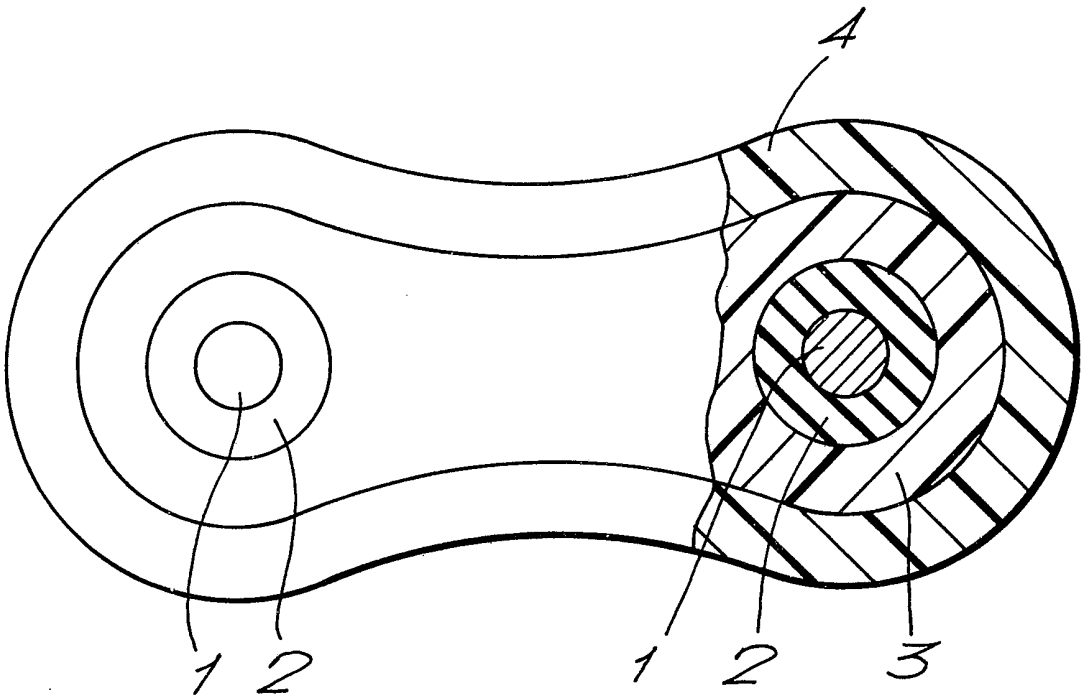
The flexible heating element is produced by extruding through a die the amorphous highly conductive rubber to cover each electrical conductor and subsequently or simultaneously extruding the PTC material to cover the amorphous highly conductive rubber.

Fig.1.



GB 2 052 228 A

Fig.1.



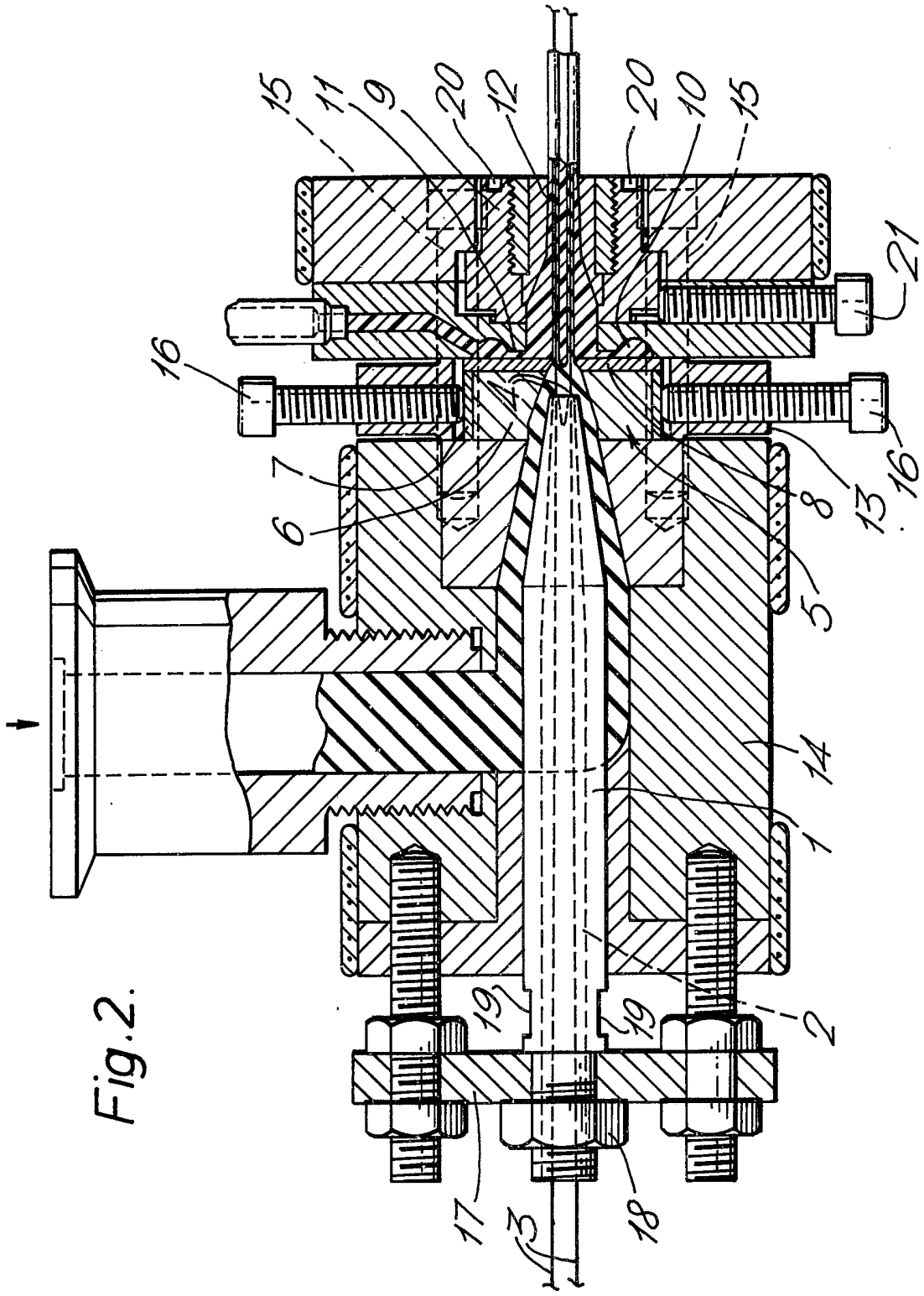


Fig.2.

SPECIFICATION

Flexible heating elements and processes for the production thereof

The present invention relates to flexible heating elements and processes for the production thereof. The flexible heating elements are for example suitable for use in electric blankets.

It is common practice in the manufacture of electric blankets to position an electrically conducting heater wire between two fabric layers. Heat from the heater wire passes through the fabric and is dissipated to the body of the user and to the surrounding atmosphere. United States Patent Specification No. 3,410,984 describes and electrically heated bedcover in which localised overheating is prevented by the use of a wire-like heater formed by a pair of conductors separated by a layer of material having a large positive temperature coefficient of resistance. In normal operation of this device substantially uniform heat is generated throughout the device by current flow between the conductors through the positive temperature coefficient (hereinafter also referred to as "PTC") material. When localised overheating occurs, however, the resistance of the material between the conductors increases in that particular region to limit the heat output of that region. The device of U.S. Patent Specification No. 3,410,984 allows localised overheating to be automatically controlled without the need to disconnect the electric blanket from the power supply.

Two major difficulties are encountered with the electrically heated bed covers described in U.S. Patent Specification No. 3,410,984. These difficulties relate to the high contact resistance between the conductors and the PTC material due to the difficulty of achieving metal adhesion to common PTC materials and also to the relatively poor stability of the heating element both with regard to the bulk resistance of the PTC material and the resistance at the electrode interface. It is believed that the elevated temperature of operation and temperature cycling cause oxidation and breakdown in the bulk material resulting in an increase in the overall resistance. Such conditions of temperature and temperature cycling can cause an increase in the resistance at the electrode interface due both to breakdown in the already poor adhesion between the electrode and the bulk material and the accelerated oxidation and reaction of the PTC material at the electrode interface. U.S. Patent Specification No. 3,858,144 attempts to deal with these problems. It thus proposes that the proportion of carbon black in the PTC material at the electrode interface be increased to at least about 1.5 times that of the proportion of carbon black at the mid-point between adjoining electrodes. In addition it is proposed to deploy uniformly, in the matrix or core which electrically connects adjoining electrodes, an effective resistance-stabilising amount of a carboxylic acid group-containing polymer of acid number greater than about 3 or the ammonium, alkali or alkaline earth metal salts thereof.

A large number of process steps are involved in making the articles described in U.S. Patent Specification No. 3,858,144 and the starting materials used are relatively expensive. Furthermore although resistance stability is improved according to U.S. Patent Specification No. 3,858,144 the electrically conductive self regulating articles produced do in fact have a relatively short life and there is a need to provide a heating element possessing long term resistance stability and sufficient flexibility for use in electric blankets. Moreover the methods employed in U.S. Patent Specification No. 3,858,144 result in positive temperature coefficient materials having a diffuse PTC anomaly point giving a linear PTC characteristic over a wide temperature range, rather than a sudden increase at the anomaly point, which makes blanket control more complex.

The present invention is based on the discovery that the deleterious interface effects of poor adhesion and interface breakdown during use may be reduced by providing an amorphous non PTC, highly conductive rubber, between the electrodes and the PTC material. This in addition to providing flexibility promotes both initial and long term adhesion and removes the oxidation sensitive PTC material from the vicinity of the electrode where oxidation effects are most pronounced. The present invention thus overcomes at least in part the disadvantages inherent in the heating elements disclosed in the U.S. Patent Specification No. 3,858,144 while ensuring that the elements are sufficiently flexible for use in a number of applications including use in electric blankets.

Thus according to one feature of the present invention there is provided a flexible heating element which comprises at least two flexible electrical conductors spaced apart by a PTC material, an amorphous highly conductive rubber compatible with the said PTC material and adhered to each conductor being interposed between the PTC material and each conductor whereby in use current passes from one conductor to another through the PTC material via the said highly conductive rubber, the conductors being spaced sufficiently close to one another to ensure that when energised the PTC material heats substantially uniformly without exhibiting a significant temperature gradient between the conductors and that any abnormal temperature increase increases the temperature of all the PTC material between the conductors in the region of the abnormal temperature increase, the arrangement being such that in use the contact resistance between the conductors and the PTC material is reduced by the amorphous highly conductive rubber interposed therebetween.

The term "Highly conductive" as used herein in relation to amorphous non-PTC rubber means rubber which has a sufficiently low resistance to ensure that substantially no Joule heat is generated by the rubber during passage of electricity therethrough. It will be appreciated, however that the temperature of the amorphous rubber may nevertheless rise as a result of transfer of heat from the PTC material.

Preferred materials for the electrical conductors include copper, especially containing about 1% cadmium, and other low resistance materials such as silver, tin nickel and aluminium and the alloys thereof as well as copper plated with silver, tin or nickel. Such plated copper is especially useful since it promotes stability by providing a fairly inert electrode surface, thus reducing reaction with the PTC material, at a much lower cost than with a pure silver or tin.

The PTC materials for use in the flexible heating elements of the present invention may be solely responsible for the PTC effect or may consist of a combination of materials to provide, for example low contact resistance, flexibility, stability and flame resistance in addition to the necessary PTC behaviour. These materials can be divided into two distinct categories: 1) Active; those materials responsible for giving rise to the PTC effect and 2) Passive; those materials which contribute in no way to the PTC effect, in fact reducing it by their dilutant action but which are compatible physically and electrically with the active components. The active materials employed advantageously include polymers having a glass transition temperature from —125 to —75 deg C and will in general be based on polymers having a degree of crystallinity such as for example polyolefines, for example high, medium or low density polyethylene and polypropylene as well as ethylene propylene copolymers and terpolymers with non conjugated dienes. Other polymers and rubbers which may be used as an active material include polyvinylidine halides, polyolefin oxides and cross linked silicone rubbers with low carbon black levels. Passive materials employed may be stabilisers, inert fillers or flame retardants and especially rubbers to provide flexibility where such rubbers are compatible with the active material used. With respect to compatibility it will be appreciated that the rubber and the active materials should be capable of combination to form a single phase or if they coexist as two phases they should be bound by forces e.g. intermolecular forces, strong enough to resist physical attempts to separate them. Thus for example if the material is fractured or torn the forces between the rubber and the active material should be sufficient to prevent the fractured surface from distinctly showing one phase standing out and separate from the other phase. Where the rubber and the active material are incompatible the application of even very small stresses tends to cause the incompatible materials to crumble into two distinct and separate phases. The requirement that the rubber and the active material should be compatible is introduced in order to avoid the use of rubbers which substantially degrade the beneficial properties of the active material, it being preferable to use a rubber which improves certain properties, for example, the flex life and flexibility of the active material without affecting the magnitude of the PTC effect and without unduly increasing resistivity except as a result of dilution. Moreover it will be appreciated that the rubber and the active material used should be stable to heat over a long period and thus the rubber used should not substantially decrease heat stability nor should it substantially increase degeneration with time. We have found Butyl rubber to be particularly preferred with respect to the above.

The combination of materials known as the PTC material will conveniently contain carbon black or another conductive filler such as carbon fibres or metallic fibres, flake or powder e.g. silver, copper, zinc etc. Other passive components of the PTC material are for example stabilising agents, inert fillers and/or flame retardants.

In addition to the above there is an interaction between the bulk PTC material and the conductor e.g. copper at the interface which causes degredation. This interaction is avoided by the introduction of an amorphous non PTC highly conductive rubber between the bulk PTC material and the conductor provided the amorphous highly conductive rubber is compatible with both the bulk PTC material and the conductor. Amorphous non PTC conductive rubbers which may be employed in the flexible heating elements of the present invention between the electrodes and the PTC material include for example certain conductive silicone rubbers and certain chlorinated rubbers such as epichlorohydrin rubber for example containing about 35% ethylene oxide e.g. Herchlor C (65% epichlorohydrin rubber 35% ethylene oxide) as well as Butyl rubber and its derivatives such as chlorinated Butyl rubber. The amorphous non PTC conductive rubbers should be compatible with the PTC material and especially epichlorohydrin rubber should contain preferably a large quantity of carbon black which promotes heating throughout the material and reduces contact resistance.

Epichlorohydrin rubber is especially preferred because we have found it to be particularly compatible with both polyethylene and copper. Thus adhesion is improved and the formation of small air gaps, which become focal points for ionisation and corona discharge is at least in part reduced. We have found epichlorohydrin rubber to be a most conductive rubber while possessing flexiblity sufficient to be advantageous, for example, in the preparation of electric blankets.

Such products are relatively easy to make reproducibly and possess long term resistance to temperature, temperature cycling and flexing.

We have found that if a spiralled wire is coated with the amorphous non PTC rubber e.g. epichlorohydrin (e.g. Herchlor C), cured and then the PTC material extruded over the rubber a measurable contact resistance is found. It is preferred therefore to coat the spiralled wire with the amorphous rubber and then to effect extrusion such that curing takes place during extrusion when the contact resistance is much lower. The above-mentioned coating and extrusion processes are effected by co-extrusion.

In a particularly preferred embodiment of the present invention the conductors are coated e.g. dip coated with a colloidal graphite solution and cured. The graphite appears to enter the core providing an

increased conductor cross-section and reducing overall resistance. The coating of the core with a colloidal graphite solution improves conductivity and surprisingly does not inhibit adhesion to any significant extent. A coating around the core moreover serves as a barrier to oils migrating from the rubber. In this connection it is believed that the graphite serves as a lubricant and improves contact between the amorphous highly conductive rubber and the electrical conductor by providing an improved contact area as a result of the physical presence of graphite particles. Thus during flexing the bonded amorphous highly conductive rubber layer is intended to deform in shear without the loss of the bond between the rubber and the PTC material whereas the colloidal graphite interlayer is believed to act as a lubricant between the rubber and the electrical conductor allowing movement to take place, contact being established by a purely physical mechanism.

It is important that the conductors be closely spaced with respect to each other for effective operation. In this connection it is important that an abnormal temperature increase increases the temperature of all the PTC material between the conductors in the region of the abnormal temperature increase. A significant temperature gradient between conductors is a characteristic of PTC materials when using long current paths. If the electrical conductors are spaced apart by a great enough distance to allow localised overheating to affect only a portion of the PTC material between the conductors then this portion would experience an increasing voltage drop between the conductors as the resistance increases due to heating and this portion would increase in temperature, possibly to an undesirable extent. Granted this however, the limiting distance between the conductors is probably smaller than would be calculated on the basis of ensuring that localised overheating occurs over the entire cross-section of the PTC material between the conductors. We have found that when a voltage is applied across the conductors then the PTC material heats up uniformly up to a certain critical separation of the conductors. If this is increased all the voltage drop suddenly shifts to a narrow section of the material where intense local overheating and run away occurs. The critical separation is a function of geometry, current density and ambient conditions.

The electrical conductors employed in the present invention may be of any convenient configuration such as for example flat, round, solid or stranded. If desired the surface of the electrical conductor may be nodulated, e.g. microscopically nodulated, to improve adhesion and reduce contact resistance. In this connection it is advantageous to use an activated conductor surface e.g. a highly oxidised surface to improve adhesion.

According to an especially preferred embodiment of the present invention the flexible heating element is of substantially dumb-bell or dog-bone cross section wherein a flexible electrical conductor spiralled around a core is positioned in each head of the dumb-bell or dog-bone.

The flexible heating element preferably has an electrically insulated layer over the positive temperature coefficient material, such layer being intended to confine and retain the shape of the PTC material during annealing temperatures at which the PTC material might otherwise tend to flow or deform. Suitable materials for performing these insulating and retaining functions are polyurethane, cross linked polyethylene, and thermal plastic rubber. Materials which include plasticizers which might migrate into and chemically alter the PTC copolymers should be avoided.

When producing flexible heating elements in the dumb-bell or dog-bone configuration the conductors are spiralled around a core. Thus, for example, the conductor may be wound around a core of for example glass fibre. It has been found that heating elements in the dog-bone configuration with a spiralled core (i.e. with the conductor wound around a core) possess good flexibility when compared with flexible wires described in the literature and are thus of particular interest in fields where flexibility of wire is essential. Flexible heating elements having the dog-bone configuration with a spiralled core are thus of particular interest for use in electric blankets. We have found that wires wrapped around a core may have a tendency to curl up as a result of the stresses produced by the wrapped conductors. In a preferred embodiment of the present invention the conductor wire is wrapped around one core in one direction and around the other core in the opposite direction or a back twisting procedure may be employed. Alternatively both procedures may be adopted. This preferred embodiment enables the tendency for the wires to curl up, to be substantially reduced. Moreover when the conductor wires are wrapped around each core in the same direction without back twisting, it has been found that the twisting or wire causes the two conductors on their cores to come together during extrusion of the dog-bone configuration resulting in varying resistance values over the length of the heater element. The last-mentioned preferred embodiment avoids, at least in part, this disadvantage.

In a particularly preferred embodiment the conductors are coated e.g. dip-coated with a colloidal graphite solution and cured. As stated above the graphite appears to enter the core portion providing an increased conductor cross-section and reducing overall resistance.

In operation of the heater element of the present invention current passes from one conductor to the other through the positive temperature coefficient material via the conductive rubber. The voltage applied to the conducting rubber surfaces allows them to dissipate the desired quantity of heat. If localised overheating occurs anywhere along the length of the wire then the PTC material increases in resistance thereby reducing the voltage of the conducting rubber conductors which in turn reduces the heat dissipated.

A specifically preferred embodiment of the flexible heating element of the present invention in

dog-bone configuration is hereinafter described with reference to the accompanying drawing.

According to a further feature of the present invention there is provided a process for producing a flexible heating element as hereinbefore defined which comprises extruding the amorphous highly conductive rubber to cover each flexible electrical conductor and subsequently or simultaneously extruding the PTC material to cover the amorphous highly conductive rubber.

The present invention also relates to a method of producing a flexible heating element in the dog-bone configuration as well as to apparatus therefor.

In a preferred embodiment of the process of the present invention the extrusion is effected using a die comprising means for feeding two spaced-apart, flexible electrical conductors through the die, means for extruding an amorphous highly conductive rubber to cover each of the said conductors, and means for extruding a positibe temperature coefficient material so as to cover said rubber and to fill the space between the conductors. Preferably the die is provided with means for adjusting the relative orientation and/or position of guide means for the conductors, a die head for the rubber and/or a die head for the positive temperature coefficient material.

In a further preferred feature, at least part of a die head for the rubber is made of a heat insulating material which is, however, capable of withstanding the extrusion temperatures, such as nylon polytetrafluoroethylene or asbestos based compositions. The use of such a material prevents heat from the positive temperature coefficient material from heating the rubber to undesirabel temperatures at which prevulcanisation of the rubber tends to occur. Alternatively or in addition, air gaps may be arranged between the two die heads.

The positive temperature coefficient material is preferably supplied from an extruder to an annular chamber connected by an annular passage to the respective die head, whereby a uniform distribution of the material is obtained.

We have found that it is important to make a careful choice of carbon blacks if the required electrical conductivity is to be achieved without affecting flexibility and flex life. In fact it is possible to select different carbon blacks in order to give the desired result, different types of carbon black having very different effects on the resistance and the PTC characteristics of the heater element. Certain carbon blacks, for example, exert such a substantial affect that even a small amount will modify the resistance of the heater element considerably. Thus while theoretically a single carbon black could be used we have found it especially advantageous to dilute the effect of one carbon black with another type of carbon black or other types of carbon blacks. The mixing of carbon blacks has resulted in improved reproducibility and has been described in Polymer Engineering Science, June, 1978, Vol 18, No. 8 pages 649-653 and in Journal of Applied Polymer Science, Vol 22, 1163-1165 (1978). We have found in our own experiments that mixtures of Vulcan P (moderately conductive carbon black) and Ketjen EC (highly conductive carbon black) have proved to be especially advantageous.

After extrusion of the PTC material through the extrusion die it is found that the PTC material possesses a very high resistance. It is therefore important to effect annealing in order to reduce the resistance of the PTC extrudate. Annealing may be effected either by heating the material above its melting point for a short period or by heating the material to just below its melting point for a longer period. Heating of the material above its melting point requires the provision of a jacket to prevent flowing and distortion of the PTC material.

It has been found important to anneal at the correct temperature if optimum resistance requirements are to be obtained. In certain circumstances annealing may result in anomalous resistance characteristics with varying temperature. Thus, for example, it has been found that annealing at an incorrect temperature may result in a PTC material with a room temperature resistance after heating to the anomaly point which is much lower than the room temperature resistance after annealing.

Where the active material is a HD Polyethylene and the PTC element comprises polyethylene, butyl rubber, carbon black and at least 3phr of antioxidant we have found the preferred annealing temperature to be 130°C.

An antioxidant is generally employed in the formulation of the heater element and this substance may have a profound affect on annealing behaviour. Thus, for example, we have found that if very large quantities of an antioxidant are used the resistance of the element may be reduced on annealing whereas if smaller quantities of the antioxidant are used the resistance of the element may increase on annealing if the annealing is not conducted at the optimum temperature. It therefore appears that there is an antioxidant level above which no rise in resistance with low temperatures is observed. A preferred antioxidant for use with the present invention is 2,5-ditertiary amyl hydroquinone (e.g. Santovar A), and the antioxidant level above which no rise in resistance with low temperatures is observed for this compound is about 3 phr to 5 phr.

The present invention will now be illustrated by way of example with reference to the accompanying drawings.

Figure 1 shows a cross-section through a heating element of the present invention having the dog-bone configuration;

Figure 2 shows a longitudinal cross-section through a preferred embodiment of a die of the present invention.

In Figure 1 the graphite (DAG) coated spiralled copper conductor on core 1 is surrounded by a

non-PTC conducting rubber 2 which serves to reduce contact resistance. Each conducting rubber extruded conductor is incorporated in opposite ends of a dog-bone shaped positive temperature coefficient polyethylene material 3 which serves as a self-limiting heater and this material is surrounded by TPR insulation 4.

As shown in Figure 2, a die according to the invention comprises a mandrel 1 having an aperture 2 extending the length thereof, through which are fed two spread-apart, flexible electrical conductors 3. The aperture 2 terminates in two separate apertures 4 for maintaining the desired spacing of the conductors. An amorphous conductive rubber is supplied to a first die head 5 by a first extruder (not shown) after flowing around the mandrel 1. The die head 5 comprises a cylindrical member 6 made of a material having a low thermal conductivity, such as nylon polytetrafluoroethylene or asbestos based compositions. The member 6 is surrounded by a protective steel ring 7 and is provided with a steel die plate 8 having two apertures therethrough, whereby as each of the conductors 3 passes through the die plate 8, it is coated with the rubber.

A second extruder (not shown) supplies a positive temperature coefficient plastics material to a second die head 9. The plastics is supplied first to an annulus 10, whereafter it flows through a narrow annular channel 11 into the die head 9. By virtue of this arrangement, the plastics material is distributed uniformly about the axes of the wires 3. The wires, together with the co-extruded rubber and plastics material leave the die head 9 through a "dog-bone" shaped aperture 12, so that the plastic surrounds the rubber-coated conductors and fills the space between the conductors.

An annular member 13 surrounds the die head 5 and is secured to a body member 14 by mens of a plurality of bolts 15. Four adjusting bolts 16 extend through the member 13 for adjusting the position of the die head 5 relative to the body member 14. The mandrel 1 is mounted to the body member 14 by means of a plate 17 bolted to the body member 14, so that the position of the mandrel relative to the body member 14 is adjustable. The mandrel is further rotatable relative to the plate 17, by loosening a nut 18 and rotating the mandrel by means of flats 19. The die head 9 is rotatable by means of a tool which fits into two recesses 20, whereby the dog-bone shaped aperture 12 can be aligned with the rubber coated conductors. Finally, concentricity between the die head 9 and the coated conductors is adjustable by means of a plurality of bolts 21.

The following Examples illustrate the production of heater elements according to the present invention:—

EXAMPLES:

Heater elements of dog-bone configuration suitable for use in electric blankets are produced as follows:—

1. WIRE

Tinned copper strip or ribbon is wound round a glass core in one direction to give a spiralled core. Tinned copper strip or ribbon is also wound round another glass core in the opposite direction to that employed for the first spiralled core to give two spiralled cores suitable for positioning in opposite heads of the dog-bone configuration.

Each spiralled core is dip-coated using a solution of colloidal graphite in ethanol (DAG 508).

2. EXTRUDED HEATER ELEMENT

The two spiralled cores having the tinned copper strip or ribbon wound in opposite directions are fed into the apparatus of the present invention specifically described herein. The amorphous conductive rubber applied to the first die head (5) by a first extruder is an epichlorohydrin rubber (Herchlor C). The PTC materials applied to the second die head (9) via the second extruder are set out in the following table, in which all parts are parts by weight:—

	A	B	C
Vestolen Type No. A 554	—	100	100
Alathon No. 7030	100	—	—
Polysar butyl type No. 301	—	40	40
Santovar A	1	1	1
Ketjen EC	—	4	4
Vulcan P	26	9	13

The ingredients of each of the PTC materials were mixed together as follows prior to introduction to the second extruder:—

The temperature of a Banbury mixer was raised to 150°C and the Vestolen Type No. A 554 or Alathon No. 7030 were added to the mixer together with Santovar A and, where appropriate, the Polysar butyl type No. 301. The mixer was run until the stock reached 120°C and the time was noted. The carbon blacks (Ketjen EC and Vulcan P) were then added and the clock reset to zero. The mixer was run until the temperature reached 150°C, at which point the steam was turned off and cooling water turned on. Mixing was then continued for ten minutes from the time of adding the carbon blacks and the chart temperature noted. The mix was then dumped and the temperature of the stock taken with a needle pyrometer. Mixing was then continued for a further ten minutes on a mill at 170°C.

The three different PTC mixes A, B and C were then introduced in turn into the above-mentioned co-extruder of the present invention in order to obtain three different heater element samples by extrusion. In this connection the PTC material is used as the heater and the control while the amorphous conductive rubber interlayer serves to reduce contact resistance.

3. INSULATING COATING

The three separate heater element samples prepared as described above were each covered with an extruded insulating layer of TPR to give three different heater elements in dog-bone configuration.

4. ANNEALING

Each of the three heater elements was then subjected to annealing in a fluidised bed at 130°C.

Heater elements according to the present invention were also produced as described above but using the following formulations for the PTC materials:

No.	Vestolen A5544	Santovar A	Butyl 301	Herchlor C	Ketjen EC	Vulcan P	Vulcan 3
4	100	5	30	—	4	11	—
5	100	5	30	—	4	—	14
6	100	5	30	—	—	22	—
7	100	5	40	—	4	12	—
8	100	5	40	—	4	—	15
9	100	5	40	—	—	24	—
10	100	2	—	30	4	8	—
11	100	2	—	30	4	—	10
12	100	2	—	30	—	16	—
13	100	2	—	40	4	7	—
14	100	2	—	40	4	—	9
15	100	2	—	40	—	14	—
16	100	2	—	40	3	11	—
17	100	2	—	40	3	—	14

CLAIMS

1. A flexible heating element for use in an electric blanket which comprises at least two flexible electrical conductors spaced apart by a PTC material, an amorphous highly conductive rubber compatible with the said PTC material and adhered to each conductor being interposed between the PTC material and each conductor whereby in use current passes from one conductor to another through the PTC material via the said highly conductive rubber, the conductors being spaced sufficiently close to one another to ensure that when energised the PTC material heats substantially uniformly without exhibiting a significant temperature gradient between the conductors and that any abnormal temperature increase increases the temperature of all the PTC material between the conductors in the region of the abnormal temperature increase, the arrangement being such that in use the contact

resistance between the conductors and the PTC material is reduced by the amorphous highly conductive rubber interposed therebetween.

2. A heating element as claimed in claim 1 wherein the PTC material comprises a polymer having a glass transition temperature of from −125° to −75°C.

3. A heating element as claimed in claim 1 or claim 2 wherein the PTC material comprises a polyolefin.

4. A heating element as claimed in any one of claims 1 to 3 wherein the PTC material comprises polyethylene, polypropylene, ethylene-propylene copolymers or terpolymers thereof with non-conjugated dienes.

5. A heating element as claimed in any one of the preceding claims wherein the PTC material comprises high density polyethylene.

6. A heating element as claimed in any one of the preceding claims wherein the PTC material comprises 2,5-ditertiary amyl hydroquinone as antioxidant in an amount of 3-5 phr.

7. A heating element as claimed in any one of the preceding claims wherein the amorphous highly conductive rubber comprises an epichlorohydrin rubber.

8. A heating element as claimed in claim 7 wherein the epichlorohydrin rubber contains about 35% ethylene oxide.

9. A heating element as claimed in claim 8 wherein the amorphous highly conductive rubber contains about 65% epichlorohydrin rubber and about 35% ethylene oxide.

10. A heating element as claimed in any one of claims 1 to 6 wherein the amorphous highly conductive rubber comprises butyl rubber or chlorinated butyl rubber.

11. A heating element as claimed in any one of the preceding claims wherein the conductor comprises copper, silver, tin, nickel or aluminium or an alloy thereof.

12. A heating element as claimed in claim 11 wherein the conductor comprises copper containing about 1% by weight cadmium.

13. A heating element as claimed in claim 11 or claim 12 wherein the conductor comprises copper plated with silver, tin or nickel.

14. A heating element as claimed in any one of the preceding claims wherein the conductor is nodulated.

15. A heating element as claimed in any one of the preceding claims wherein the surface of the conductor is activated.

16. A heating element as claimed in any one of the preceding claims wherein a layer of graphite is interposed between the amorphous highly conductive rubber and the conductor.

17. A heating element as claimed in any one of the preceding claims of substantially dumb-bell or dog-bone cross section wherein a flexible electrical conductor spiralled around a core is positioned in each head of the dumb-bell or dog-bone.

18. A heating element as claimed in claim 17 wherein the core comprises glass fibre.

19. A heating element as claimed in claim 17 or claim 18 wherein the flexible electrical conductor is spiralled around the core in one direction in one head of the dumb-bell or dog-bone and the flexible electrical conductor is spiralled around the core in the opposite direction in the other head of the dumb-bell or dog-bone.

20. A heating element as claimed in any one of claims 17-19 wherein the flexible electrical conductor is spiralled around the core by back twisting.

21. A heating element as claimed in any one of the preceding claims provided with an outer electrically insulating layer of polyurethane, cross-linked polyethylene or thermal plastic rubber.

22. A flexible heating element as claimed in claim 1 substantially as herein described with reference to Fig. 1.

23. A flexible heating element substantially as herein described in any one of the Examples.

24. A process for producing a flexible heating element as claimed in any one of the preceding claims which comprises extruding the amorphous highly conductive rubber to cover each flexible electrical conductor and subsequently or simultaneously extruding the PTC material to cover the amorphous highly conductive rubber.

25. A process as claimed in claim 24 wherein each flexible electrical conductor is coated with a colloidal graphite solution and cured prior to extrusion of the amorphous highly conductive rubber thereover.

26. A process as claimed in claim 25 wherein each flexible electrical conductor is dip coated with the colloidal graphite solution.

27. A process as claimed in any one of claims 24 to 26 wherein each flexible electrical conductor, in the form of a spiralled wire, is covered with the amorphous highly conductive rubber and the PTC material extruded over the amorphous highly conductive rubber whereby curing of the amorphous rubber is effected during extrusion.

28. A process as claimed in any one of claims 24-27 wherein annealing is effected whereby to reduce the resistance of the positive temperature coefficient extrudate.

29. A process as claimed in claim 28 wherein the positive temperature coefficient material comprises high density polyethylene, butyl rubber, carbon black and at least 3 phr of an antioxidant and

in which annealing is effected at about 130°C.

30. A process as claimed in claim 24 substantially as herein described.

31. A process for the production of a flexible heating element substantially as herein described in any one of the Examples.

32. A flexible heating element as claimed in claim 1 when prepared by a process as claimed in claim 24.

33. A die for producing a flexible heating element according to the invention by co-extrusion, the die comprising means for feeding two spaced-apart, flexible electrical conductors through the die, means for extruding an amorphous highly conductive rubber to cover each of the said conductors, and means for extruding a positive temperature coefficient material so as to cover said rubber and to fill the space between the conductors.

34. A die as claimed in claim 33 provided with means for adjusting the relative orientation and/or position of guide means for the conductors, a die head for the amorphous rubber and/or a die head for the positive temperature coefficient material.

35. A die as claimed in claim 33 or claim 34 wherein at least part of the die head for the amorphous rubber comprises a heat insulating material capable of withstanding the extrusion temperatures.

36. A die as claimed in claim 35 wherein the heat insulating material comprises nylon, polytetrafluoroethylene or asbestos.

37. A die as claimed in any one of claims 34 to 36 wherein air gaps are provided between the die head for the positive temperature coefficient material and the die hed for the amorphous rubber.

38. A die as claimed in any one of claims 34 to 37 wherein the positive temperature coefficient material is supplied from an extruder to an annular chamber connected by an annular passage to the die head for the positive temperature coefficient material.

39. A die substantially as herein described with reference to Fig. 2.

40. A process for producing a flexible heating element as claimed in any one of claims 24 to 31 wherein a die as claimed in any one of claims 33 to 39 is used.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1981. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.