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ELECTRICAL RESISTOR AND HIGH-RESISTANCE CARBON
COMPOSITION AND RESISTANCE ELEMENT THEREFOR
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2,495,199

FIG. 1.

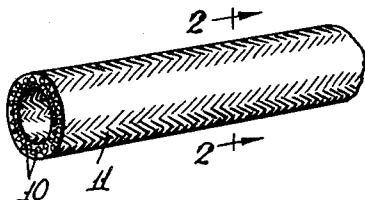


FIG. 2.

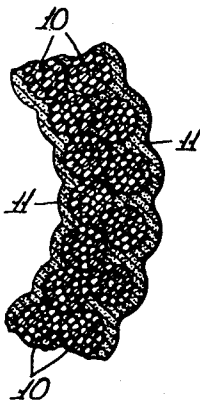
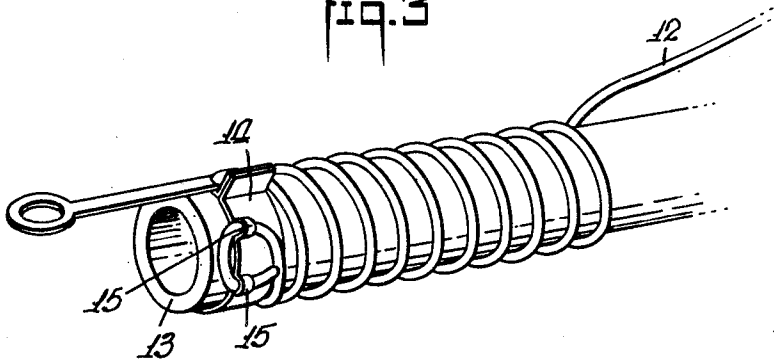


FIG. 3.



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ELECTRICAL RESISTOR AND HIGH-RESISTANCE CARBON COMPOSITION AND RESISTANCE ELEMENT THEREFOR

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6 Claims. (Cl. 201—75)

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My present invention relates generally to electrical resistors, and has particular reference to resistors of very high ohmic values, i. e., in the megohm range.

Coordinately, my invention relates to an improved electrically-conductive composition of matter having high ohmic resistance, to a novel way of employing this composition, as part of an elongated flexible resistance element, and to a method of forming such a resistance element.

Megohmic resistors are required in various electrical and radio communication systems or the like. Generally speaking, such a resistor must be of a character which not only provides the desired high resistance path in a relatively small space, but which reliably retains its physical and electrical properties for prolonged periods of time under high voltages and at high operating temperatures.

A general object of this invention is to provide a resistor having these desirable attributes and capable of manufacture at such relatively low cost that its use becomes commercially feasible in numerous cases where, heretofore, the use of megohmic resistors has been precluded because of prohibitive cost. An example of the type of use for which the present improved resistor is admirably suited is in a domestic television receiving set in which it is desirable, as a safety precaution, to use such a resistor as a bleeder across high voltage capacitors to discharge the capacitors rapidly after the power supply has been shut off. The voltages employed range from 1,000 to 25,000 volts, and, so far as I am aware, no practical resistor of adequately reasonable cost and size has ever heretofore been available for such use.

Since the limitations of metallic resistance wires as to specific resistance make it difficult to use them in creating high resistance in a small space, particularly where any appreciable voltage is involved and where power must be dissipated, the present resistor is of the carbon-compound type. In my earlier patents, Nos. 2,347,795 and 2,347,796, I have alluded to the discovery that, so far as carbon compound resistors are concerned, satisfactory performance, stability, and durability, under impressed voltages in the multi-kilovolt range and at high operating temperatures, can be achieved only if the resistance path has a predetermined minimum length and a predetermined minimum cross-sectional area, depending upon a predeterminable relation between the voltage impressed, the current to be carried, and the maximum temperature which the resistor must withstand during its operation. In Patent

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2,347,796, I have described and illustrated a resistor construction of segmentary character well suited to comply with these requirements and to produce a high-resistance path in a relatively compact space, but for many purposes this construction is currently too costly to justify its use on a commercially feasible basis.

My present invention is predicated upon the successful development of a continuous elongated flexible resistance element which defines a carbon-compound resistance path which may be caused to have the requisite dimensional characteristics, and which lends itself to the formation of a compact, durable, and relatively inexpensive resistor by merely supporting a selected length in a suitable fashion, as, for example, by simply winding it around a ceramic object or the like. This resistance element, constituting by itself a useful product resulting from the present invention, has a basically simple and inexpensive structure, a continuity which permits indefinite lengths to be formed, if desired, and a flexibility which facilitates not only its manufacture, but also the employment of selected lengths in a variety of ways for the assembly of low-cost resistors on a commercial scale. The resistance element may be made of uniform cross-sectional character, in which case resistors of different ohmic values may be conveniently constructed by simply using appropriate lengths of the resistance element.

Of primary importance is the fact that the present improved resistance element has the added and unique advantage of being completely immune to water or moisture, whereby it becomes unnecessary to provide a resistor with any special enclosure, and whereby the difficulties and expense of special impregnation and of hermetic sealing may be avoided.

Briefly, my invention resides in (a) the creation and employment of a flexible electrically-conductive composition of matter having high ohmic resistance and consisting of a dispersion of carbon in a heat-resistant moisture-resistant material such as a silicone resin, and (b) the application of this suspension in the form of an adherent continuous flexible coating to a carrier element which is itself flexible, preferably a woven tubular braid, composed of a material, such as glass, which is non-conductive, unreactive toward the resin, and of unusual heat-resistant and moisture-resistant character.

A preferred way of achieving these general objects and advantages, and such other objects and advantages as may hereinafter appear or be

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pointed out, is illustrated in the accompanying drawings, in which:

Figure 1 is a perspective view of a section of a flexible resistance element of the present improved character, drawn on an exaggerated scale;

Figure 2 is an enlarged fragmentary cross-sectional view taken substantially along the line 2—2 of Figure 1, this view being also somewhat exaggerated and idealized; and

Figure 3 is a fragmentary perspective view of a resistor embodying the features of the present invention, this view indicating also one manner of associating the several parts.

In manufacturing a resistance element of the character illustrated, a flexible tubular braid is formed, the threads of which are composed of a heat-resistant moisture-resistant non-conductive material such as glass fibre. These threads may be either of spun or drawn variety, and those illustratively indicated in Figure 2 by the reference numeral 10 are of the spun variety. They may be braided together in well-known woven relationship by any suitable means such as a conventional braiding machine. The dimensions of the threads, and of the resultant braid, may obviously be varied to suit different requirements, and a typical construction would involve a tubular braid of approximately #24 A. W. G. gauge, i. e., having an inside diameter adequate to clear a #24 wire. The threads in the finished tubing may not necessarily assume the particular positional relationships shown in Figure 2, this view being intended merely to illustrate the well-known fact that in a woven tubular braid there are longitudinal, transverse, and diagonal interstices between the threads, thus defining a rather extended surface area upon which a coating may be formed.

A tubular braid of this character is illustrative of the flexible type of heat-resistant strand which is employed as a carrier for the electrically-conductive composition of matter which is to define the desired resistance path. A strand or tube of glass is uniquely suitable for the purpose, since the threads are completely non-absorbent, so far as moisture is concerned, and because they are capable of withstanding continuous operating temperatures of 300° C. or more without disintegration or impairment of their stability.

Coated on this flexible carrier, as indicated by the reference numeral 11, and covering the exposed surfaces on the inside and the outside of the tube and also in the interstices between the threads, is a coating composition of novel character, consisting essentially of a dispersion of powdered carbon, preferably gas carbon, in a heat-resistant moisture-resistant binder or carrier such as a silicone resin. Silicone resins are compounds, sometimes known as "polyorganosiloxanes," whose molecular structure is not yet fully understood, consisting of silicon, oxygen, and organic radicals. I have successfully employed, by way of example, a material which is a mixture or copolymer of methyl and phenyl silicones. This type of resin is characterized by its great heat stability. Because of this, and because of its unreactiveness toward glass, and its ability to adhere to glass, it is an excellent complement to the glass-fibre strand or braid upon which the present coating is to be formed. Of particular importance is the fact that a silicone resin is totally impervious to moisture, being resistant even to "wetting."

To counteract the negative temperature co-

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efficient of carbon, the powdered conductive material which is dispersed in the resin may include a minute extraneous material such as molybdenum sulphide, and where such a mixture is employed, the carbon constitutes at least 90% of the mixture.

In forming a resistor of commercial character, a selected length of the coated braid or strand, designated by the reference numeral 12 in Figure 3, may be wound around a ceramic tube or element 13, as indicated, the winding pitch being of such magnitude that the several turns, though arranged as closely as possible to one another, are nevertheless adequately spaced with respect to the voltage between adjacent turns to prevent short-circuiting. Where very high voltages are involved, it may be advantageous to provide the ceramic support 13 with a helical groove within which the coated strand is laid, thus allowing the ceramic wall between adjacent turns to act as a voltage barrier.

The resistance element may be secured in any desired fashion to a terminal band 14 of suitable metal, this band being clamped to the ceramic element 13 and provided with struck-up portions 15 or the like beneath which the end of the resistance element is securely engaged. In order to make a low resistance stable joint, a coating of colloidal silver paste may be applied to the contact area, if desired.

Figure 3 shows only one end of the resistor construction, and it will be understood that in the completed structure, the resistance element 12 forms a continuous winding from the connection terminal at one end to a second connection terminal at a remote point (not shown).

As an example of the detailed procedure which may be followed to produce a resistance element of high flexibility, a suspension is first formed consisting of—

	Per cent
Silicone resin	70
Thinner or solvent	20
Gas carbon	10
	100

The silicone resin may be of the general character hereinbefore mentioned, and I have successfully employed a resin which is currently manufactured by Dow-Corning Corporation and sold under the designation "990 A." The thinner or solvent may be of any suitable volatile type such as toluol. By submitting this mixture to ball milling for a period of about two hours, the carbon may be thoroughly dispersed in the resin. The resin is of course in unpolymerized state during this procedure.

A tubular glass braid of the character hereinbefore mentioned is preferably preliminarily heated at about 300° C. to drive off any residual spinning or weaving lubricants, and is then drawn through a vessel within which the foregoing suspension is contained. The tubing is then allowed to air-dry for approximately four hours, and may even be baked for a period of time sufficient to allow the coating to cure to a tack-free condition. Baking at approximately 250° C. for about two hours has proven sufficient for this purpose.

The tube is then wound on a suitable support, such as the ceramic support indicated in Figure 3, secured to copper terminals or the like, as hereinbefore mentioned, and the entire assembly is then placed in an oven and baked for approximately

eight hours at about 250° C. to bring about a complete polymerization of the resin.

While not absolutely essential, it may be found desirable thereafter to give the complete resistor unit an over-all coating with a silicone resin varnish, as by dipping it and then baking it to cure. This affords a desirable over-all mechanical protection for the resistor, and minimizes any likelihood of surface leakage due to possible collection of a moisture film on the ceramic tube itself.

Where the braid is of the character hereinbefore mentioned, and the composition is of the approximate character indicated in the foregoing example, tests indicate that the resistance element provides a conductive path having a resistance of approximately 100,000 ohms per lineal inch. Obviously, variations in the nature and amount of the carbon content of the suspension permits corresponding variations in resistance to be achieved. I have found that any desired resistance between 100 ohms and 10 megohms per inch of braid may be obtained. For higher current capacity resistors, larger diameter braids may be used, since this permits the electrically-conductive coating to have a greater effective cross-sectional area.

In practice, the selection of the sizes of braid to be employed, and the amount of carbon to be incorporated in the coating composition, will depend, as hereinbefore indicated, upon the voltage to be impressed upon the resistor, the current to be carried, the amount of resistance desired in a given over-all length, and the temperature conditions to be met. Under certain circumstances, the carrier strand need not necessarily be a tubular braid, and a single thread of spun or drawn variety, or possibly a group of such threads, may be suitable for the purpose. For most practical uses, however, it has proven preferable, in order to retain the desired flexibility of the resistance element, and to provide a resistance path of adequate cross-sectional area, to construct the carrier strand in the form of a braid such as that illustrated in the present drawings.

As an example of the capabilities of the present invention, I may state that I have successfully made resistors having a total length of no more than 2½ inches, employing a ceramic tube of approximately ⅞ inch diameter, having resistances ranging from 10,000 ohms to 500 megohms; and that resistors of this size and character have been successfully operated, without damage or deterioration, at voltages up to 20,000 volts.

For large-scale production purposes, it is contemplated that a resistance element of the present improved character may be made in a continuous process, the original braid being drawn from a suitable supply reel through a bath of the coating material, thence through a pre-drying oven and a multiple-pass curing oven, to a suitable take-up reel. In this way, many thousands of feet may be produced at one time, and the braid can subsequently be cut up as may be desired and wound on a suitable support or otherwise mounted for the purpose of providing a resistance path of predetermined ohmic value.

Having thus described my invention and illustrated its use, what I claim as new and desire to secure by Letters Patent, is:

1. A flexible electrically-conductive composition of matter having high ohmic resistance, consisting of a dispersion in a silicone resin of a powdered mixture composed of carbon and molybdenum sulphide, the carbon constituting at least 90% of the mixture.

2. An electrical resistor comprising a rigid, non-conductive, heat-resistant, moisture-resistant core, a pair of connection terminals mounted thereon, and an elongated resistance element of uniform, small cross section and uniform, high ohmic resistivity per unit of length space wound spirally about said core between said terminals, said resistance element forming the sole path for electrical current between the terminals and being composed of a flexible strand of a non-conductive, heat-resistant, moisture-resistant material bearing a continuous coating of a dispersion of powdered carbon in a flexible, heat-resistant, moisture-resistant resin.

3. An electrical resistor comprising a ceramic core, a pair of connection terminals mounted thereon, an elongated resistance element of uniform, small cross section and uniform, high ohmic resistivity per unit of length space wound spirally about said core, said resistance element forming the sole path for electrical current between the terminals and being composed of a flexible strand of glass fibres bearing a continuous coating of a dispersion of powdered carbon in a silicone resin.

4. An electrical resistor as claimed in claim 3 wherein the ceramic core is tubular in shape and the glass fibre strand is in the form of a tubular braid.

5. An electrical resistor as claimed in claim 3, wherein the glass fibre strand is coated with a dispersion in a silicone resin of a powdered mixture composed in major part of carbon and in minor part of a substance adapted to counteract the negative temperature coefficient of the carbon.

6. An electrical resistor as claimed in claim 3, wherein the glass fiber strand is coated with a dispersion of about 10 parts of powdered carbon in about 70 parts of a silicone resin.

LEON PODOLSKY.

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