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2,559,077

RESISTANCE ELEMENT AND METHOD OF PREPARING SAME

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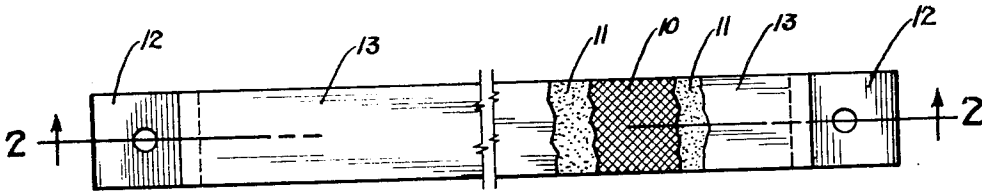


FIG. 1

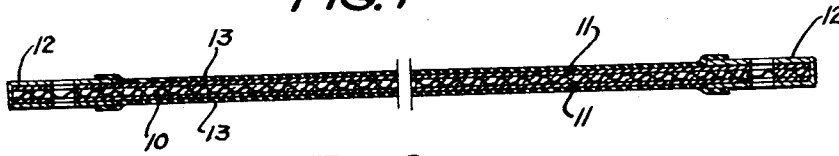


FIG. 2

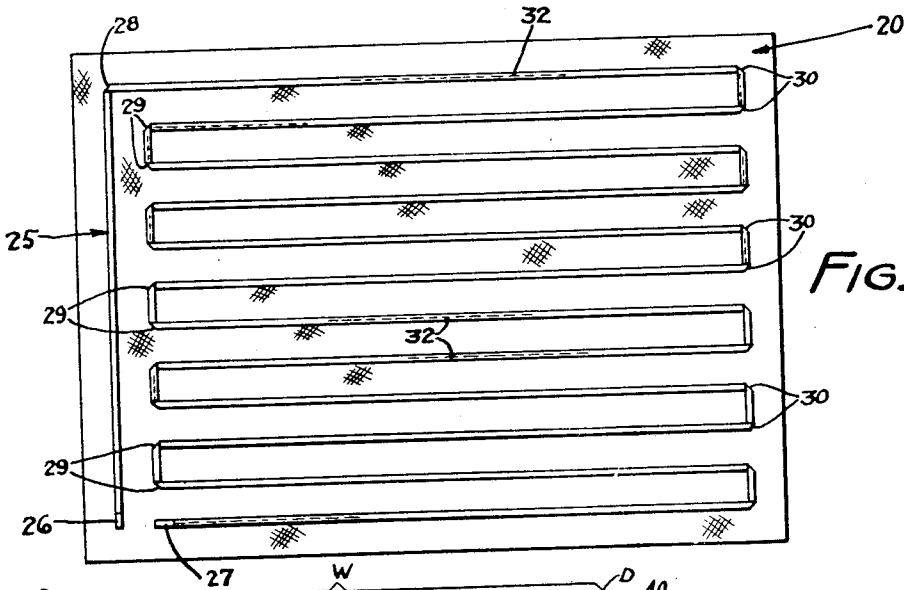


FIG. 3

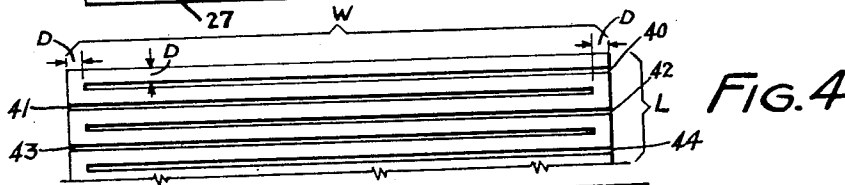


FIG. 4

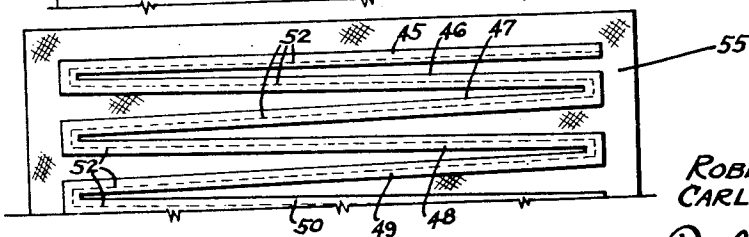


FIG. 5

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4 Claims. (Cl. 201—46)

1

This invention relates to electrical heating elements and more particularly to heating elements of flat or curved surface types and flexible types. The invention is especially suitable for use wherever it is desired to conform the heating element to a curved surface or where it is desired to use the heating element in a pad or the like which may be subjected to bending during use. The invention also relates to methods of making such elements.

It has heretofore been the practice to utilize metallic wire conductors for heating elements requiring flexibility and to insulate those heating elements with any available insulation, such as asbestos fiber, organic insulations and the like. The heating elements of this character heretofore available have been subject to the disadvantage that the insulation has been incapable of being heated beyond the point of decomposition of the organic constituents in the insulating media and the covering of the element, and as a result the temperatures of operation of such heating elements have been very limited. Furthermore, the flexibility of wire heating elements is very limited.

It is an object of the present invention to provide an improved heating element and particularly to provide a heating element of highly flexible character, capable of being fabricated into thin sheets or the like, and suitable for use under conditions of increased temperature and where extreme curvature or extreme and frequent variations in curvature are likely to occur. It is also an object to provide a heating element capable of producing immediate heating over a wide area, either flat, curved and/or flexible. It is a further object to provide an improved heating element utilizing a conductive polysilicone mixture base material as the heating element itself. It is a further object of the invention to provide a method of manufacturing heating elements and components thereof.

Other and further objects of the invention are those inherent in the methods and apparatuses herein illustrated, described and claimed.

The invention is illustrated with reference to the drawings in which corresponding numerals refer to the same parts and in which

Figure 1 is a plan view, partly in section, illustrating one type of heating element of the present invention;

Figure 2 is a sectional view taken along the lines 2—2 of Figure 1;

Figure 3 is a plan view illustrating certain of the component parts of a heating pad utilizing

2

the improved heating element of the present invention;

Figure 4 is a plan view of a heating element of the present invention during the course of manufacture and Figure 5 is a plan view of the same heating element showing an illustrative method of application.

In carrying out the present invention there is first prepared a mixture of finely divided electrically conductive material, such as colloidal carbon, graphite, the metallic carbides or finely divided metal, with a polysilicone base. A diluent (thinner) for the polysilicone may be added in some instance to facilitate mixing the ingredients together.

A wide variety of the polysilicones may be used in compounding the electrically conductive resistance material of the present invention. Any of these polysilicone materials which cure into a hard, usually pliable, film or mass when heated may be utilized in preparing the heating element composition. Thus, for example, there may be utilized a polysilicone resin such as Dow Corning silicone resin No. 993 containing 70.7% solids, or polysilicones of somewhat lower or higher molecular weight.

The polysilicones, per se, are electrically non-conductive even at high temperatures and, for example, Dow Corning silicone resin No. 993 can be operated continuously at temperatures of 175° C. and for short intervals at temperatures up to 250° C. We have discovered that an electrically conductive mixture of great serviceability and stability may be prepared by adding to the polysilicone base an electrically conductive material, such as carbon black (sometimes called colloidal carbon), or equally finely divided metals, graphite or metallic carbides. The specific resistance of the mixture may be varied widely by varying the amount and kind of electrically conductive substance added. Thus, there may be used Columbia Carbon Company "Micronex" carbon black, which has a comparatively high electrical resistance, "Supertex" carbon black by the same company, which has a medium electrical resistance. Any desired grade or kind of carbon black not intended for insulating purposes and having a low, medium or high electrical resistance may be used. Carbon blacks are sometimes designated colloidal carbon and the terms are used interchangeably in the trade. The term carbon black is used hereinafter in the specification and claims.

The mixture of polysilicone, the electrically conductive substance (e. g. carbon black or ex-

3

tremely finely divided metals, graphite, conductive carbides or conductive oxides or salts), together with a diluent for the polysilicone, when used, are thoroughly admixed in a ball or rod mill or in a Banbury mixer until a thoroughly homogeneous mass is obtained. The proportion of conductive substance, polysilicone and diluent, if used, may be varied to accommodate the resultant mixture to the method used in its application. Thus, where the resistance mixture is extruded, very little or no diluent or thinner is needed, but for coating applications a diluent or thinner is desirable in that the resultant mixture is more fluid and it spreads and adheres more readily to bases to which it is applied.

The resistance element mixture of polysilicone, the resistance material, with or without a diluent (thinner), is then applied. In some applications the mixture is simply extruded in rods, sheets, films or strips. In other applications the mixture is coated onto a base material which may be filaments, threads, sheets, yarn or woven fabrics. A very desirable base is a sheet, strip, tape or filament of cured polysilicone resin itself. Other desirable bases are woven or filamentary shapes, such as tape, cloth, parallel thread fabrics, etc., made from fiber glass or asbestos. The base material should be capable of withstanding the temperatures to which the resistance mixture itself is capable of being heated.

The extruded sections of the polysilicone-conductive material mixture or the cross section of the coating of polysilicone-conductive material on a base material, where a base material is used as a support, may be widely varied so as to determine the heat developed per unit of area of the finished resistance element. The extruded section or coated base may be formed while still in plastic condition into any desired shape.

The resistance material mixture of polysilicone and conductive material, whether alone or as a coating on a base material, is then dried by warming to drive off any diluent or thinner that may have been included to facilitate working the mixture, and is then heated to an elevated temperature to cure and set the polysilicone-conductive material mixture into a cured state. The warming period is especially important where a diluent or solvent has been incorporated into the original resistance material mixture to facilitate mixing, spreading or coating. Usually a warming period of one-half hour to one and one-half hours at about 100° C. will drive off the diluent or solvent without causing undesirable bubble formation. The criteria at this stage is to cause evolution of the diluent or solvent without causing bubbles to form therein and thus obtain a homogeneous mixture of the polysilicone and conductive material. The time period and temperature of warming are accordingly varied to accomplish this end.

After the warming period, the temperature is gradually raised and is held at about 275° C. for about two hours. This causes the polysilicone resin-like material to cure and to set into a relatively tough mass (or coating).

It is frequently desirable then to provide an insulating coating on top of the polysilicone-conductive material resistance element where the resistance element has been extruded and cured into a set form and also where the resistance element has been applied by coating it onto a filamentous strand, sheet, strip or woven cloth base. To accomplish this there is next applied to the extrusions or to the coated base material

4

a further coating of polysilicone resin which may, if desired, be sufficiently diluted so as to facilitate the application of the coating. The thickness of the insulating coating may be varied in accordance with the intended use. The resistance element, with coating applied, is then put through a warming and final curing process, as previously described, that is to say, the coated element is preliminarily warmed for about one-half hour to about one and one-half hours at about 100° C. so as harmlessly to drive off the diluent or solvent, where used, without the formation of bubbles in the coating. The temperature may then safely be raised to around 250° C. for about two hours, during which the polysilicone resin coating is cured into a relatively tough electrically non-conductive coating.

It is frequently desirable to apply terminals to the electrical resistance element before applying the final electrically non-conductive polysilicone coating. The terminals may be applied by crimping, perforating or otherwise fastening metal strips or plates to appropriate places in the electrical resistance element. Alternatively, it is possible to electroplate an electrically conductive metal terminal at appropriate places in the electrical resistance element. This is done by usual electroplating procedures, and there is accordingly deposited a plated metallic area which serves admirably to facilitate connection of outside circuits to the electrical resistance element. Thereafter, the polysilicone resin electrically non-conductive coating may be applied to any desired portion of the resistance element.

By way of further illustrating the method and products of the invention, but without any limitation thereon, there is included the following example in which all parts are parts by weight unless otherwise stated.

Example

To three parts of Dow Corning silicone resin No. 993 there was added one part of acetylene carbon black. As received the Dow Corning resin contained 70.7% solids, and the calculation of the weights of silicone resin was therefore made on the basis of solids content. To the mixture there was also added 75 cc. of heptane for each 20 gm. silicone resin (dry basis) used and the mixture was placed in a ball mill and milled for two hours so as to produce an entirely homogeneous mixture of silicone resin, conductive material (acetylene carbon black) and diluent (heptane). The mixture is a highly viscous paste after milling.

The mixture was then coated onto a sheet of fiber glass cloth, the coating being about 12 mils thick. It may be pointed out that the resistance per unit of length of the finished product depends upon the thickness of the coat, the width of the strip, the concentration of the conductive material (in this instance acetylene carbon black), the type of conductive material, that is to say whether it has a high or low specific resistance. The specific dimensions given in the present example are, therefore, merely illustrative. The coated sheet was then electroplated with a copper plating at its ends so as to provide a terminal area, and was thereafter placed in an oven for one-half hour at approximately 100° C. until the coating became tacky. At this stage most of the heptane diluent was evaporated, and accordingly the danger of bubble formation in the coating was minimized. The coated strip was then placed in a cool oven and the tempera-

ture of the oven was then gradually raised to 250° C. and the coated strip heated at this temperature for approximately two hours in order to cure the polysilicone-conductive material mixture. By placing the strip in a cool oven and gradually heating to the curing temperature, the danger of bubble formation at this stage is likewise minimized. The sheet with terminals applied at each end thereof was then cut into strips of varying width and utilized as heating elements by connecting to external circuits.

Some of the resistance element strips were insulated by applying a coating of polysilicone resin as received. The polysilicone resin was then coated onto the already prepared resistance element except for the terminal areas, the thickness of the coating being approximately 8 mils. The insulated strips were then warmed for one-half hour at 100° C. and were then removed to a cool oven which was gradually raised to 250° C. and held at that temperature for approximately two hours, during which time the polysilicone resin set into a hard insulating coating.

In some instances the coating was applied to wide strips of glass cloth and in other instances to tapes of woven glass cloth and woven asbestos cloth. The resistance elements were then wired into electric circuits and the current flow adjusted until the desired temperatures were attained. Adequate heating and heat distribution throughout the resistance strip area was obtained.

Referring to the drawings, Figures 1 and 2 illustrate the product resulting from the process described in the foregoing portions of the specification. A glass cloth or asbestos cloth base is illustrated at 10 and is coated with a polysilicone-resistance ingredient mixture illustrated at 11. After the strip coated with the polysilicone-resistance material ingredient has been dried and cured, it is then provided with crimped on or copper plated terminals 12 and is then provided with an insulating coating of polysilicone resin, as indicated at 13.

In Figure 3 there is illustrated a heating pad in which the main carrying element or flexible element of the pad is illustrated at 20. The element 20 may be of ordinary cloth, flannel or the like, or may be a previously formed sheet of polysilicone resin or polysilicone rubber, such as Silastic rubber produced by Dow Corning Corporation. Upon the base sheet 20 or to it there is attached a resistance element strip generally designated 25 which may conveniently be of the type shown in Figures 1 and 2. One terminal area is illustrated at 26, whereas the other terminal area is illustrated at 27. The resistance element strip 25, produced in accordance with the present invention, is exceedingly flexible and is accordingly capable of being folded over on itself as indicated at the corners 28, 29 and 30. Where the base material 20 is of ordinary woven cloth, such as flannel or blanket material, the strip 25 may be fastened in place by basting, or it may be fastened by stitching down the center of the strip, as indicated at 32. Where the base sheet 20 is a previously formed sheet of polysilicone resin, the resistance element strip 25 may be cemented in place by diluted polysilicone resin and a second sheet of previously formed polysilicone resin 20 applied as a covering and likewise cemented in place and cured. In this manner the heating element 25 is effectively bonded between two layers 20 of polysilicone resin sheet, and the entire mass may be cured between

heated pressure plates so as to form a comparatively homogenous heating pad which is thereafter, within limits, capable of being bent or curved into any desired shape.

As an alternative method of construction of the heating pad shown in Figure 3, the resistance element strip 25 may be formed directly in place upon a base sheet 20 of polysilicone rubber, such as a sheet of "Silastic." For this purpose the previously prepared mixture of polysilicone resin and resistance material, such as Dow Corning No. 993 polysilicone resin and carbon black as hereinbefore described, is coated as a strip upon the base sheet 20, the strip being curved wherever desired so as to continue back and forth, thereby generally covering the entire area to be heated. The sheet 20, with the resistance element strip coated thereon, is then warmed and cured so as to cure the polysilicone resin on the resistance strip, per se, as hereinbefore described. Thereafter, the sheet 20 may be insulated by coating the entire sheet with a mixture of polysilicone resin and diluent, if desired, which is then warmed so as to drive off the diluent, and then heated to an elevated temperature, for example 250° C., to cure the polysilicone resin non-conductive layer. Alternatively, a polysilicone resin and diluent may be coated in a strip, back and forth on a sheet 20 of Dow Corning polysilicone rubber Silastic, and the unit preliminarily warmed so as to drive off most of the diluent and until the resistance strip layer becomes tacky. Then a second sheet 20 of polysilicone rubber, such as Dow Corning Silastic, is placed upon the bottom layer 20 carrying the coated-on resistance strip 25, and the entire unit placed between heated pressure plates for curing purposes. It may be pointed out that the pressure plates used for curing during the final cure may, if desired, be curved so that the final element is shaped to fit any particular application desired, such as the leading edge of an airplane wing, as during the making of de-icing shields, or as the leading edge of propellers where the de-icing shield is utilized for the propeller blade. Likewise, a wide variety of shapes and sizes of heating elements shaped to fit particular vessels or areas may be fashioned in this manner.

In Figures 4 and 5 there is illustrated another method of fabricating the resistance elements of the present invention. In Figure 4 there is illustrated a sheet having any length dimension L and any desired width dimension W which may be of base material, such as fiber glass cloth, asbestos fiber cloth or the like. The sheet is coated all over with a resistance element mixture of polysilicone resin and resistance ingredients, such as carbon black, and warmed and thereafter cured as previously described. Then to form the resistance strip, the sheet is cut in alternately from side to side, as indicated at 40, 41, 42, 43 and 44. The cuts 40, 42 and 44 extend from the right-hand edge to within a short distance of the left-hand edge, the distance D being approximately equal to the width of the resultant strip. Likewise, the cuts 41 and 43 extend from the left-hand side to within a similar distance D of the right-hand side of the sheet. In this way there is produced a zigzag strip of resistance element. The application of the resistance element of Figure 4 to any area to be heated is illustrated in Figure 5 where it will be noted that the resultant strip portions 45, 46, 47, 48, 49 and 50 are flexed apart so that the previously uniform spaces 48-49 are wider at their open end

than at their closed end. The flexing of the strip is easily accomplished due to its relatively thin and flexible character. The strip is then basted or sewed in place, as indicated by the stitching 52 and is thereby attached to any desired base sheet 55. As previously indicated the base sheet may be flannel, blanket cloth or the like for the low temperature installations, or where it is desired to provide more elevated temperatures, the base sheet may be of fiber asbestos cloth or fiber glass cloth. In the latter instances, of course, the stitching 52 is made utilizing fiber glass thread so that the stitching or basting will be resistant to the more elevated temperatures involved. It is understood, of course, that in installations as shown in Figures 4 and 5 suitable terminal areas are electroplated on so as to facilitate electrical connection of the unit to external circuits.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that we do not limit ourselves to the specific embodiments herein except as defined by the appended claims.

What we claim is:

1. The process of preparing an electrical heating element which comprises mixing acetylene carbon black, an uncured polysilicone resin and a solvent for said resinous material and milling said mixture until a homogeneous viscous electrically conductive and electrically resistant paste is obtained; coating a flexible non-conductive fabric with said viscous paste; heating said coated fabric at about 100° C. until said conductive coating becomes tacky; cooling said coated fabric and thereafter heating said coated fabric to about 250° C. to cure said resinous material.

2. The process as set forth in claim 1 wherein an electrical insulating coating is applied to said electrical heating element by applying a viscous coating consisting of a polysilicone resin and solvent therefor, heating said insulating coating to a temperature of about 100° C. until said coating becomes tacky, cooling said coated electrical heating element and thereafter heating said insulating coating to a temperature of about 250°

C. until said insulating coating of polysilicone resin hardens.

3. The process as set forth in claim 1 wherein said flexible non-conductive fabric coated with said homogeneous viscous electrically conductive and electrically resistant paste is electroplated at spaced intervals to deposit an electrically conductive coating thereon adapted to provide electrically conductive terminal areas and wherein said subsequently applied electrical insulating coating is applied only to said electrically conductive resinous coating.

4. An area of non-inflammable, electrically non-conductive base material coated with an electrical heating resistance composition comprising acetylene carbon black in a polysilicone varnish base, said area being provided with metallic electrical terminals in contact with the heating resistance composition and extending across the width of the area at spaced intervals along the length thereof, said metallic electrical terminals comprising electroplated metallic areas deposited on said heat resistance conductive coating thus providing flexible terminal portions, and wherein the area between said terminals is further coated with a flexible electrically non-conductive polysilicone coating.

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