April 5, 1955 A. M. DAILY ET AL 2,705,749

VARIABLE ELECTRICAL RESISTOR AND METHOD OF MANUFACTURE

Filed May 13, 1952

2 Sheets-Sheet 1

Fig. 1.

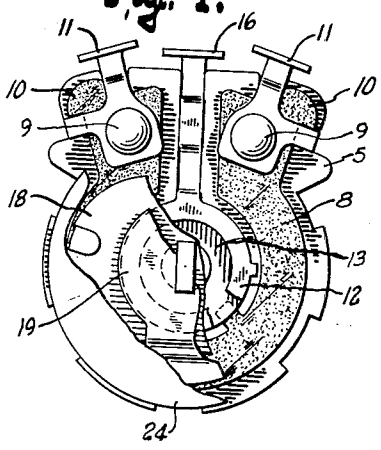


Fig. 2.

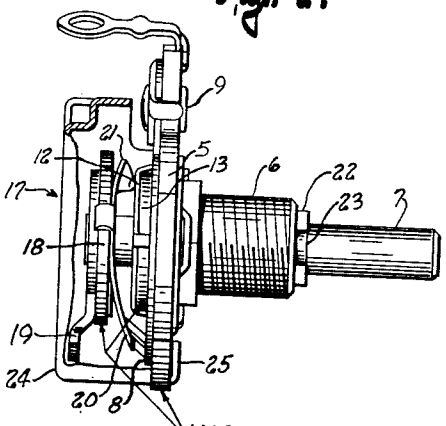


Fig. 3.

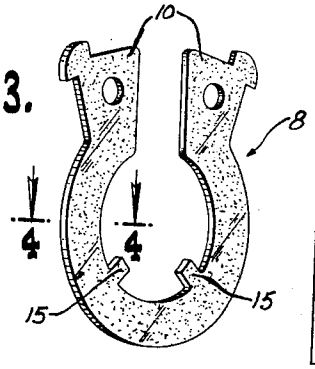


Fig. 5.

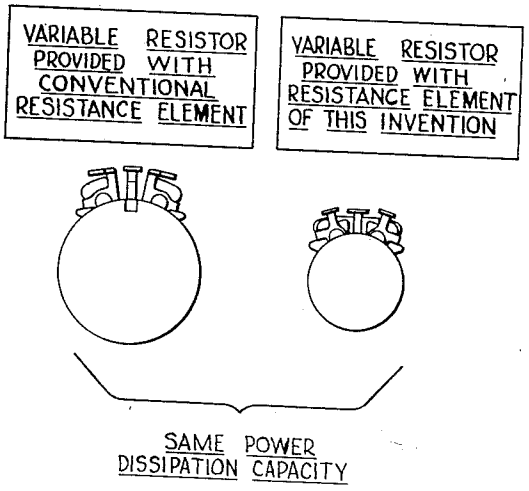
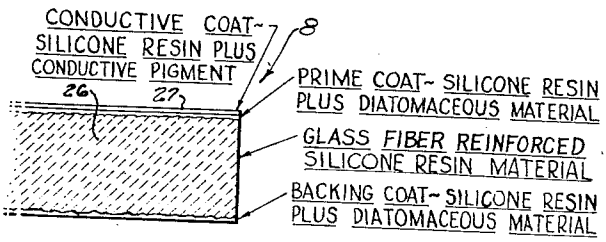


Fig. 4.



Inventors
Arthur M. Daily
Glenn M. Cocanower
By Bradshaw Jones
Attorney

April 5, 1955

A. M. DAILY ET AL

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VARIABLE ELECTRICAL RESISTOR AND METHOD OF MANUFACTURE

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2 Sheets-Sheet 2

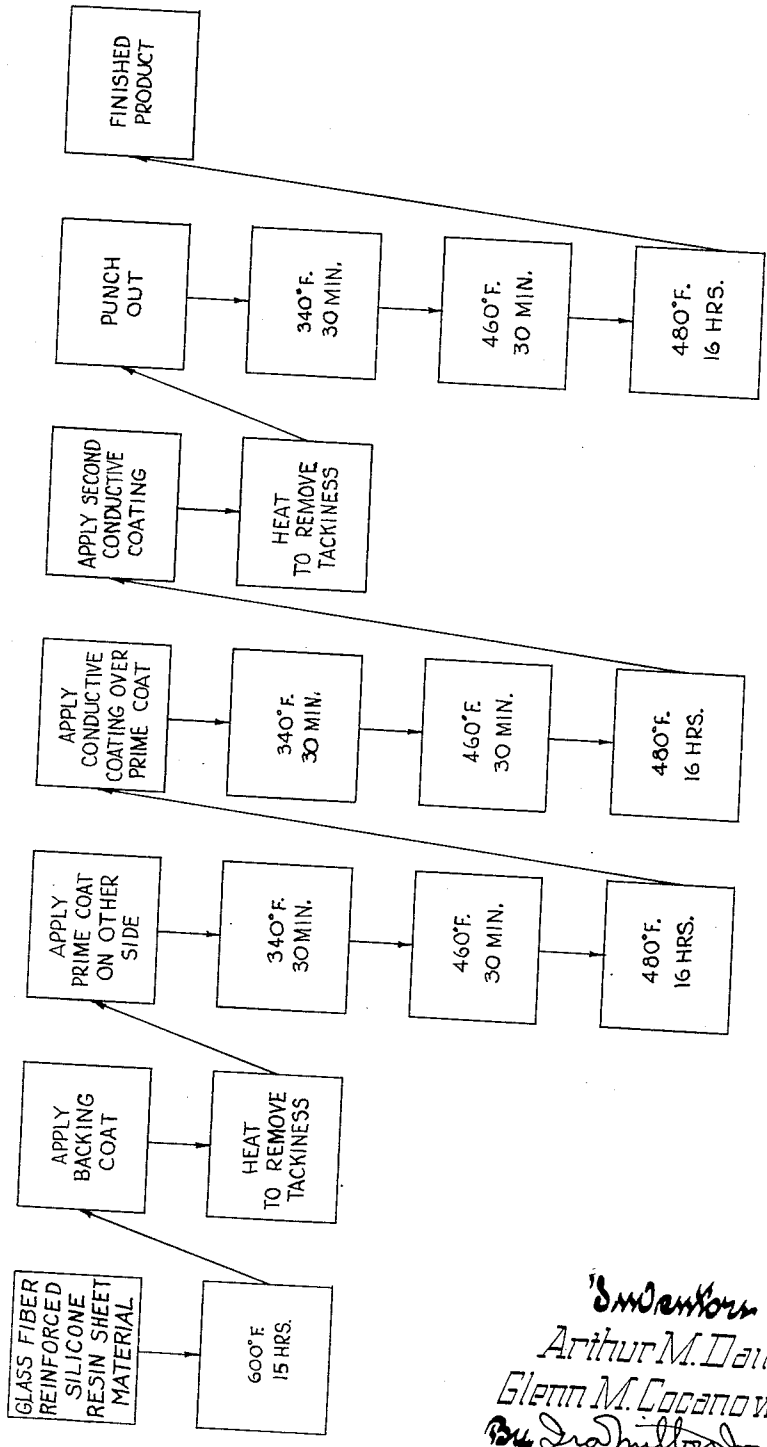


Fig. 6.

Inventors
Arthur M. Daily
Glenn M. Cocanower
By Drummond Jones
Attorney

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VARIABLE ELECTRICAL RESISTOR AND METHOD OF MANUFACTURE

Arthur M. Daily and Glenn M. Cocanower, Elkhart, Ind., assignors to Chicago Telephone Supply Corporation, Elkhart, Ind., a corporation of Indiana

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11 Claims. (Cl. 201—55)

This invention relates to variable resistors of the type wherein the resistance element comprises a conductive coating painted, sprayed or otherwise deposited, while in a liquid state, on a base of insulating material; and resides more particularly in a novel combination of supporting base and conductive coating.

The purpose of this invention is to provide a variable resistor of the type described which is electrically stable and in other respects capable of satisfactory operation at elevated temperatures on the order of 400° F., and under conditions of extreme humidity.

Another purpose or objective of this invention is to provide a resistor which is not only capable of satisfactory performance under conditions of high ambient temperatures or extreme humidity but also to achieve these results without increasing the overall size of the units or altering their physical design or mode of construction from that previously adopted.

Variable resistors of this type heretofore available could not meet these demands since the insulation employed therein, usually a laminated paper phenolic, ordinarily cannot maintain the desired high leakage resistance under extreme conditions of humidity and deteriorates at temperatures above 200° F., and also because the conductive coating was incapable of withstanding elevated temperatures.

This invention not only makes possible the achievement of this entirely unprecedented performance in a variable resistor of the type under consideration but in addition greatly increases the wattage that can be satisfactorily handled by a resistor of given size. Thus for instance, it has been found that with this invention the conventional sized 1⅛" overall diameter unit can have its wattage rating increased more than fourfold, and that a miniaturized version of the resistor having an overall diameter of only ¾" has a power dissipating capacity greater than that heretofore possessed by the 1⅛" diameter unit.

In the evolution of this invention the use of ceramics for the base to which the conductive coating is applied naturally suggested itself because of its known ability to withstand high heat, but ceramics are brittle and therefore do not lend themselves well to fabrication into small sized pieces or to the attachment of terminals thereto. Again, even if small size was not a compelling objective the relatively fragile and brittle quality of ceramics would increase rejections to an extent that commercially economical manufacture would be impossible.

Another serious disadvantage of ceramics results from its porosity. This makes it impossible to secure uniformity of resistance values since the degree to which the conductive coating penetrates a ceramic base is entirely unpredictable. All in all, tests showed that ceramics were not the answer to the problem to which this invention is addressed.

Moreover, the discovery or attainment of a suitable material for the base of the resistance element would solve only part of the problem. It is also necessary that the conductive coating, which constitutes the resistance per se, and hence can be considered the heart of the resistor, must be capable of withstanding the elevated temperatures contemplated, and perform satisfactorily under extreme conditions of humidity. But above all the conductive coating must be compatible, especially in a physical sense, with the material used for the base and be so attached to the base that extreme temperatures and rapid temperature changes encountered in use

and which often subject the base to great thermal shock will not create disruptive stresses in the conductive coating which might affect the stability of its resistance or the smoothness of its surface.

The solution to all of these problems has been found to reside in a resistance element having a relatively stiff base of thermo-setting high heat resistant resin such as the silicones, reinforced with a suitable high heat resistant material such as glass fibers, and a conductive coating composed essentially of silicone resin and a finely divided conductor in a suitable solvent, sprayed, painted or otherwise deposited on the base in such a way that despite the characteristic rough surface texture of the material used for the base the conductive coating has a smooth exterior surface to assure the necessary quietness in operation and is protected from the consequences of thermal shock within the base.

Silicone resins is the term generally applied by the art to thermo-setting resins composed essentially of organosilicon polymers. The finely divided conductor, often referred to as a conductive pigment, may be graphite, carbon black or the like.

Thermo-setting high heat resistant resins in reinforced relatively stiff sheet form suitable for use in the making of a resistance element of the type with which this invention is concerned are now available upon the open market. Some of the reinforced sheet material found to be satisfactory in the production of resistance elements were composed of silicone, melamine, high heat resistant phenolic and polyester resins with glass fibers, asbestos fibers, and/or mica flakes as the reinforcing agent.

The resistance to high heat and, the excellent dielectric and low-moisture absorption properties which characterizes these materials makes them ideally suited to the purpose of this invention but it was found that when resistance elements were made therefrom by painting a conductive coating having suitable high heat resistivity directly on the surface of the material as it comes from the manufacturer, the results were disappointing. The surface of the conductive coating cracked; it was rough and noisy; and it was impossible to gain uniformity in resistance values despite adherence to strict and careful control over the composition of the conductive coating and the manner of its application.

After considerable experimentation it was finally found that if the reinforced thermo-setting high heat resistant resin is adequately and properly heat cured and if measures are taken to cushion the conductive coating against the consequences of thermal shock in the base material and to assure a smooth contact surface for the coating, a resistance element is obtained which surpasses anything heretofore available.

In general, therefore, the invention contemplates subjecting the reinforced resin sheet material to a curing heat well above the maximum that might be encountered in use of the resistor and coating the surface thereof with a film of silicone resin and a filler material such as diatomaceous earth or its equivalent to fill and close the many surface depressions and interstices which are inherent in the base material and are aggravated by the shrinkage of the resin during the heat treatment, to thereby provide a smooth surfaced foundation for the conductive coating and a more-or-less pliable bond between the base and the conductive coating which cushions the conductive coating against the consequences of thermal shock within the base and assures a smooth contact surface.

While a description of the invention without benefit of drawings might be sufficient to those skilled in the art, for convenience and clarity the type of the variable resistor to which this invention pertains is illustrated in the accompanying drawings in which:

Figure 1 is an end view of the resistor with parts broken away;

Figure 2 is a side view thereof with parts broken away and in section;

Figure 3 is a perspective view of the resistance element per se;

Figure 4 is a cross sectional view through the resistance element on the plane of the line 4—4 in Figure 3 and at

a greatly enlarged scale and with the surface irregularities of its base exaggerated;

Figure 5 is an end view of two different sized resistors of the same type to illustrate one of the advantages of this invention, namely, size reduction without sacrificing ability to dissipate power; and

Figure 6 is a block diagram depicting one specific example of the procedure followed in the production of resistance elements in accordance with this invention.

Since the construction of the variable resistor generally, forms no part of this invention, a detailed illustration or description thereof is unnecessary. Hence, many of the details of construction are not illustrated in the drawing which is intended merely to depict the type of resistor with which this invention is concerned. Thus it is sufficient to observe that the resistor comprises a flat terminal head **5** of insulating material to the front of which a mounting bushing **6** is secured. This bushing provides the means by which the resistor is mounted and also affords a bearing in which the operating shaft **7** of the unit is journalled. The inner or back face of the terminal head has a resistance element indicated generally by the numeral **8** mounted thereon and held in place by rivets **9** which pass through terminal extensions **10** on the resistance element, the terminal head **5** and terminals **11**.

As best shown in Figure 3 the resistance element **8** is a split ring with the terminal extensions **10** projecting radially outwardly from its ends. Since the invention resides in the specific construction and composition of the resistance element it will be discussed in detail hereinafter.

At this juncture it should be observed, however, that a collector ring **12** is encircled by and positioned coaxially of the resistance element, and that an insulating washer **13** is interposed between the underside of the collector ring and a pair of tangs **15** extending radially inwardly of the inner edge of the resistance element. In this manner the collector ring acting through the washer **13** and the tangs **15** coacts with the rivets **9** to hold the resistance element flat against the terminal head. The collector ring **12** is, of course, of metal and has a terminal extension **16** projecting outwardly therefrom and suitably fastened to the terminal head.

The rotatable shaft **7** protrudes through the terminal head **5** and mounts a contactor assembly indicated generally by the numeral **17**. This contactor assembly includes an insulated drive head **18** and a metal stop plate **19** both nonrotatably secured to the end of the shaft, and resilient contactor fingers **20** and **21** which ride respectively on the surface of the resistance element and the collector ring.

A C-washer **22** engaged in a groove **23** in the shaft and bearing against the adjacent end of the bushing holds the entire rotating assembly in a position at which its spring fingers **20** and **21** are under tension, and as is customary the unit is protected by an enclosing housing **24** which preferably is in the form of a stamped sheet metal cup secured to the terminal head by tangs **25**.

The shape of the resistance element **8** and its manner of attachment to the terminal head follows the practice more or less well established in the art and thus forms no part of this invention, but the composition of the resistance element, i. e. the physical make-up of its base **26** and is conductive coating **27**, is all important.

The conductive coating **27**, as is the practice in the production of resistors of the type here under consideration, is painted, sprayed or otherwise deposited on the base, and since the specific manner in which the coating is applied, that is, whether it is painted on, sprayed on, or otherwise deposited, is not critical as long as it is deposited in liquid form, it is to be understood that when the term "painted on" is employed herein and in the claims any one of the possible ways of applying the coating in liquid form is meant.

A specific example of the way in which the resistance element of this invention is produced is diagrammatically illustrated in the chart, Figure 6. The high heat resistant reinforced resin material selected for the base, which, for purposes of illustration, may be silicone resin reinforced with glass fibers and which is obtained in sheet form of the desired thickness, from the manufacturer, is first cut into appropriate sized pieces or strips and then heat-cured at a temperature of 600° F. for fifteen (15) hours.

Next, as indicated on the chart, Figure 6, a backing coat is applied to one face of the heat treated material. This backing coat consists essentially of silicone resin and any suitable filler, in a hydro-carbon or other suitable solvent.

After the backing coat is applied the sheets or strips are then subjected to a drying heat to remove the tackiness of the backing coat. This done, the opposite face of the sheets or strips have a prime coat applied thereto which consists essentially of silicone resin and a filler of diatomaceous earth or its equivalent.

With the prime coat applied, the sheets or strips are then subjected to a rather extended heat curing treatment consisting of three stages—the first at 340° F. for thirty (30) minutes; the second at 460° F. for thirty (30) minutes; and the third at 480° F. for sixteen (16) hours.

Upon completion of this heat treatment the conductive coating is applied to the sheets or strips over the prime coat. This conductive coating comprises essentially silicone resin and a finely divided conductor such as graphite or carbon, in a suitable solvent, preferably a hydro-carbon.

With the conductive coating applied the sheets or strips are again subjected to a three stage heat treatment similar to that given them after the application of the prime coat, and upon completion of this heat treatment a second coat of conductive material is applied over the first, the second coat preferably being of the same composition as the first.

Thereafter, the sheets or strips are heat treated only sufficiently to remove the tackiness of the second and final conductive coat.

All that remains following drying of the final conductive coat is to punch out the resistance elements, to the shape shown in Figure 3, and give them an additional final three stage heat treatment the same as the previously mentioned treatments.

As noted hereinbefore, resistance elements made this way have been found to perform entirely satisfactorily under the most severe conditions of humidity and at temperatures far above those which could be withstood by resistors of this general type heretofore available. The smooth, hard contact surface of the resistance element retains its ability to withstand the abrasive effect of the metal contact finger sliding thereover even under conditions of very high humidity coupled with temperatures on the order of 400° F. But what is perhaps one of the most significant aspects of the invention, as depicted in Figure 5 of the drawings, is that a tiny, miniaturized unit of ¾" overall diameter equipped with the resistance element of this invention has a higher power dissipating capacity than that of the much larger 1⅛" in diameter unit having the conventional resistance element; and that as a corollary the invention enables greatly increasing the wattage rating of resistors of any given size.

It follows, of course, that the ability of the resistance element per se to withstand high heat would be of little value if the rest of the insulation in the resistor were not also capable of withstanding such elevated temperatures. Hence, the terminal head **5**, the contactor carrier **18** and the spacing washer **13** must also be made of high heat resistant material. Any one of the mentioned thermo-setting high heat resistant reinforced resins can be employed for this purpose.

By curing the base material at a temperature far above the maximum that will be encountered in use of the resistor, the material is dimensionally stabilized; but as a result of this severe heat treatment and the consequent shrinkage of its resin content, its inherent rough surface texture is aggravated. However, the prime coat of silicone resin and diatomaceous earth, or its equivalent, completely seals and closes all the tiny interstices and depressions in the heat-treated base material and provides a smooth surfaced foundation for the conductive coating. In addition, this prime coat also serves to cushion the conductive coating against the consequences of thermal shock which might take place in the base as a result of extreme changes in ambient temperatures, and since it seals and closes the areolar surface of the base material and provides a smooth surfaced foundation for the conductive coating, it affords assurance of uniform resistivity in the conductive coating which would not be had if the coating were applied directly to the base material. Of course, where extremely close electrical tolerances need not be held, the intermediate film provided by the prime coat can be omitted, but in that case it may be necessary to incorporate more of an elastic filler at least in the first of the two conductive coatings applied.

The separate heat curing of each of the coats, prime as well as conductive, at a temperature well above the maximum likely to be encountered in use of the resistor, is important, since it is these heat treatments which effect the conversion of the resin therein and give the conductive coating its resistance to high heat and also render it impervious to moisture.

From the foregoing description taken in connection with the accompanying drawings, it will be readily apparent to those skilled in the art that this invention adapts the type of resistor which is characterized by the resistance element per se being in the form of a painted-on coating to service at elevated temperatures and wattages heretofore believed to be entirely out of the question and assures electrical stability even under the most severe conditions. It will also be understood that while a specific embodiment of the invention has been set forth, modifications of the described manner of practicing the invention will no doubt suggest themselves. It follows, therefore, that the protection to be afforded hereby shall extend to the full limit of the inventive advance herein disclosed as defined by the following claims.

What we claim as our invention is:

1. A variable resistor comprising a resistance element having a smooth hard contact surface in the form of a coating possessing the desired electrical conductivity, a contactor engaging said contact surface, and means to cause the contactor to traverse the contact surface, characterized by the fact that the resistance element comprises: a base consisting essentially of a high heat resistant resin; a smooth, hard outer conductive coating providing the contact surface of the element and consisting essentially of a silicone resin and a conductive pigment; and an intermediate film interposed between the base and the outer conductive coating, said intermediate film consisting essentially of silicone resin and bonding the outer conductive coating to the base and thereby cushioning the outer conductive coating against the consequences of thermal shock within the base and providing a smooth surfaced foundation for the outer conductive coating so that the resistor is stable and quiet in operation even in the presence of high heat and despite severe ambient temperature changes.

2. The variable resistor of claim 1 further characterized by the fact that the intermediate film contains a filler of diatomaceous material.

3. A variable electrical resistance device comprising; a resistance element having a contact surface, a contactor having a finger engaging the contact surface, and means to adjust the resistor by sliding the contact finger along the surface of the resistance element, characterized by the fact that the resistance element comprises: a relatively stiff base of thermo-setting resin; and a coating of silicone resin painted on one face of the base, said coating having a conductive pigment dispersed therein and providing an exposed electrically conductive surface on the base which surface is smooth and hard so as to be able to withstand the wiping action of the contact finger as it is slid thereover.

4. The variable electrical resistance device set forth in claim 3 wherein the base is reinforced with inorganic particles.

5. The variable electrical resistance device set forth in claim 3 wherein the base is formed of a thermo-setting high heat resistant resin selected from the group consisting of silicone, melamine, phenolic and polyester resins.

6. The variable resistance device set forth in claim 5 further characterized by the fact that the base is heat cured to the extent that the resin thereof is permanently shrunk.

7. A variable resistor comprising a resistance element having a contact surface, a contactor having a finger engaging the contact surface, and means to adjust the resistor by sliding the contact finger along the surface of the resistance element, characterized by the fact that the resistance element comprises: a supporting base formed essentially of a high heat resistant resin in which the resin has been permanently shrunk by subjecting the base to high heat; and a plurality of coatings of silicone resin on one face of the base, the outer coating having an electrically conductive pigment uniformly dispersed therein, and the inner coating serving as a primer to fill the fissures and surface irregularities in the base and providing a smooth surfaced barrier between the base and said outer electrically conductive coating.

8. The variable resistor set forth in claim 7 wherein said inner coating includes a filler of diatomaceous material.

9. The method of making a resistance element for a variable resistance device of the type wherein a selected resistance value is obtained by sliding a contact finger across the conductive contact surface of a resistance element and which contact surface must be hard and smooth to assure stability and quietness in operation and wherein the contact surface of the resistance element comprises a coating of conductive material painted on a relatively stiff electrically insulative base formed of a thermo-setting high heat resistant resin so that the element will satisfactorily withstand elevated temperatures as high as 400° F. which method comprises: subjecting the base material in sheet form to a prolonged heat treatment at a temperature well above 400° F. but not substantially higher than 600° F. to thereby permanently shrink the resin and dimensionally stabilize the base material; applying a prime coat consisting essentially of silicone resin to one surface of the heat-cured base material to seal the fissures therein and render the surface smooth; drying said prime coat; applying over said dried prime coat at least one other coating of silicone resin having a conductive pigment uniformly dispersed therein; and subjecting the thus coated base material to a prolonged heat treatment at a temperature above 400° F. to effect drying and hardening of the outer conductive coating thereon.

10. The method set forth in claim 9 further characterized by the step of heat-curing said prime coat at a temperature above 400° F. over a protracted period of time.

11. The method of making a resistance element for a variable resistor of the type wherein a selected resistance value is obtained by sliding a contact finger across the conductive contact surface of a resistance element and which contact surface must be hard and smooth to assure stability and quietness in operation and wherein the contact surface of the resistance element comprises a coating of conductive material painted on a relatively stiff electrically insulative base formed of thermo setting high heat resistant resin reinforced with inorganic particles, which method comprises: subjecting the base in sheet form to a heat treatment of about fifteen hours duration at a temperature of approximately 600° F. to thereby permanently shrink the resin and dimensionally stabilize the base: applying a prime coat of silicone resin and a filler to one surface of the heat-cured base to seal the fissures therein and render said surface smooth; applying over said prime coat a plurality of coats of silicone resin, the outermost one of which has a conductive pigment uniformly dispersed therein; and subjecting the coated base after the application of each of said coats to a heat treatment at temperatures ranging from 340° F. to 480° F. over a period of about seventeen hours to thoroughly dry and harden each coat before the next coat is applied thereto.

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