Dec. 17, 1957 W. M. KOHRING 2,816,996

RESISTANCE PRODUCTION

Filed Dec. 14, 1953



Fig. 1

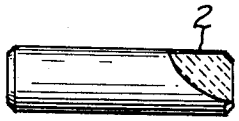


Fig. 2



Fig. 3

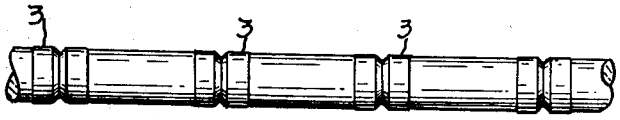


Fig. 4

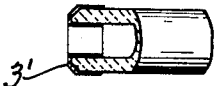


Fig. 5



Fig. 6

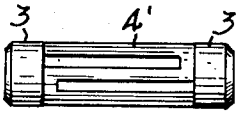


Fig. 8

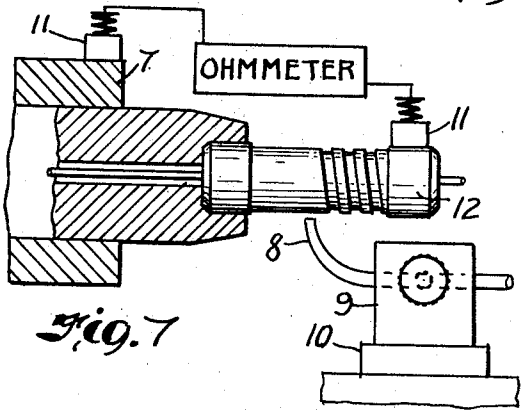


Fig. 7

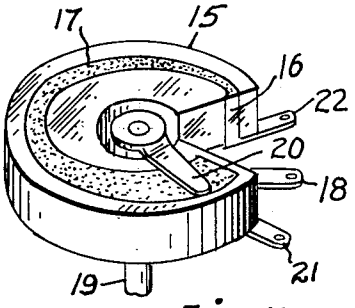


Fig. 11

Fig. 9

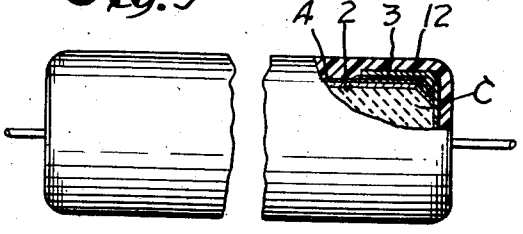
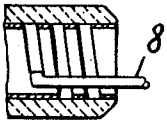


Fig. 10



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RESISTANCE PRODUCTION

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13 Claims. (Cl. 201—63)

This invention relates to resistors, including such as are for heavy duty usages, or operation under unfavorable conditions, as high temperature, exposure to chemical fumes, exposure to moisture, etc. Detail objects and advantages of the invention will appear from the following description.

To the accomplishment of the foregoing and related ends, said invention, then, comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawing setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principle of the invention may be employed.

In said annexed drawing:

Fig. 1 is a side elevational view of a multi-unit blank as used in the present manufacture;

Fig. 2 is an enlarged scale side elevational view, part in section, of a detached unit, the blank being of rod form;

Fig. 3 is a similar view where the blank is of tubular form;

Fig. 4 is a side elevational view like Fig. 1, showing the stage in manufacture involving application of conductive metal;

Fig. 5 is a fragmentary section, on enlarged scale, of a tubular form of blank, showing how the conductive metal may be applied at the ends so as to extend within;

Fig. 6 is a similar view showing the stage in manufacture where the resistance metal has been applied;

Fig. 7 is a schematic side elevational view showing a manner of adjusting the resistance element to precision value, here by helical removal of metal;

Fig. 8 shows metal removal axial-wise of the resistor instead of helix-wise;

Fig. 9 is a side elevational view, part in section, of a completed resistor;

Fig. 10 is a fragmentary sectional view showing adjustment for internal resistances in tubular form; and

Fig. 11 is a perspective view of a variable resistance.

In general, the present manufacture involves applying conductive metal and resistance metal at respectively appropriate locations on glazed ceramic blanks, adjusting to precision value of the resistance element film, and in cases where appropriate, protectively covering the resistance element by synthetic resin.

As seen in Fig. 1, a cylindrical multi-unit of ceramic C, grooved as at **1**, in spaced apart locations according to the size of the resistor units to be made is provided. Thus, starting with the multi-unit blank, this may be glazed in its production at the ceramic works, or in any event is provided with a glaze **2**, Figs. 2, 3, desirably of thermal expansion coefficient on the order of that of the ceramic or porcelain body. The fusing temperature of the glaze is around 1200° F. for resistors where a soft glaze is desired, or around 1800° F. where resistors with a harder glaze are preferred. Such compositions, as known, involve liquid-applicable mixtures of clay and frit including silica, boron, calcium, aluminum, etc.; an instance of a desirable glaze being a lime-boro-manganese-alumina silicate. Such, as an aqueous suspension is applied as by dipping or spraying, and after drying out, the glaze is fired to fusion and union on the body of suitably higher melting ceramic. The thickness of glaze is desirably 0.001–0.003 in. On the glazed base so provided, conductive metal is applied at appropriate locations. As for the multi-unit blank form of Fig. 1, this involves applying the conductive metal at the grooves **1**, as a coating **3**, Fig. 4, extending at each side from the groove, sufficiently to ultimately receive a terminal. Of the conductive metals available, I prefer silver, and this in form such as can be applied as the rod or tube is rotated for instance by suitable means. Thus the silver applied for this purpose may be the colloidal silver as known in connection with applying terminals to resistors heretofore in low temperature work, or in some cases the silver and volatile oil vehicle as known in the chinaware decorating art may be used. By now heating the blank to a temperature softening the glaze, i. e., 1200°–1250° F. in the case of low temperature glaze, or around 1800° F. in case of high temperature glaze, the conductive metal is set into the surface such as to be particularly durable and invulnerable against change or mechanical damage. The resistance metal, such as nickel or nickel alloy, for instance 80 percent nickel and 20 percent chromium, or commercial alloys, "Invar," "Constantan," etc., is next applied as a covering film deposited on the glaze and on the silver, thus in thorough contact. The resistance metal is preferably applied by vacuum deposition on the order of the known technique, the metal being vaporized by heated elements or filaments in a chamber under high vacuum, such as the commercial device of Distillation Products Co., and the generally well known technique, as for instance "Vacuum Technique" by Saul Dushman (pub. by John Wiley & Sons, Inc., N. Y., 1949) pp. 757–764. In this the resistance metal is in the form of filaments or wires mounted in a carrier in the vacuum chamber, in relation to the ceramic blank to be coated. Heating current is passed through the filaments or wires, to the extent of softening the glaze and also vaporizing metal from the filaments, the vacuum chamber being under very high vacuum, as well understood. The thickness of the vacuum deposited metal film is contingent to some extent on the general value of resistance desired. A thin coat of synthetic resin, e. g., silicone, may be then applied on the resistance areas for protection against oxidation, as illustrated at **5**, on the right of Fig. 6.

Where it is desired to apply the resistance metal film to the interior surface of a tubular form blank, this is readily accomplished in the same vacuum deposition manner, by positioning the vaporizing filament or wire inside the tubular blank, the operating conditions being the same.

The multi-unit then has the silver contact areas, at the grooves, there being sufficient overlap therefrom to provide ample receiving connection areas for terminal caps to be ultimately applied to the individual units as severed from the initial multiple blank. A multiple unit as at such stage shows groove bands **3** of silver, Fig. 6, and surfaces **4** of the nickel resistance film on the body between.

In some cases the multiple unit blank may be severed before the applying of the silver and resistance metal, and if a tube form multiple blank is used, the silver end coating **3'** may be extended slightly within the lumen as shown in Fig. 5. In any case the multiple unit blank is severed at the grooves, and the individual units then have body coating of vapor-deposited nickel resistance metal, and end coatings of silver. In small diameter multiple unit bodies, severing is easily accomplished by breaking at the grooves.

In most cases I prefer to subject the resistors to prolonged temperature treatment or aging, as this is found to take out stresses, and also apply mild annealing to the metal. Thus, they may be treated to a baking temperature of around 285°–320° F. for about 40 to 60 hours. A resistor so-treated I find to be outstandingly stable, and invulnerable against damage in subsequent drastic operating conditions.

End terminals are applied. While these may be of different forms, for most usages I prefer cap terminals **12**.

In the adjusting of the resistance value to precision, the resistor is placed with one end in the rotary chuck **7**, Fig. 7, of a lathe or special lathe-like machine, and as the resistor is rotated thereby, an abrading tool is moved along against the resistor periphery to cut a helical groove therein and so provide a desired total length of resistance path. The grooving tool may be a rotary edge-grinder or diamond wheel, or by preference I employ a cutter on the order of the sand blast principle, such as the "Airbrasive" cutter of the S. S. White Mfg. Co., this involving a small nozzle **8** through which finely divided abrasive particles are blasted in a gaseous stream against the rotating resistor in the chuck. The cutting unit is carried by the tool post **9** of the traveling slide **10** of the lathe. With this, the relative speeds of the rotating chuck **7** and of the axially-traveling slide **10** are set according to the particular spacing of helical cutting desired. In the helical cutting operation the resistor as rotated by the chuck has its coating in a circuit with an ohmmeter, spring-pressed brushes **11** in the circuit completing contact on the rotary chuck cylindrical area and on the other end silver band of the resistor or the end cap if already on. Observing the ohmmeter, the operator stops the cutting at the predetermined resistance value which is desired. Where instead of helical cutting, longitudinal cutting is more appropriate to the desired resistance value to be obtained, such as for the lower values, the resistor similarly held in the chuck as afore-described, is maintained stationary, while the cutting tool carried by the slide **10** is moved axial-wise, thereby cutting on longitudinal lines and removing the resistance metal film correspondingly as shown in Fig. 8. The resistance value can be raised or lowered according as the cutting is applied to leave the resistance metal in the form of series or parallel strips between the silver end contacts. As can be seen, the cutting or abrading tool can also be applied in adjusting to precision where the deposited resistance metal is on the inside surface of a tubular blank of diameter permitting, and the tool post is set to right height and the cutting tool **8** is clamped in the tool post **9** with a sufficient extending length to permit its desired travel within the lumen of the tube.

For protection against mechanical and other damaging agencies, the resistor body is next completely covered with a synthetic resin. This may be in thick liquid form applied as a coating, or preferably the synthetic resin is molded on the resistor as an encasement. The synthetic resin is set or hardened by heating to a setting temperature appropriate for the resin. While resins such as phenol-formaldehyde, polystyrene, etc., may be employed, I prefer silicone resin, and this particularly fits in with high temperature conditions of operation in ultimate usage of the resistor.

In some cases it is advantageous to proceed by glazing, and silvering as foregoing, and then on the blank thus far prepared there is applied, as by spraying, dipping or brushing, a lacquer-like composition of finely divided mineral filler. A particularly desirable composition is chromium oxide in collodion or setting oil or lacquer vehicle. After this is hardened or set, it is subjected to a spiraling tool, which in simple form may be a blade of desired width bearing upon the lacquer coating at an angle so as to shave off a cutting correspondingly and leave an exposed spiral of glaze. This cutting tool, as the others previously described may be carried in the tool post of the lathe or lathe-like machine, thus being propelled to effect a spiraling shaving contact on the resistor, and such tool is applicable on the outside as carried by tool post **9**, Fig. 7, or as shown at **8'**, Fig. 10 is analogously applicable to spirally shave on the interior surface where the resistance film has been coated on the interior of a tubular form blank. In other words, the cutting or scraping tool at its proper cutting angle can be set for operation equally on the inside or outside surface of a blank. If a longitudinal or axial-wise arrangement of resistance metal film areas is desired instead of a spiral-wise arrangement, this may be readily accomplished by propelling the cutting or scraping tool in axial-wise direction, as afore-described in connection with Fig. 8.

With the blank silvered and provided with the masking lacquer, and the latter removed spiral-wise or axial-wise, the blank is subjected to the vapor-deposition of the resistance metal as described foregoing. Permanent adherence of the resistance film will occur only on the areas which have been denuded. With the terminals applied, preferably cap terminals, and any further fine adjustment of the resistance value taken care of, in the manner described again, it is usually preferable to subject the product to a prolonged high temperature or aging treatment as afore-described. The resistor finally is covered with a protective of synthetic resin coated on or molded on as foregoing.

Other forms of resistance, such as variable resistors, potentiometers, etc., can be produced by the procedure of the present invention. Thus for instance, as shown in Fig. 11, a ceramic base **15** may have a glaze applied as described, and be fired, and silver areas as at **16** may be applied, and an area of resistance metal **17** is vapor-deposited through a masking in sheet form or applied ultimately-removable water glass composition, such masking leaving exposed the appropriate area desired for the resistance metal film. Slide contactor **20** on the shaft **19** completes the contact with the resistance element, and depending upon how the terminals **18**, **21**, **22** are connected, a simple variable resistance or a potentiometer is had. In general, irrespective of the particular form of the insulative base, the invention provides resistance element films of vapor-deposited metal appropriate to the category and intended usage of the resistance device. It is to be noticed that vapor-deposited resistance metal is of unique structure and is characteristic, being uniform in its molecular placement and in its resistance to current flow. To those acquainted with metallography, vapor-deposited metal is readily identifiable.

As an example: A rod of high di-electric low coefficient of expansion porcelain, grooved at spaced intervals, was coated with a neutral glaze composition of lime-boro-manganese-alumina silicate frit with clay in aqueous vehicle, and after drying was fired at 1200° F. Colloidal silver, Hanovia Chem. Co.'s #543 silver paste, was applied at the grooves for contacts, and the coated rod was fired to softening of the glaze again to secure the silver. Then in a vacuum chamber desirably at about 3×10^{-5} mm. Hg, filaments of nickel-chromium, 80:20, alongside the rod were heated to soften the glaze and to vaporize metal from the filaments, by a current of 5.5 amp. for 27 minutes, 6 amp. for 3 minutes, and 9 amp. for 1½ minutes, a deposit of the nickel-chromium being set into the glaze on the rod. After removal from the vacuum chamber, and cooling, a thin coat of silicone resin was applied on the resistance metal areas only to prevent oxidation while aging as next the rod was subjected to heat at 285–320° F. for 50 hours. The rod was severed into its units and cap terminals were next applied to the ends of the units, and in a lathe device the units were subjected to helical cutting of the resistance metal while in circuit with an ohmmeter for precision adjustment of the resistance value. Finally the units were coated with a protective cover of silicone resin and this was set by heating at 300–350° F.

The relationship of the glaze applied to the porcelain and then the metal applied on top of the glaze, the glaze then being softened to set the metal in is found to give different and much better results than would be possible with a reverse order of metal applied to the porcelain and then glaze applied over the metal. This appears to be due to the fact that in applying metal to the glaze surface there is a completely uniform face upon which the metal is placed, instead of a surface of somewhat variable porosity in the case of porcelain. At any rate, the conductive metal, and the resistance metal are in uniform lines and areas and are bedded into the glaze.

As another example: A cylindrical porcelain body grooved at spaced intervals was glazed, and silver was applied at the grooves, and the whole was heated at around 1200° F. to soften the glaze and bind the silver. Then a coating of chromium oxide in lacquer vehicle was applied, and after setting, the coated body was severed at the grooves into units, and each unit was adjusted to precision resistance value by applying in a lathe device a narrow blade shaving tool held in the tool post of the lathe slide in angle to the resistor surface such as to shave off a narrow shaving and correspondingly expose the glazed surface. Then in a vacuum chamber under high vacuum, nickel-chromium alloy was vaporized and deposited onto the body as highly heated to softening of the glaze as in the foregoing example. And here the metal deposited and adhered selectively to the exposed glaze for an ultimate spiral of resistance metal. Terminals and a protective covering of synthetic resin completed the resistor units.

As another example: A plate of high di-electric low coefficient of expansion porcelain in shape of a partial torus, leaving a central space for a shaft and a sweep-arm contactor, and a cut-out sector to the periphery, was glazed as in the first example, and silver was applied to complete contact at appropriate locations at the cut-out sector (see Fig. 11 of drawing). The body was then heated at 1200° F. to soften the glaze and set the silver in. Then masking as a water glass and filler composition was applied leaving an exposed area on the face of the plate in the form of a progressively widening curved area from one silver terminal location around to the other. After the masking was set, a nickel alloy was vapor-deposited on the exposed area, in a vacuum chamber under high vacuum as foregoing. After removal from the vacuum chamber, and cleaning off the friable masking coat, terminals were applied to the ends of the resistance strip, and an operating shaft and sweep-arm contact was assembled to complete a potentiometer. By a terminal application to only one end of the resistance band, and the provision of the operating shaft and sweep-arm contactor, a variable resistor was analogously made.

Other modes of applying the principle of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims or the equivalent of such be employed.

I therefore particularly point out and distinctly claim as my invention:

1. In a process of the character described, making a resistor by coating ceramic glaze composition on a multi-unit cylindrical ceramic body having spaced peripheral grooves, firing to fusion of the glaze, coating the glazed surface with a lacquer, applying silver coating about the grooves, vacuum-depositing a resistance metal, severing the body at the grooves to form a plurality of units, applying cap terminals to the unit ends, removing metal from the resistance film to desired precision, applying an overall covering of synthetic resin insulation, and curing.

2. In a process of the character described, making a resistor by coating a lacquer on a glazed multi-unit cylindrical ceramic body having spaced peripheral grooves, applying silver coating about the grooves, vacuum-depositing a resistance metal, severing the body at the grooves to form a plurality of units, applying terminals to the unit ends, removing metal from the resistance film to desired precision, applying an overall covering of synthetic resin insulation, and curing.

3. In a process of the character described, making a resistor by coating a ceramic glaze composition on a multi-unit cylindrical ceramic body having spaced peripheral grooves, firing to fusion of the glaze, coating the glazed surface with a lacquer, applying silver coating about the grooves, vacuum-depositing a resistance metal, severing the body at the grooves to form a plurality of units, removing resistance metal to precision adjustment, and finally applying an overall covering of synthetic resin insulation, and curing.

4. In a process of the character described, making a resistor by glazing a multi-unit ceramic rod having spaced peripheral grooves, coating the glazed surface with a lacquer, silver coating the grooves, vacuum-depositing a resistance metal, severing the rod at the grooves to form a plurality of units, applying terminals to the units, applying an overall covering of synthetic resin insulation, and curing.

5. In a process of the character described, making a resistance device by coating a ceramic glaze composition on a multi-unit cylindrical ceramic body having spaced peripheral grooves, firing to fusion of the glaze, silver coating the grooves, vacuum-depositing a resistance metal over the surface, severing the body at the grooves to form a plurality of units, applying terminals to the unit ends, applying an overall covering of synthetic resin insulation, and curing.

6. In a process of the character described, making a resistance device by coating a lacquer on a glazed cylindrical ceramic body, applying conductive metal at spaced intervals, vacuum-depositing a resistance metal, severing the body at the conductive metal areas to form a plurality of units, and removing metal from the resistance films to desired precision.

7. In a process of the character described, making a resistance device by applying conductive metal at the grooves of a glazed cylindrical ceramic body having spaced peripheral grooves, vacuum depositing a resistance metal over the surface, severing the body at the grooves to form a plurality of units, applying terminals to the units, applying an overall covering of synthetic resin insulation, and curing.

8. In a process of the character described, making a resistance device by applying conductive metal coating as spaced peripheral bands on a glazed cylindrical ceramic body, vacuum-depositing a resistance metal, severing the body at the conductive metal areas to form a plurality of units each with conductive coating on its end portions and resistance metal on the body, and applying terminals to each unit.

9. In a resistor, a glazed ceramic cylindrical body, a lacquer coating on the glaze having a groove at which the glaze is exposed, a resistance metal film of the character of vacuum-deposited metal thereon in form to adjusted precision value, such resistance metal being disposed in the groove formed in the lacquer coating and set in the glaze exposed thereby, silver coating at the ends, cap terminals on the silver coated ends, and synthetic resin insulation overall.

10. In a resistor, a glazed ceramic cylindrical body, a lacquer coating on the glaze having a groove at which the glaze is exposed, a resistance metal film of the character of vacuum-deposited metal thereon, the resistance metal being confined to the groove formed in the lacquer coating and set in the glaze exposed thereby, conductive metal and terminals on the ends, and synthetic resin insulation overall.

11. In a process of the character described, making a resistance device by applying a lacquer coating to a glazed ceramic body, grooving such lacquer coating to expose the glazed surface of the body in a predetermined pat-

tern, vacuum-depositing a resistance metal in such groove, heating the body to a temperature at which the glaze softens to secure the metal firmly thereto, and applying conductive terminals.

12. In resistor manufacture, the steps of placing a ceramic blank having a compatible glazed coating thereon in a vacuum chamber, disposing a metal element in the chamber in proximity to said blank, heating the blank to a temperature at which the blaze is softened, heating said metal element to vaporization temperature to form a deposit of metal on the softened glaze of the blank, and thereafter cooling the blank.

13. In a resistor, a glazed ceramic body, a resistance metal film of the character of vacuum-deposited metal overlying said body and at least partially bedded in the glaze thereof, and spaced terminals secured to the body in contact with said metal film.

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