

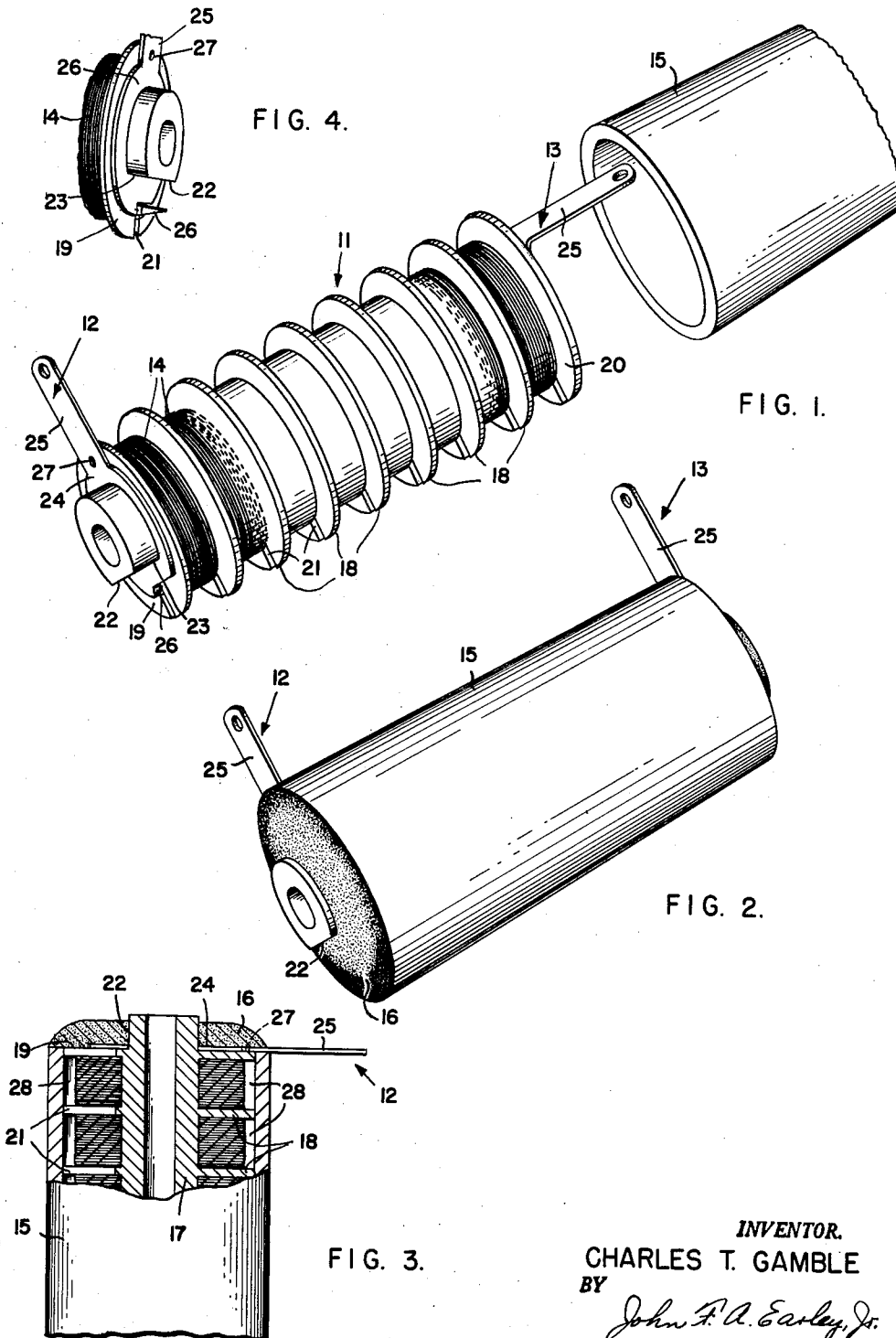
Nov. 13, 1962

C. T. GAMBLE
ELECTRICAL RESISTOR

3,064,223

Filed May 18, 1960

2 Sheets-Sheet 1



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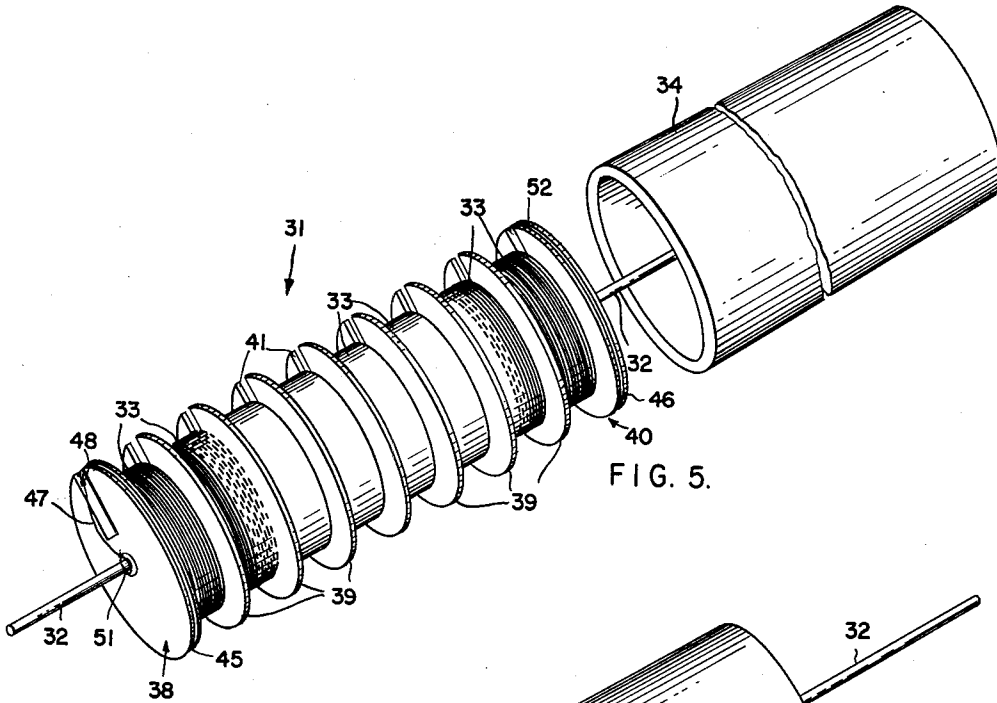


FIG. 5.

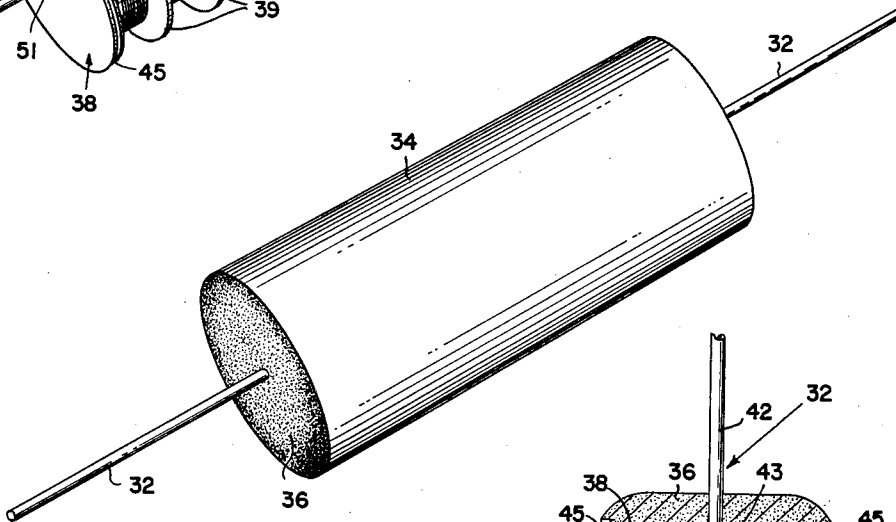


FIG. 6.

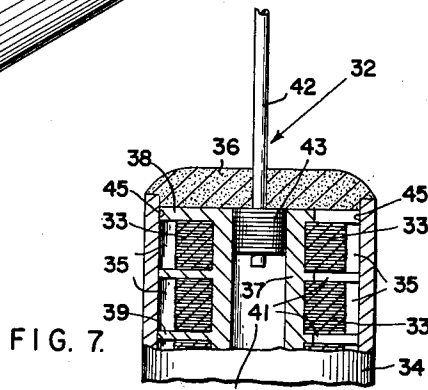


FIG. 7.

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ELECTRICAL RESISTOR

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Filed May 18, 1960, Ser. No. 29,939
3 Claims. (Cl. 338-261)

This invention relates to improvements in an electrical resistor, and more particularly concerns a precision resistor and a process of making it. Such resistor is of the type having a bobbin of cylindrical shape with radially notched flanges extending therefrom to form a plurality of pi sections, resistance wire wound around the bobbin in opposite directions in alternate pi sections to cancel inductance, and a hermetically sealed cover.

Heretofore, manufacturers of precision resistors have experienced a great deal of difficulty in making a precision resistor on a mass production basis which would consistently measure up to the required testing without giving a high percentage of rejects. Such resistors were at one time made out of a ceramic material and an attempt was made to hermetically seal the resistor by using soft solder at its ends.

One of the biggest difficulties with the ceramic core type of precision resistor was that the encapsulating solder would flow down inside the resistor and contact the wires and create a short circuit. Precision resistors must be hermetically sealed and to be acceptable they must withstand a 95% relative humidity test, and a salt water immersion test. These tests would cause the rejection of perhaps 50% of the ceramic core, solder-end-cap resistors.

Another method previously used to manufacture precision resistors comprised a molding process wherein an end piece was placed on each end of a resistor bobbin, a slotted sleeve was placed between the end pieces, and a liquid epoxy resin was poured through the slot into the mold formed by the slotted sleeve and the end pieces. The resin was allowed to cure and the slotted sleeve and the end pieces were removed with a kick press and discarded. If the resistor were of the axial lead type, wires were provided that extend into the bobbin through the end pieces to form holes which were adapted to receive the axial leads. This molding method of manufacturing precision resistors was time consuming and required a great number of manual operations. This method was also wasteful, in that the mold formed by the slotted sleeves and the end pieces was not re-useable and was discarded.

Further, the mold method of forming precision resistors had other disadvantages. Precision resistors must also meet certain requirements as to temperature characteristics of the resistance wire. Specifications may call for a variation in the temperature characteristics of the resistance wire of no more than 20 parts per million per degree C. In the mold method of forming precision resistors, the epoxy resin was poured directly over the wire and, in cooling and shrinking, it created stresses and strains in the resistance wire which resulted in change in the temperature coefficient, so much so that the resistor would be unacceptable as being outside the permissible limits of temperature coefficient variation.

Also, in the mold method, the slotted sleeves were delivered to the plant as long tubes which had to be cut to the desired sizes and slotted. They had to be cleaned, all burrs removed, and dipped in a mold release solu-

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tion so that after the resistor was made they could be knocked out and released from the epoxy resin.

Another disadvantage of resistors formed by the mold method was that they varied in length and diameter because of shrinkage. Moreover, in the mold method, the pouring of the epoxy resin into the mold created a certain number of air pockets so that when the resistor was knocked out of the mold, the resistor surface was spotted with little pin holes which had to be patched. In patching, the hole was opened to a larger size and was packed with the same material.

In the resistor formed by the mold method, there was formed a gate portion at the location where the resin was poured into the slot of the sleeve. This gate portion was rough and created a humidity trap which attracted moisture and provided a rough surface on which the moisture would lay.

Accordingly, it is an object of this invention to provide an electrical resistor and a method of making it which overcomes the foregoing problems and disadvantages.

It is another object of this invention to provide an electrical resistor which is hermetically sealed and capable of withstanding satisfactorily the salt water immersion test, and the 95% humidity test.

It is another object of this invention to provide an electrical resistor and a method of manufacturing it which does not disturb the temperature coefficient of the resistance wire.

It is another object of this invention to provide a method of manufacturing a precision electrical resistor on a mass production basis in which the number of rejects is kept to a minimum.

Other objects and advantages of this invention, including its simplicity and economy, will further become apparent hereinafter and in the drawings, in which:

FIG. 1 represents a view in perspective of an electrical resistor constructed in accordance with this invention and being partly assembled;

FIG. 2 represents a view in perspective of the assembled electrical resistor of FIG. 1;

FIG. 3 represents a partial view in cross-section, taken through the axis of the electrical resistor;

FIG. 4 represents a view of the left end of the electrical resistor shown in FIG. 1;

FIG. 5 represents a perspective view, similar to FIG. 1, of another embodiment of the present invention;

FIG. 6 represents a view, similar to FIG. 2, of the electrical resistor shown in FIG. 5; and

FIG. 7 represents a partial view in cross-section taken along the axis of the electrical resistor of FIG. 6.

Although specific terms are used for clarity in the following description, these terms are intended to refer only to the structure shown in the drawings and are not intended to define or limit the scope of the invention.

Turning now to the specific embodiment of the invention selected for illustration in FIGS. 1-4, there is shown an electrical resistor which includes a bobbin 11, electrical terminal lugs 12 and 13 mounted at each end of bobbin 11, a resistance wire 14 wound around bobbin 11 and connected between terminal lugs 12 and 13, a cover tube 15 which is positioned around bobbin 11 (FIG. 3), and end caps 16 which seal the ends of cover tube 15 to hermetically seal the electrical resistor.

Bobbin 11 has a cylindrical core 17 and radial flanges 18-20 extending therefrom so that a pair of radial

flanges and the portion of the core 17 therebetween define a pi section. Flanges 18—20 are provided with radial notches 21 through which the resistance wire 14 passes from one pi section to another. Resistance wire 14 is wound in the same direction in alternate pi sections in order to cancel out inductance.

Both ends of core 17 are provided with a flattened portion 22 which cooperates with the flattened portion 23 of terminal lugs 12 and 13 to prevent rotation of the terminal lugs around said core 17.

Terminal lugs 12 and 13 are provided with an annular base 24 and a tongue 25 extending therefrom past the periphery of the flanges 18. An anchor tab 26 protrudes from the base 24 to provide an anchor about which an end of the resistance wire 14 is tightly wound to form a good mechanical joint. A sealing hole 27 is formed in tongue 25 inside the periphery of the radial flanges 18—20 so as to insure penetration of the material of the end caps 16 between the terminal lugs 12, 13 and their associated end flanges 19, 20 to adhesively join the end caps to the end flanges.

Electrical terminal lugs are preferably made of an electrically conductive metal which is flexible and capable of being bent at substantially right angles (as is shown by terminal lug 13 in FIG. 1), and returned to upright position (as is shown by terminal lug 13 in FIG. 2).

Cover tube 15 fits snugly around radial flanges 18—20 to inhibit penetration of the end cap material past the end flanges 19, 20, and cover tube 15 and end flanges 18—20 form insulating air spaces 28 around resistance wire 14.

The process of manufacturing and assembling the electrical resistor of FIGS. 1-4 is as follows.

Resistance wire 14 is wound on the bobbin 11 in the same direction in alternate pi sections formed by the radial flanges 18—20 and is passed between the pi sections through the radial notches 21. Electrical terminal lugs 12 and 13 are mounted on each end of bobbin 11 and the ends of the resistance wire 14 are tightly wound on their respective anchor tabs 26 to form a good mechanical joint, after which the mechanical joints are soldered. Then tongue 25 of terminal lug 13 is bent to a substantially right angle, and cover tube 15 is passed over bent tongue 25 into position around the flanges 18—20 and between terminal lugs 12 and 13 to form the insulating air space 28 around the resistance wire 14. Tongue 25 of terminal lug 13 is bent back into upright position and a viscous solution of the same epoxy resin of which bobbin 11 and cover tube 15 are made is placed on both rims of cover tube 15. Cover tube 15 is spun to insure a good seal between the cover tube rims and their associated terminal lugs 12, 13.

Another portion of the viscous solution is placed on and caused to spread over the outer surface of terminal lug 12, and to flow through sealing hole 27 to insure that contact is made between the lug 12 and end flange 20. The solution is set by applying heat or ambient temperature thereto to form end cap 16.

One end cap 16 having been formed at the lug 13 end, the resistor is turned over and another portion of the viscous solution is placed on and caused to spread over the outer surface of lug 13, and to flow through the sealing hole 27 to insure that contact is made with end flange 19, and the solution is set by the application of heat or ambient temperature to form an end cap 16 which hermetically seals the resistor.

If desired, instead of applying a viscous solution of epoxy resin on the terminal lugs 12 and 13 to form end caps 16, a pellet of solidified epoxy resin may be placed on the terminal lug and subjected to heat to cause it to melt and form the end cap.

Turning now to the embodiment of the invention illustrated in FIGS. 5-7, there is shown an electrical resistor having a bobbin 31, electrical terminal axial leads 32

mounted at each end of bobbin 31, a resistance wire 33 wound around the bobbin 31 and connected between the terminal leads 32, a cover tube 34 positioned around bobbin 31 and forming insulating air spaces 35 around resistance wire 33, and an end cap 36 hermetically sealing each end of cover tube 34 to hermetically seal the resistor.

Bobbin 31 is provided with a cylindrical core 37 and radial flanges 38—40 extending therefrom. Each pair of radial flanges together with the core 37 extending therebetween forms a pi section, and resistance wire 33 is wound in the same direction in alternate pi sections in order to cancel out inductance. Radial notches 41 are provided in flanges 38—40 to provide a passage for the resistance wire 33 as it is placed between the pi sections.

Bobbin 31 is provided with a lead wire 42 which is mounted in a lead base 43 which is seated in the hollow center 44 of cylindrical core 37.

End flanges 38 and 40 are provided with peripheral grooves 45, 46, respectively. A tinned copper connecting wire 47 is looped around end flange 38 and seated in groove 45 and one end of wire 47 is twisted around wire 47 at a point spaced away from its other end to form a first mechanical joint 48. The start end of resistance wire 33 is also wound tightly around joint 48. The other end of connecting wire 47 is tightly wound around axial lead 32 to form a second mechanical joint 51. To insure a good electrical connection, the mechanical joints 48 and 51 are also soldered.

A tinned copper connecting wire 52 is looped around end flange 40 and seated in groove 46 and is provided with mechanical and solder joints in like manner.

The process of manufacturing and assembling the electrical resistor of the embodiment shown in FIGS. 5-7 is as follows.

Grooves 45 and 46 are formed in the end flanges 38 and 40 of an epoxy resin bobbin 31. A tinned copper connecting wire 47 is looped over end flange 38 and seated in groove 45, and a tinned copper connecting wire 52 is looped over end flange 40 and seated in groove 46. One end of connecting wire 47 is tightly wound around the wire at a point away from its other end to form a first mechanical joint 48. The start end of resistance wire 33 is wound around first mechanical joint 48, and the resistance wire is wound on the bobbin 31. The electrical resistance of wire 33 is measured. The finish end of resistance wire 33 is wound around the first mechanical joint of connecting wire 52.

Electrical terminal axial leads 32 are mounted in the hollow center 44 at each end of bobbin 31. The free end of connecting wires 47 and 52 are tightly wound around their respective axial leads 32 to form a second mechanical joint 51. The first mechanical joint 48 and the second mechanical joint 51 are soldered. Epoxy resin cover tube 34 is slid over flanges 38—40 to form the insulating air space 35 around resistance wire 33. Then a solution of epoxy resin is placed on the outer surface of end flange 38 and is set by applying heat or ambient temperature to form an end cap 36 which hermetically seals that end of the resistor.

In like manner, another portion of the epoxy resin solution is applied to the outer surface of the end flange 40 to form an end cap 36 which hermetically seals the resistor.

If desired, instead of applying a viscous solution of the epoxy resin to form the end caps 36, a pellet may be deposited on the outer surface of each end flange in turn, and subjected to heat to cause the pellet to melt and form the end cap.

The advantages of the electrical resistor and process of manufacturing it in accordance with this invention are numerous, and include a substantial reduction in both production cost and in number of rejects.

The time consuming of the operations of the mold method, and the waste involved in discarding the end

pieces, slotted sleeve, and other parts which form the mold, are eliminated.

In the present invention, the temperature characteristic of the resistance wire unaffected by the encapsulating process since the encapsulating material does not come in contact with the resistance wire; there is an air space formed around the resistance wire between the bobbin and the cover tube. The electrical resistor of this invention is hermetically sealed and is considerably lighter in weight than previous units.

The previously used molding process also required the performance of the steps of slotting the tubes, cutting them to the desired sizes, cleaning burrs, and dipping them in the molding solution (that permits them to be knocked out easily and released from the formed resistor). All these steps are eliminated from the method of the new invention.

The pin holes and air pockets formed by the mold method of construction are eliminated by the process of this invention.

Another advantage of the present invention is that the dielectric path from the end surface of the core of the bobbin to the tongue of the terminal lug is considerably lengthened because the outer surface of the end cap is curved. In the resistors formed by the mold method, the distance between the end surface of the core and the tongue of the terminal lug was a straight line, which is shorter. The curved end cap is advantageous, for example, in the 95% humidity test, during which one of the end caps of the resistor is seated on an electrode. The curved end cap provides a longer dielectric path from the electrode to the tongue of the terminal lug.

The electrical resistor of the present invention is smooth and does not have the rough gate surface, and humidity trap formed thereby, of the mold-formed resistor.

One of the tests utilized in testing a precision resistor for variation in temperature coefficient is to subject the resistor to a temperature cycle of between minus 55 to plus 125 degrees C. This temperature cycle is repeated five times, with 10 minutes between temperature extremes. Such a test causes expansion and contraction of the resistor material. Accordingly, the cover tube, the bobbin, and the end caps of the present invention are all made of the same material, so that their temperature coefficient is the same. This eliminates cracking caused by expansion and contraction. It is to be noted that the material of the end caps is in contact with the end flanges but not with the resistance wire, and the cover tube fits snugly over the bobbin to prevent the molding material of the end cap from going down inside the resistor.

The process of the present invention lends itself to batch-wise, or to continuous production. In the batch method, the operator sits in front of a table with a swatch stick and a pot of viscous epoxy resin, and applies the resin to the ends of the bobbin and cover tube. The lug type of the resistor may be mounted on racks, and the axial lead type may also be mounted by inserting the axial leads into stiff sponge-like material such as that used by florists. The resistors are first encapsulated on one end, the end cap material is hardened, and then the resistor is turned around and encapsulated on the other end.

In the continuous method, the resistors pass on a conveyor in front of the operator who drops a pellet of epoxy resin on one end of the resistor, whereupon the conveyor transports the resistor to a baking oven in which the pellet is melted to form an end cap.

In practice, satisfactory results have been obtained by using rods and tubes made of a solid, infusible plastic (thermo-setting group) of the epoxide type (such as Hysol 6000-600), with a potting and encapsulating epoxy resin and suitable hardening agent (such as Hysol 6020-600). Both Hysol products are supplied by Houghton Laboratories, Inc., Olean, New York.

It is to be understood that the form of the invention herewith shown and described is to be taken as a pre-

ferred embodiment. Various changes may be made in the shape, size and arrangement of parts. For example, equivalent elements may be substituted for those illustrated and described, parts may be reversed, and certain features of the invention may be utilized independently of the use of other features, all without departing from the spirit or scope of the invention as defined in the subjoined claims.

Having thus described my invention, I claim:

1. An electrical resistor comprising a bobbin of cylindrical shape having radially notched flanges extending therefrom, an electrical terminal lug mounted at each end of the bobbin and having an annular base and a tongue extending therefrom past the periphery of said flanges, a resistance wire wound around the bobbin and connected between said terminal lugs, a cover tube positioned around said flanges and between said terminal lugs, said cover tube and said flanges forming an insulating air space around said resistance wire, and an end cap covering said terminal lugs except for the protruding tongues thereof and sealing the ends of said cover tube to hermetically seal the resistor, said tongue having a sealing hole formed therein which provides a passageway between the end cap and the surface of the end flange to provide for penetration of the end cap material between the terminal lug and the end flange so as to insure good adhesion therebetween, said end cap extending between and connecting the terminal lug and the end flange, said end cap being made of the same material as said bobbin and cover tube so as to have the same coefficient of expansion.

2. A process of making a hermetically sealed resistor of the type having a bobbin of cylindrical shape with radially notched flanges extending therefrom, an electrical terminal mounted at each end of the resistor, and a cover tube, comprising winding resistance wire on a bobbin made of insulating material, mounting an electrical terminal axial lead at each end of the bobbin, said axial lead having a lead wire seated in a lead base, and the end flange of the bobbin having a peripheral groove formed therein, seating a tinned copper connecting wire in said groove, winding one end of said connecting wire around the connecting wire at a point spaced away from its other end to form a first mechanical joint and to form a loop of connecting wire around said groove, winding an end of the resistance wire tightly around said first mechanical joint to form a second mechanical joint, soldering said first and second mechanical joints to form a first solder joint, winding the other end of said connecting wire around said axial lead to form a third mechanical joint, soldering said third mechanical joint to form a second solder joint, passing a cover tube made of the same said insulating material over said flanges to form an insulating air space around said resistance wire, and placing a viscous solution of the same said insulating material on the ends of the cover tube and solidifying said solution to form an end cap which hermetically seals the resistor with the bobbin, cover tube and end caps having the same coefficient of expansion.

3. A process of making a hermetically sealed resistor comprising winding resistance wire on a bobbin made of epoxy resin and having a cylindrical shape with radially notched flanges extending therefrom, mounting an electrical terminal lug at each end of the bobbin, said terminal lug having an annular base portion and a tongue extending past the periphery of said flanges with a sealing hole formed in a portion of said tongue which is inside said periphery, connecting said resistance wire between said terminal lugs, bending one of said tongues at substantially a right angle, passing a cover tube made of the same said epoxy resin over said bent tongue into position around said flanges and between said terminal lugs to form an insulating air space around said resistance wire, bending said bent tongue back into upright position, placing a viscous solution of the same said epoxy resin on

the rims of said cover tube, spinning the tube to insure a good seal between the lugs and the cover tube, placing another portion of said viscous solution on and causing it to spread over the outer surface of one lug and to flow through the sealing hole in said lug to insure that contact is made between the lug and the end flange, setting said solution to form an end cap, placing another portion of said viscous solution on and causing it to spread over the outer surface of the other lug and to flow through the sealing hole in said other lug to insure that contact is made between said other lug and the end flange, and set-

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ting said solution to form an end cap which hermetically seals the resistor.

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