

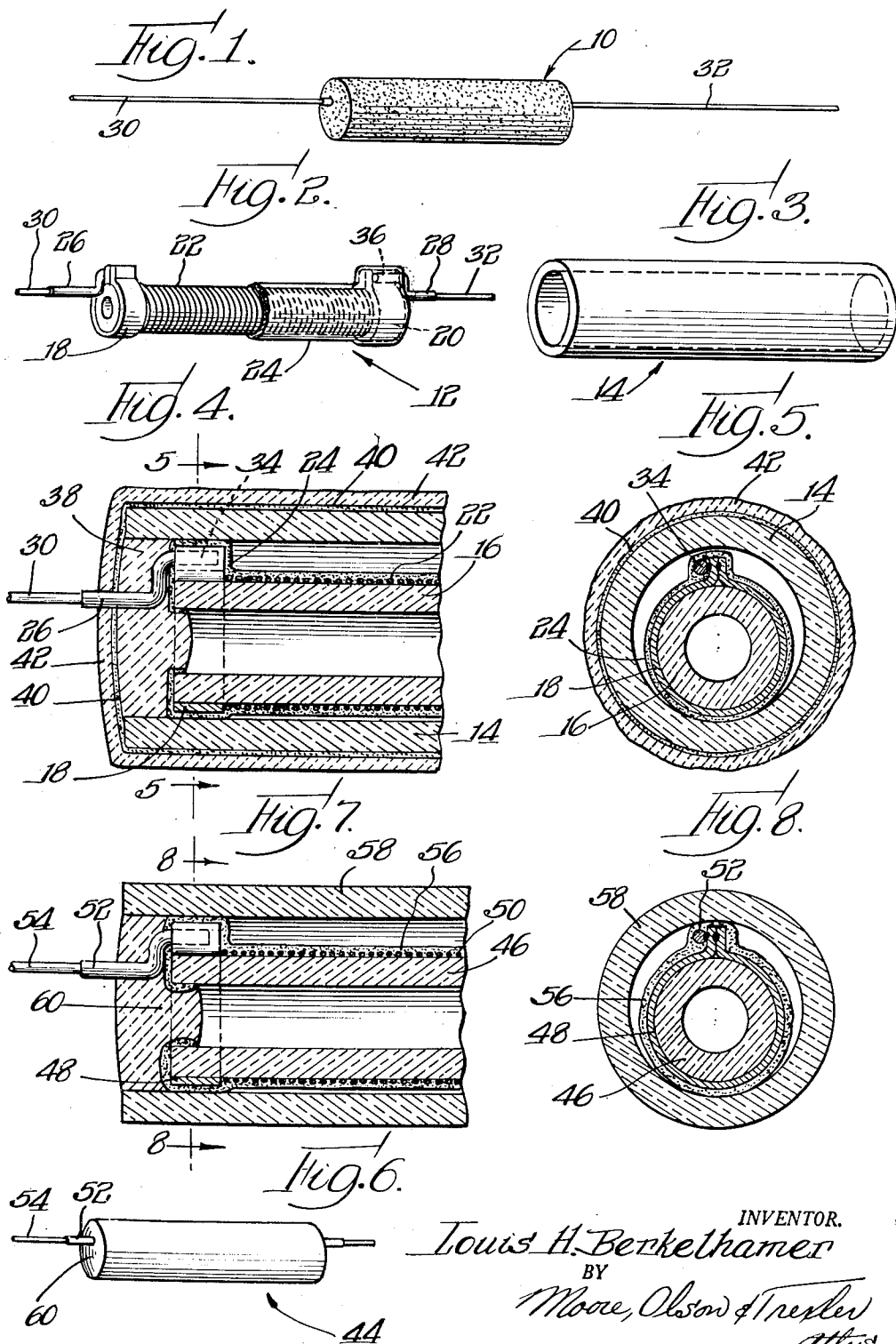
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RESISTOR AND METHOD OF MANUFACTURE

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RESISTOR AND METHOD OF MANUFACTURE

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1 This invention relates to electrical circuit elements, and particularly to wire coil circuit elements such as resistors and to methods for manufacturing such circuit elements.

Certain electrical circuit installations are subjected to a high degree of thermal shock, i. e., extreme and rapid temperature changes and must operate satisfactorily under conditions of high humidity. An example of such installations is to be found in naval electrical circuits wherein the parts are subjected to thermal shock and to exposure to salt water.

The present invention is particularly directed to providing resistors for such installations which can operate satisfactorily under the described conditions. Wire coil resistors which are coated with conventional varnishes or lacquers are unsuitable for these installations due to the fact that the varnishes and lacquers do not withstand a high temperature without deterioration and failure in their insulating properties. Wire coil resistors which are coated with vitreous enamel are adapted for high temperature installation since vitreous enamel has high thermal resistivity and maintains an effective insulating coating for the coil even under conditions of continuous high temperatures. However, in installations wherein the resistor is subjected to thermal shock the vitreous enamel shows a tendency to craze and the multiplicity of surface cracks thus formed, even though relatively minute, impair the effectiveness of the enamel coating, particularly in respect to moisture resistivity, durability and other operating conditions.

In accordance with the present invention a circuit element, and particularly a wire coil resistor structure, is provided which is particularly adapted for high temperature installations by providing protection for the wire coil or other electrical circuit component while at the same time being capable of withstanding a high degree of thermal shock and being suitable for use under high humidity conditions.

Accordingly it is an object of the present invention to provide an improved circuit component such as a wire coil electrical resistive element which will effectively resist high degrees of thermal shock and which is capable of continuous operation at high temperatures.

Another object of the invention is to provide an improved circuit component and particularly a wire coil electrical resistive element which retains its electrical properties under conditions of high humidity.

Still another object of the invention is to pro-

vide an improved resistor structure in which the wire coil element is highly protected from physical blows and thermal shock whereby to maintain the electrical characteristics of the resistor substantially constant.

A further object is to provide in combination with a resistor structure set forth above an improved connecting lead wire which aids in prolonging the watertight and water-repellent characteristics of the resistor.

Yet another object is to provide an electrical circuit element and particularly a wire coil resistor wherein silicone is employed in an improved manner to provide a protective coating for the wire coil.

A still further object of the invention is to provide an improved method of manufacturing a circuit element and particularly a wire coil resistor of the type described.

Various other objects, advantages and features of the invention will be apparent from the following specification when taken in connection with the accompanying drawings wherein certain preferred embodiments of the invention are set forth for purposes of illustration.

In the drawings wherein like reference numerals have been used to refer to like parts throughout:

Figure 1 is a perspective view of a wire coil resistive circuit element constructed in accordance with and embodying the principles of the present invention;

Figure 2 is an enlarged perspective view of the resistor core which forms a part of the resistive element shown in Figure 1, one end of the core being shown in the condition prior to the application of the silicone coating;

Figure 3 is an enlarged perspective view of the outer shell or tube which forms part of the resistive element of Figure 1;

Figure 4 is a further enlarged view in vertical cross section of one end of the resistive element shown in Figure 1;

Figure 5 is a view in cross section of the resistor substantially as seen in the direction of the arrows along the line 5—5 of Figure 4;

Figure 6 is a perspective view of another embodiment of a wire coil resistive circuit element made in accordance with the principles of the present invention;

Figure 7 is an enlarged view in cross section of one end of the resistor shown in Figure 6; and

Figure 8 is a cross sectional view of the resistor shown in Figure 6 substantially as seen

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in the direction of the arrows along the line 8—8 of Figure 7.

In the drawings the invention has been illustrated as applied to an electrical resistor of the wire coil type to which it has particular application. It is to be understood however that the invention is also adapted for use with other electrical circuit units or elements containing circuit components to be protected and particularly wherein high temperature and high humidity operating conditions and conditions of thermal shock are to be encountered.

Referring more specifically to the drawings there is illustrated in Figure 1 a resistor, generally designated by the numeral 10, made in accordance with and embodying the principles of the present invention. Resistor 10 comprises a core 12, best illustrated in Figure 2, an outer shell or tube 14 within which core 12 is disposed and an outer covering which will be more fully described hereinafter.

As may be best seen in Figures 2 and 4, core 12 includes a body portion 16 carrying on its opposite ends a pair of terminal lugs 18 and 20. These terminal lugs have projecting tine portions formed integral with band portions engaging the body of the resistor, the tine portions being secured together as by welding to hold the band portion assembled about the body portion 16. A resistor wire coil 22 is disposed around body portion 16 and is connected as by welding at its opposite ends to the lugs 18—20 for an electric interconnection therewith in the usual manner.

The details of the core 12 are more particularly illustrated in Figure 4 wherein it will be seen the body portion 16 comprises a ceramic center in the form of a cylinder upon which is wound the resistor wire 22 with its convolutions positioned in predetermined spaced relationship thereupon. The wire convolutions are embedded within and covered by a coating 24 of a silicone, such as a silicone rubber or elastomer, which completely covers the outer portions of core 12 and extends a short distance into the aperture in the center thereof. Each convolution of the resistance wire is maintained in spaced relationship with respect with the adjacent convolutions and is embedded and encased within the silicone coating 24. The manner and method of applying coating 24 will be described more fully hereinafter.

An important feature of the present invention is the improved terminal lead wire connections which make electrical contact with the terminal lugs 18 and 20. Each of these terminal connections includes a heavier wire portion as at 26 and 28 which is fastened to a lighter wire of smaller diameter such as the wires 30 and 32. The wires 26—30 and 28—32 are preferably connected by butt welding. To facilitate attachment of the terminal leads to the terminal lugs 18—20, the heavier wires 26—28 are formed with offset portions 34 and 36, respectively, which have a length slightly greater than the width of terminal lugs 18—20. The offset portions 34—36 are connected to the terminal lugs 18—20 respectively in any suitable manner such as by welding or soldering. When the leads are attached in the manner described the wires 30—32 are disposed toward the central axis of core 12 and extend substantially parallel therewith. Heavier wires 26 and 28 extend through the outer covering of the finished resistor which will be described more fully hereinafter.

As was stated above, the coating 24 is prefer-

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ably made of silicone rubber. Silicones are a class of organo silicon oxide polymers which possess insulating properties and which can be cured by the action of heat. In fabricating the silicone coating 24, a suitable silicone is mixed with a thinning agent, such as carbon tetrachloride, and the resulting mixture is stirred or beaten to form a suspension having a suitable viscosity. Coating 24 is preferably applied by immersing the fabricated core 12 in a body of the silicone suspension, the lead wires 30—32 being cleaned by wiping after the immersion. After application of the coating of silicone, the layer so formed is dried. The coating 24 may, if desired, and preferably is built up by a plurality of sequentially dipping and heat curing operations whereby to build up and develop a coating 24 of the desired thickness.

While in the particular embodiment disclosed the coating 24 has been described by being built up by a plurality of dipping operations, it will be understood that the coating may be applied by various means such as pouring, spraying, or otherwise.

The finished core 12 is assembled within the ceramic shell 14. As is best seen in Figure 3, shell 14 is cylindrical in form and has an inner diameter which is slightly greater than the greatest diameter of core 12 whereby core 12 fits snugly therein. Referring to Figure 4 it is seen that shell 14 is slightly longer than body portion 16 so that substantially all of core 12 is disposed within shell 14 with the exception of the terminal leads.

Means is provided for holding core 12 in position within shell 14 in the form of a body of silicone cement 38, a quantity of which is disposed in both ends of shell 14. The silicone cement 38 comprises generally silicone resins, a non-metallic filler, and a thinner. Preferably two silicone resins are used, one of the resins being more plastic than the other, the least plastic resin being preferably brittle. An example of a suitable non-metallic filler material is silica. It is desirable to utilize two sizes of filler material, one of the sizes of filler material being smaller than the other. The use of two sizes of non-metallic filler material gives improved workability of the mixture and better suspension properties of the particles. Enough thinner is added to produce a mixture having a consistency such that the silicone cement can be troweled during application.

After the silicone cement 38 has been packed into both ends of shell 14, a plurality of silicone coatings are applied to the article to obtain increased resistance to water and humidity penetration. The first coat 40 is an elastomeric silicone coat similar to coating 24. This coat may be applied by sequential immersion, pouring, or spraying as described above with respect to coating 24.

An outer silicone coating 42 is next applied to form an outside protective layer. Coating 42 comprises silicones and a quantity of non-metallic filler material. The silicones utilized in coating 42 preferably include a silicone elastomer and a silicone having less plasticity, the least plastic silicone being preferably brittle. Two different sizes of non-metallic filler material are used to give improved workability and better suspension of the particles in the material. A suitable filler material is silica. A thinner such as carbon tetrachloride is added to the mixture of silicones and filler materials to form a suspension into which the resistor can be immersed.

The coating 42 may be formed as a single layer or by a series of successive dipping and drying operations. Coating 42 is highly abrasion resistant whereby to give added protection for coating 40.

After the application of the coatings 24, 40, and 42, the lead wires are cleaned and the resistor placed within a heating device such as an electric oven and subjected to sufficient heat to effect a curing of the silicone coatings applied. The curing temperature may vary depending upon the length of time of the heat application, the temperature and length of time utilized being such as to give a relatively hard outer coating 42 while leaving the coatings 24 and 40 relatively soft and elastic. Coating 40 is preferably cured to a greater degree than coating 24 and this results from the curing method employed since the temperature to which the coating 24 is subjected is less than that to which coating 40 is subjected. It is desirable to slightly undercure coating 24 since this coating is heated during use due to the heat evolved by the resistive wire coil 22 when electrical current passes therethrough. By undercuring coating 24 a longer useful life of this coating is obtained.

Although a single heat curing operation has been described as the preferred procedure, a plurality of heat curing operations could be utilized, that is, a separate heat curing operation could be applied to each coating. It has been found, however, that the described procedure gives a superior resistor and provides an economical process.

Referring to Figure 4 it will be seen that the resistor is provided with several layers of materials to protect the resistive wire coil 22 from the atmosphere and more specifically moisture whereby to prolong the life of the resistor. The coatings 24, 40, and 42 are each water-repellent in character and, in addition, the shell 14 and the coatings 40 and 42 provide mechanical protection for the coil 22.

The heavier portions 26—28 of the terminal leads extend through the silicone cement 38 and the silicone coatings 40 and 42. To retain the waterproof characteristics of the resistor, the material from which wire 26 is fabricated is chosen to have substantially the same coefficient of thermal expansion as the silicone cement 38 and coating 42. Similarly, silicone cement 38 and coating 42 are so compounded as to have substantially the same coefficient of thermal expansion. By making all of these materials, including wire 26, from materials having substantially the same coefficient of thermal expansion, there is no tendency to crack cement 38 or the outer resistor coating 42 when the resistor is heated as would be the case if these materials had different coefficients of thermal expansion.

The reason for making the terminal lead wires from wires having different diameters will be now more apparent. When using the resistor, substantially all of the bending of the lead wires will occur in the sections 30—32 of smaller diameter and substantially no bending will occur in the heavier wires 26—28. This feature also helps protect the watertight seal since, if the wires 26—28 were bent instead of the lighter wires 30—32, there would be a tendency to crack either the outer coating 42, the silicone cement 38, or both. With the present construction, there is no tendency to crack these water protective coatings since substantially all of the bending of the terminal leads occurs in wires 30—32.

A resistor made in accordance with the above

process and constructed as shown in Figures 1—5 is particularly adapted for high temperature installations since the resistive wire coil 22 is well protected. The resistor is highly resistive to thermal shock and therefore can be used in those installations in which rapid and great changes of temperature are encountered. The multiplicity of water repellent coatings surrounding the coil 22 aid in reducing damage due to thermal shock by virtue of their insulating properties and in addition render the resistor highly water repellent whereby to make the resistor useful in installations wherein conditions of high humidity or even exposure to water are encountered.

By providing the outer shell 14 and its associated coatings, the wire coil 22 is protected from physical blows as well as thermal shock. The improved terminal lead wire structure contributes to maintaining the watertight and water-repellent characteristics of the resistor since there is little or no tendency to bend that portion of the lead wire which passes through the coatings surrounding the resistor. The two component structures of the lead wires makes it possible to utilize a material having substantially the same coefficient of thermal expansion as the associated silicone materials for that portion of the lead wires which pass through the protective silicone layers whereby to further aid in maintaining the water repellent characteristics of the resistor. As was explained above, this feature eliminates failures from water and humidity penetration due to cracking of the outer silicone layers when the resistor is heated.

Referring now to Figures 6—8 there is shown a second embodiment of the invention. This form of resistor, generally designated by the numeral 44, includes a core similar to core 12 which comprises a ceramic body portion 46, terminal lugs 48, a resistive wire coil 50, and a terminal lead wire having a heavier wire section 52 and a lighter wire section 54. These parts are assembled and constructed in the same manner as the corresponding parts of the resistor shown in Figures 1—5.

This core is coated with a silicone composition designated by the numeral 56. Coating 56 contains the same materials as the silicone cement 38 described above, viz., two silicones and two sizes of non-metallic mineral filler. An additional quantity of thinner is added to the silicone cement, as compared with the quantity used to make cement 38 whereby to make it more fluid and therefore suitable for application by immersion.

The core is disposed within an outer shell 58 which is identical with the shell 14 described above and the core is held in position within shell 58 by means of a quantity of silicone cement 60 which is packed in both ends of shell 58. The composition and consistency of cement 60 are identical with those of the silicone cement 38 described above. The assembled resistor is heated whereby to heat cure the coating 56 and the silicone cement 60 in the manner described above.

The resistor of Figures 6—8 possesses substantially all of the desirable characteristics of the resistor of Figures 1—5. The ceramic shell 58 and the silicone cement 60 in co-operation with the coating 56 provide protection from thermal shock, mechanical blows, and humidity. The watertight integrity of the resistor is maintained by forming lead wire 52, coating 56, and silicone cement 60 from materials having substantially

the same coefficient of thermal expansion whereby to eliminate cracks between these materials when the resistor is heated. The improved terminal lead structure co-operates to retain the water-repellent characteristics of the resistor by substantially eliminating bending of the heavier wire 52 thereby to prevent cracking of the silicone cement 60.

It is obvious that various changes and modifications may be made in the specific structures and method steps set forth herein and described without departing from the spirit of the invention. The invention is accordingly not to be limited except as indicated in the following claims.

The invention is hereby claimed as follows:

1. An electrical unit comprising a body portion, a circuit impedance element carried by said body portion, a coating of insulating material overlying said circuit element to provide insulation therefor, sealing means for the end of said body portion, and lead means including a relatively heavy wire portion connected to said circuit element and projecting through said sealing means and in sealed contact therewith, said sealing means and said relatively heavy wire portion having substantially equal coefficients of thermal expansion to resist cracking or breaking of the seal therebetween, said lead means also including a relatively light wire portion connected to the projecting end of said relatively heavy wire portion to assume substantially all bending stresses with resultant elimination of tendency toward cracking or breaking the seal.

2. An electrical unit as claimed in claim 1, wherein there is provided an outer shell over the assembled circuit element and body portion and sealed thereto by said sealing means.

3. An electrical unit as claimed in claim 2,

wherein the outer shell is provided with a coating extending over the sealing means and having substantially the same coefficient of thermal expansion as said relatively heavy wire portion and said sealing means.

4. An electrical unit as claimed in claim 3, wherein the sealing means and the coating for the outer shell consist of a mixture of silicone materials of greater and lesser plasticity.

5. An electrical unit as claimed in claim 4, wherein the silicone material of lesser plasticity approaches brittleness.

6. The method of making an electrical unit comprising mounting a circuit impedance element upon a body portion, applying a coating containing silicone over said circuit element, inserting said element carrying body portion within a rigid shell, sealing said body portion within said shell with a cement containing silicone, thereafter applying a silicone containing coating over said sealing shell, and differentially heat-curing both coatings by completely curing the coating on the sealing shell and uncuring the coating over the circuit element and body portion.

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