May 21, 1957 W. M. KOHRING 2,792,620

SEALED RESISTORS

Filed Aug. 20, 1953

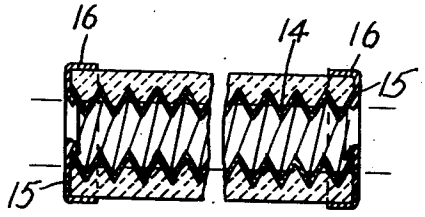


Fig. 1

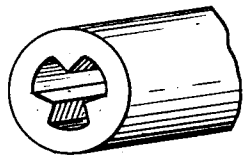


Fig. 2

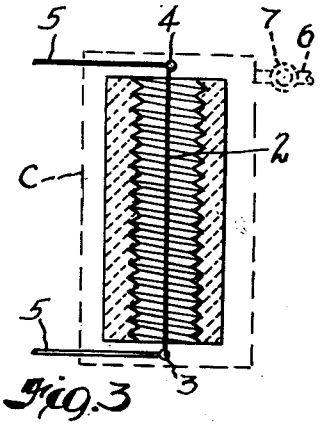


Fig. 3

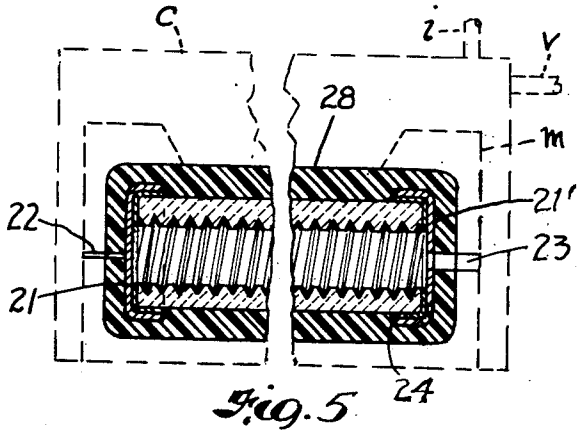


Fig. 5

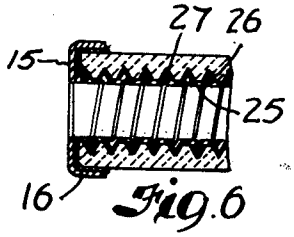


Fig. 6

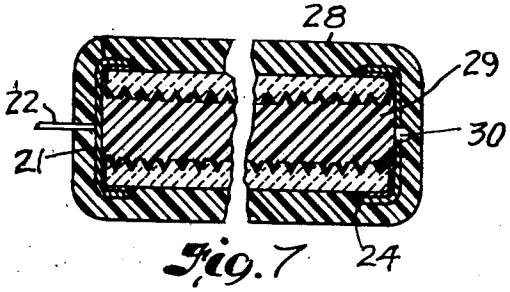


Fig. 7

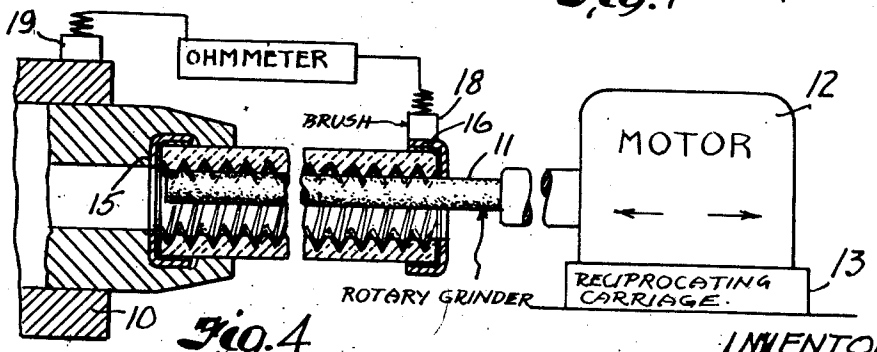


Fig. 4

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SEALED RESISTORS

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4 Claims. (Cl. 29—155.5)

Resistors, in order to give satisfactory continuing service, must of course have insulation, but additionally they should in particular be safeguarded against access of moisture. In resistor-containing devices used in tropical or humid regions or in exposure in chemical fumes, customary type construction tends to allow premature change and failure. In the present invention the form of construction is involved which gives special attention to all such conditions. Other objects and advantages 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 broken, somewhat enlarged, axial sectional view of a stage in the manufacture of resistors in conformance with the present invention;

Fig. 2 is a fragmentary perspective view of a modified form;

Fig. 3 is a diagrammatic sectional view of an arrangement for applying the metal coating;

Fig. 4 is a diagrammatic broken partly sectional view of an arrangement for carrying out one stage of the manufacturing operation;

Fig. 5 is a broken sectional view of a finished resistor;

Fig. 6 is a fragmentary sectional view showing a stage of manufacture; and

Fig. 7 is a broken sectional view of a modification.

In general, the invention involves providing a resistor body of hollow form and having on its interior a ridge contour, and resistance metal is vacuum-deposited in a thin film on the interior of such body, covering the entire surface, and next the crests of the ridge contour are ground off, thereby leaving resistance metal in a plurality of turns or strips. Then on the ends of the body a settable metal coating is applied to provide contact from the interior metal to the outside periphery at the ends. Finally, terminals are applied, and insulative material. The latter may be inside and out.

The material of the tubular body is steatite or ceramic. Desirably the groove or ridge contour of the bore may be molded in initially, but in some cases it may be provided after the formation of the tube. The ceramic body may be glazed throughout with a relatively low melting glaze. To the body so prepared, there is next applied a resistance metal film on the interior. For this, the vacuum-deposition is preferred. The vacuum-deposited metal is unique over metal films deposited by deposition, electrolytically or chemically, the vacuum-deposited metal having a characteristic uniform molecular structure and density, recognizable and identifiable by suitable examination. For vacuum-depositing the metal, the resistor body is arranged in a vacuum chamber C, Fig. 3, and a

wire 2 of the desired resistance metal is positioned axially in the bore of the ceramic body between connections 3, 4, of bus bars 5 which enter the chamber through suitable insulative and sealing bushings. A vacuum is applied to the chamber through the connection 6 provided with control valve 7. The technique of the vacuum provision and metal deposition is of the well-known order, vacuum equipment being commercially available, as produced for instance by Distillation Products Company, and vacuum technique is described for instance in "Vacuum Technique," by Saul Dushman (pub. by John Wiley & Sons, Inc., N. Y., 1949). With a current of sufficient amperage to vaporize the metal from the wire 2 under a high vacuum, which may run as high for instance as 5–10 microns, the metal vaporized from the wire deposits on the adjacent surfaces of the bore of the resistor body. Metals which may be used are in general nickel, chromium, and alloys, for instance an 80% nickel and 20% chromium alloy wire being satisfactory. A temperature range around 850° C. is in general satisfactory for such type of resistance metal. A peculiarity resulting from the action of a glaze on the surface of the resistor bore is that there is incurred a temperature coefficient substantially less than 50 parts per million per degree centigrade. And, even from a wire in which nickel is greatly predominant, the film coated onto the glaze, for instance of pyrex type, may be found to contain nickel in percentage approaching 50%. Other alloys of course may be applied in the same vacuum and evaporating arrangement; alloys as desired may be applied which are proportioned to evaporate both elements together, rather than one ahead of the other.

The resistor body at this stage then has a layer of vacuum-deposited metal over its whole interior surface, whether that surface be of spiral thread form as in Fig. 1 or as parallel longitudinal ridges, Fig. 2. The so-coated body is next subjected to a grinding off of the crests of the internal ridges; and for this, one form of operation may involve the holding of the resistor body in a chuck 10, Fig. 4, as of a lathe, or special lathe-like machine. The resistor body so held and rotated by the machine is subjected to an internal grinder 11, Fig. 4, rotarily driven by a motor 12 which is carried on a reciprocating slide or carriage 13 as in lathe practice. Thus, the resistor body being rotated by the chuck, and the grinder of lesser diameter than the bore of the resistor being rotated by the motor, all parts of the internal periphery are subjected to the grinder action, but this is controlled as to extent of depth of cut. By having the resistor in circuit with an ohmmeter, the effect and extent of a grinding down of the apices can be closely watched and controlled. Then for instance, the resistor body as internally coated with the metal film, next receives a metal end-coating which extends from the interior over the end surface and out on the periphery to form a band, as at 16, Figs. 1 and 4, such band being an extension as noted, of the end coating 15 which contacts inwardly with the vacuum-deposited metal film 14. The end coating may be of various metal composition, but ordinarily colloidal silver or liquid silver- containing material is desirable. The external band 16 makes possible a convenient circuit connection, as by spring pressed brush 18 contacting therewith. As indicated in Fig. 4, the other contact may be a similar spring pressed brush 19 contacting the peripheral surface of a chuck casing 10. In such arrangement, the ohmmeter shows the change in resistance value for the interior of the resistor as the ridges are progressively taken off. Whether the ridges be in the screw thread form as in Figs. 1 and 4, or as longitudinal parallel ridges, Fig. 2, the action and result are the same. Grinding first removes the connecting portion of the continuous metal coating and results in a resistance metal

contour which is a spiral of groove form, Fig. 1, or a number of parallel strips as in Fig. 2. In the latter, the number of ridges may of course be as desired, more or less than the three shown in Fig. 2. Starting then with a uniform resistance film on the entire internal bore of the resistor body, the grinding produces in effect a strip or strips of the resistance, and with progressive grinding away, the resistance value of these increases. At the value predetermined, the grinding is stopped, by the grinder being withdrawn from the bore of the tube by regressive movement of the carriage which supports the motor-driven grinder. The spiral form or threaded contour, as in Figs. 1 and 4, makes possible high resistance values, and the parallel strip form as in Fig. 2 particularly favors the production of low resistance values. Thus, whether resistance units on the order of 10,000–100,000 ohms for instance be desired, such may be realized by the form shown in Fig. 1, and resistances on the order of 10,000 ohms down may be particularly advantageously realized by the parallel form in Fig. 2.

Having ground down ridge crests internally of the bore to the desired resistance value, terminals are applied to the ends of the body. While these may be of simple form, a preferred form is a cap **21**, Fig. 5. This may carry a connected wire **22**. Both ends of the resistor body can be equipped with such terminals. But where it is additionally desired to subject the interior to a vacuum, and this is true for a large proportion of instances, the terminal cap may have an opening, such a form involving a cap **21'**, and a small tubulature **23**. The terminal caps are desirably soldered as at **24** to the peripheral end metal coating **16**. When such resistor form is enclosed in mating mold members *m* and is placed in a chamber which has vacuum connections and means for supplying insulating material, the resistor is subjected to the vacuum, thereby drawing off air and moisture. Molten synthetic resin insulative material, for instance polystyrene, phenol-aldehyde, silicone resins, etc., may be run in, filling the space left between the outside of the resistor body and the mold, this insulating resin being run into the receiving opening at the top of the mold, while the tubulature **23** is exposed at the opening between the mold sections at the end. If a gaseous insulative filling is desired, this may be supplied to the general vacuum chamber, displacing the vacuum, and entering into the interior of the resistor body by way of the tubulature **23**. In some cases in like manner, a liquid insulative material can be supplied at the outside of the mold to enter the tubulature **23**, and such liquid can be for instance transformer oil, molten wax, etc. In some cases it may be desired to so supply a thin synthetic resin, and on removal of the resistor from the mold, excess of the resin may be poured out, leaving the interior surface with a coating **25**, Fig. 6, which covers the bare portions **26** of the cut-down ceramic, and the trough resistance metal portions **27**. In some cases it is desirable to completely fill the interior of the resistor body, and for this, the insulating resin supplied for the encasement **28** of the resistor may be also overflowed to enter the tubulature and provide a complete filling **29**, Fig. 7. The tubulature is closed as at **30**, and soldered.

It will be understood that the encasement synthetic resin **28** is ordinarily set or finished by heating to a temperature, for instance 200° C., or as required by the particular resin which is employed.

As an example: A ceramic tubular body internally threaded and glazed with a relatively low melting glaze, is subjected to a high vacuum and with a wire of 80:20 nickel-chromium alloy centrally in its bore and subjected to a current of amperage evaporating the metal, is thereby provided with vacuum-deposited coating of nickel-chromium on the interior surface of the tubular body. The interior surface is then subjected to grinding to cut down the apices of the ridge contour, while the metal coating is in circuit with an ohmmeter and the grinding away is stopped as the pre-desired resistance value is shown by the ohmmeter. The tubular body with its groove-form spiral contour of resistance metal film is supplied with an end coating of colloidal silver which extends from the metal inside and over the end surface and out onto the periphery to form a narrow band. Cap terminals are applied to the ends, one being of a form having a tubulature. The assembly is placed in a mold with the tubulature exposed at the end opening between the mating mold sections, and the whole is placed in a vacuum chamber and is de-aerated. Polystyrene resin is supplied to the top of the mold to form an encasement about the resistor, and a similar resin in liquid form is supplied through the tubulature at the end. On removal of the mold, and heating to the setting temperature of the polystyrene, the resin is solidified, and the end tubulature is closed and soldered.

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 resistor manufacture, the steps of forming a ceramic tubular body having a threaded inner peripheral surface, applying a glaze to such surface, exposing the threaded and glazed surface in a vacuum to a metallic member heated to vaporization temperature and thus depositing a thin continuous film of metal on the threads, removing the deposited metal from the tops of the threads so that the remaining film coating the walls and bottoms of the threads forms a helical resistance element, abrading uniformly the thread tops while measuring the resistance of such element, thereby to reduce the cross-sectional area of the element until the desired resistance value is obtained, and sealing the resultant resistor by molding a plastic jacket about the tubular body.

2. In resistor manufacture, the steps of providing a tubular body of non-conducting material with a helical groove and an intervening helical rib in the inner peripheral surface thereof, exposing the grooved surface to a metal member heated to vaporization temperature thus to deposit a continuous coating of metal on the surface, removing the deposited metal from such helical rib so that the metal left in the groove forms a helical resistance element, abrading uniformly such rib while measuring the resistance of such element, thereby to reduce the groove depth and hence the cross-sectional area of the element until the desired resistance value is obtained, and sealing the ends of the tubular body.

3. In resistor manufacture, the steps of providing a tubular body of non-conducting material with a groove in its inner peripheral surface, exposing such surface to vaporized metal thus to deposit a continuous coating of metal on the surface, removing the deposited metal from the ungrooved portion of such surface, abrading the surface to reduce the depth of the groove and hence the cross-sectional area of the metal left therein while measuring the resistance of the latter, the area thus being reduced until the desired value of resistance is obtained, and sealing the ends of the tubular body.

4. In resistor manufacture, the steps of applying a low melting glaze to the inner peripheral surface of an internally threaded tubular body of non-conducting material, positioning a wire in the bore of said body, heating said wire in a vacuum to vaporization temperature by flowing electric current therethrough, thereby to deposit a coating of the thus evaporated metal on the bore surface, abrading such surface to remove the deposited metal from the tops of the threads, whereby a helical resistance element formed by the metal left in the thread groove is produced, and molding a jacket of insulating material about the body to seal the bore.

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