Sept. 27, 1966 T. M. PLACE, SR 3,274,669

METHOD OF MAKING ELECTRICAL RESISTANCE ELEMENT

Original Filed Dec. 11, 1961

Fig. 1.

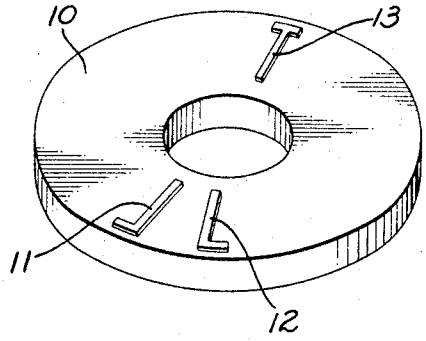


Fig. 2.

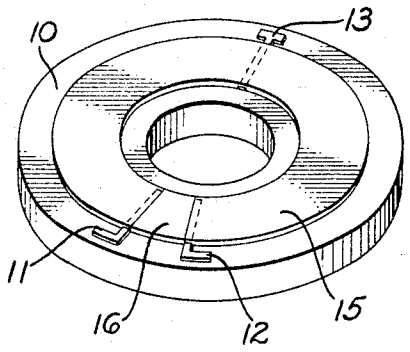
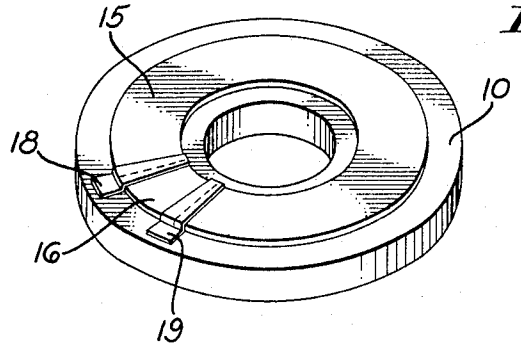


Fig. 3.



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3,274,669

METHOD OF MAKING ELECTRICAL RESISTANCE ELEMENT

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Original application Dec. 11, 1961, Ser. No. 158,317. Divided and this application Dec. 31, 1964, Ser. No. 435,767

4 Claims. (Cl. 29—155.7)

This is a division of my copending application, Serial No. 158,317, filed December 11, 1961, entitled Electrical Resistance Element and Method of Making Same.

This invention relates to a method of manufacturing a resistance element that is particularly suitable for use with variable resistors and potentiometers which have a wiper for traversing the resistance material. The inveniton is particularly directed to the manufacture of a resistance element which eliminates the discontinuities normally encountered by a wiper as it moves along the surface of the resistance element. The method of this invention is primarily intended for use in manufacture of rotary potentiometers which require full 360° or continuous rotation of the wiper, but of course can be used with resistance elements of any shape or form.

The invention is intended for use in the manufacture of resistance elements in which the resistance material is formed as a film on a nonconductive support or base and is specifically directed to the manufacture of resistance elements comprising fired mixtures of glass and metal, which are often referred to as cermet materials. A number of typical cermet resistance films and methods of making same are described in U.S. Patents Nos. 2,950,995 and 2,950,996.

In a rotary potentiometer using a film of resistance material on a base, the annular film necessarily is formed with a gap. The terminal connections are ordinarily applied to the resistance film at each edge of the gap and one or more additional terminal taps may be utilized along the film. Ordinarily the rotation of the wiper is limited to something less than 360° by mechanical stops to avoid traversing the gap in the film. When continuous rotation of the device was desired, the wiper would traverse the nonconductive gap or dead space, with a number of deleterious effects. While traversing the gap, the wiper rides on the base material, typically a high-temperature resistant and electrically nonconductive fired steatite or alumina having a relatively rough and highly abrasive surface. Excessive wiper wear results from this contact and the life of the unit is materially diminished. Electrically conductive particles are abraded from the wiper by contact with the base and are imbedded in the surface of the base forming a conductive path across the gap. Contact of the wiper with the edge of the resistance material at the gap produces wear of the resistance material and also results in changes in the driving torque required for the potentiometer, which torque variations are significant in some applications.

Electrical connections to a resistance film may be made in various ways, such as by pressure contacts or wires affixed to the film. The most widely used system is the application of a film of electrically conductive material onto the resistance film. The electrically conductive film, ordinarily a fired metal film, usually continues onto the base and provides a surface suitable for soldering or welding wires thereto.

Application of a terminal film onto the resistance film results in a zone of material raised above the surface of the resistance film. As the wiper moves over the terminal area, it is raised from the resistance material and then drops onto the resistance material, causing rapid degradation of the surface of the resistance material and

additional wear of the wiper. Metallic particles from the terminal strip are carried into the resistance element and into the gap introducing undesirable changes in resistance of the structure.

It is an object of the invention to provide a new and improved method of making a resistance element which will eliminate the problems discussed above.

It is also an object of the invention to provide new and improved methods for producing a resistance element having a nonconductive gap therein filled with resistance material of substantially the same type as used for forming the resistance element but made nonconductive.

The invention also comprises novel details of construction and novel combinations and arrangements of elements and steps, which will more fully appear in the course of the following description. The drawing merely shows and the description merely describes preferred embodiments of the present invention which are given by way of illustration or example.

In the drawing:

FIG. 1 is an isometric view of a base for a resistance element of a rotary potentiometer, with two end terminal strips and one tap terminal strip applied to the base;

FIG. 2 is an isometric view of the structure of FIG. 1 with the resistance film and nonconductive film applied; and

FIG. 3 is a view similar to that of FIG. 2 showing an alternative form of the invention.

The method of the present invention will be described hereinbelow as applied to a resistance element for a single turn rotary potentiometer. Of course, it is equally applicable to the manufacture of linear potentiometers and other forms of resistance elements.

The resistance element includes a support structure or base **10** which may have the form of an apertured disc as shown in FIG. 1. The base should be electrically nonconductive or have a nonconductive coating thereon and is preferably made of a refractory material such as steatite or alumina. In conventional practice, the steatite base is molded, fired, and ground or lapped to produce a smooth, flat surface for carrying the resistance film.

Terminal strips **11**, **12**, **13** of electrically conductive material are applied to the base **10**. The terminal strips may be applied by various of the known methods but it is preferred to use a metallic paste which is silk-screened onto the base and subsequently fired to convert the paste to a metal film.

A metallic paste may include a combination of metal and glass powders mixed with a volatile liquid carrier such as toluol, xylol, isopropyl alcohol, or even water. A suitable composition may comprise in percent by weight, silver 8.5, platinum 76.5, and lead borosilicate glass 15.0 The base with the paste terminal strips is then heated to convert the paste into a layer of metal which is firmly attached to the base. With the particular paste described above, the unit may be heated to 870° C. to 950° C. for a period of ten minutes.

A resistance film **15** is applied to the base **10** and overlies a portion of each of the terminal strips for making electrical contact with the strips. The resistance film **15** has a gap therein which ordinarily occurs between the terminal strips **11**, **12**, these terminal strips providing for electrical connection of the resistance element to an external circuit. The terminal strip **13** provides a tap for the resistance element and, of course, may be omitted or a number of taps may be used as desired for the particular circuit application.

An electrically nonconductive film **16** is applied to the base filling the gap between the ends of the resistance film **15**. The nonconductive film **16** is made substantially the same thickness as the resistance film **15** resulting in a continuous, smooth and substantially flat surface on

the resistance element for contact by the wiper. Of course, the nonconductive film **16** can be applied before the resistance film **15** if desired, and either order is intended to be covered in the specification and claims.

The resistance film and the nonconductive film may be produced in any of the conventional forms and methods now in use. It is preferred to utilize the ceramic-type materials and processes described in the aforementioned U.S. Patents Nos. 2,950,995 and 2,950,996. A viscous cermet resistance material mixture corresponding to one of the compositions described in the aforementioned patents may be placed on the base as by silk screening. The nonconductive film **16** may then be applied in the same manner using a viscous mixture of nonconductive material. The unit is then fired as described in detail in the aforementioned patents to produce a continuous glassy and substantially flat surface on the films.

Typically, the nonconductive film may be formed of a glass which is nonconductive, such as glass A, glass **1** or glass **2** of the aforementioned patents. However, it is preferred to form the nonconductive film of a cermet resistance material which is made nonconductive by the addition of a few percent (typically in the range of about 1–2 percent by weight) of another component which is relatively inert, not reacting with the glass component of either film. Suitable additives include the refractory oxides such as tin oxide, zirconium silicate, magnesium oxide, antimony oxide, and ground fired steatite. By making the resistance film and the nonconductive film of cermets and particularly of the same cermet, diffusion of material from one film to the other is substantially eliminated. Antimony oxide is preferred as the additive since it provides a superior surface on the fired film. A typical nonconductive cermet material may comprise in percent by weight, gold 2.50, platinum 1.67, antimony oxide 1.65, and glass A 94.18.

The reason why inclusion of a small amount of such additional component in a cermet resistance mixture produces a nonconductive film is not fully understood. However, it is presently felt that the additional component functions in the nature of a filler, separating the conductive metal particles in the film. Another explanation being considered is that the added component causes the metal particles to gather in large lumps and thereby interrupt the conduction path in the film.

The resistance material is applied as a viscous film overlying portions of the terminal strips. While this film is relatievly stiff, it flows slightly prior to and during the heating to form a smooth upper surface over the discontinuity produced by the terminal strips. Hence the resistance film will be slightly thinner where it overlies the terminal strips but the upper surface of the resistance element will be flat and no variations in contour will be encountered by the wiper as it traverses the films. The terminal strips are relatively thin in comparison with the resistance and nonconductive films. Typically a terminal strip will be in the order of 0.0001 inch thick while the films will be in the range of 0.0005 to 0.003 inch thick. Of course, the maximum firing temperature for the cermet films should be less than the melting point of the terminal strips so as not to disturb the terminal strips during the subsequent firing operation.

The resistance element of FIG. 2 is now ready for assembly in the usual manner to form a potentiometer. The wiper will traverse the upper surface of the resistance and nonconductor films which present a smooth, continuous and flat surface. There are no discontinuities or bumps or changes of elevation in the surface and the wiper never contacts the base material. Hence all of the disadvantages previously discussed are eliminated.

An alternative embodiment of the invention is shown in FIG. 3. In this form, the resistance film **15** and the nonconductive film **16** are applied to the base **10** in the usual manner, as by silk screening and firing, after which terminal strips **18, 19** are applied. The method of formation of the films and strips may be the same as described in the preceding embodiment. The arrangement of FIG. 3 would primarily be used in units wherein the films were quite thick in comparison to the terminal strips so that the minor discontinuity caused by the terminal strips would not be objectionable. It is desirable, although not essential, that the terminal strips be applied over the areas where the resistance film and the nonconductive films meet. If a fired terminal strip is used, of course the firing temperature should be below that which would produce melting of the film so as not to disturb the previously formed films.

Although exemplary embodiments of the invention have been disclosed and discussed, it will be understood that other applications of the invention are possible and that the embodiments disclosed may be subjected to various changes, modifications and substitutions without necessarily departing from the spirit of the invention.

I claim as my invention:

1. A method of making a resistance element, including the steps of:
   - applying a metallic paste to a nonconductive support structure in a thin layer to define a terminal;
   - heating the unit to a first temperature to convert the paste to a metal layer adhered to the support structure;
   - applying a cermet resistance material mixture to the support structure in a first film, with the film covering a portion of the metal layer and having a gap therein;
   - applying a cermet resistance material mixture with a refractory oxide additive therein to render said mixture nonconductive to the support structure in a second film and bridging the gap in the first film;
   - and heating the unit to a second temperature lower than the first temperature and lower than the melting point of the metallic constituents of the mixtures and exceeding the melting point of the glass constituents of the mixture to produce a continuous glassy and substantially flat surface.

2. A method of making a resistance element, including the steps of:
   - applying a cermet resistance material mixture to a nonconductive support structure in a first film having a gap therein;
   - applying a nonconductive cermet material mixture of substantially the same composition as the resistance material mixture to the support structure in a second film of substantially the same thickness as the first film and bridging the gap in the first film;
   - and heating the unit to a temperature lower than the melting point of the metallic constituents of the mixtures and exceeding the melting point of the glass constituents of the mixtures to produce a continuous glassy and substantially flat surface.

3. A method of making a resistance element, including the steps of:
   - applying a cermet resistance material mixture to a nonconductive support structure in a first film having a gap therein;
   - applying a cermet resistance mixture having up to a few percent by weight of antimony oxide therein to render said mixture nonconductive to the support structure in a second film of substantially the same thickness as the first film and bridging the gap in the first film;
   - and heating the unit to a temperature lower than the melting point of the metallic constituents of the mixtures and exceeding the melting point of the glass constituents of the mixtures to produce a continuous glassy and substantially flat surface.

4. A method of making a resistance element, including the steps of:
   - applying a cermet resistance material mixture to a nonconductive support structure in a first film having a gap therein;

Applying a cermet resistance material mixture having up to a few percent by weight of calcined steatite therein to render said mixture nonconductive to the support structure in a second film of substantially the same thickness as the first film and bridging the gap in the first film;

and heating the unit to a temperature lower than the melting point of the metallic constituents of the mixtures and exceeding the melting point of the glass constituents of the mixtures to produce a continuous glassy and substantially flat surface.

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