April 6, 1954 R. E. B. WAKEFIELD 2,674,678

RESISTOR

Filed Aug. 16, 1950

FIG. 1

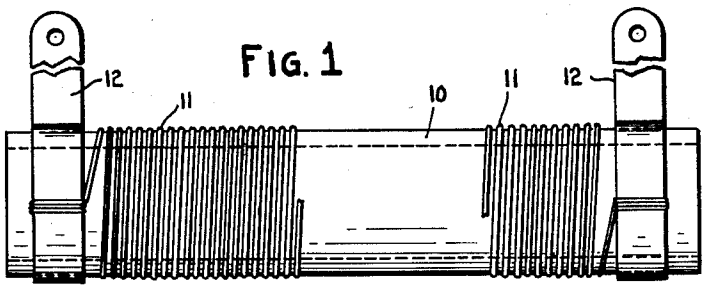


FIG. 2

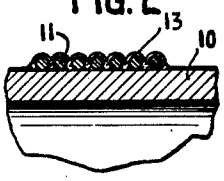


FIG. 3

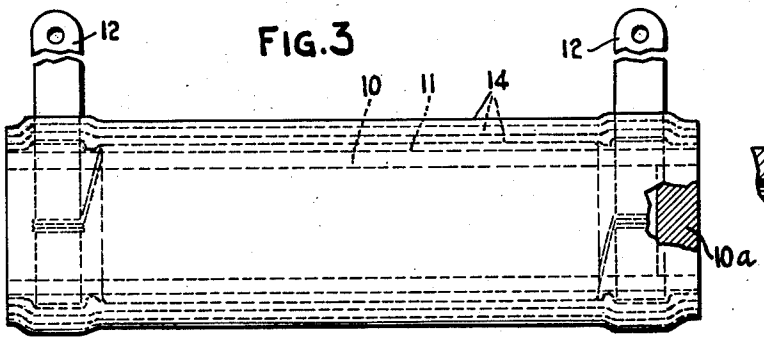


FIG. 4

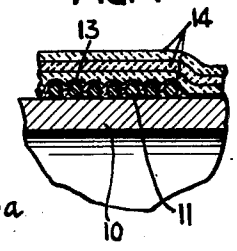


FIG. 5

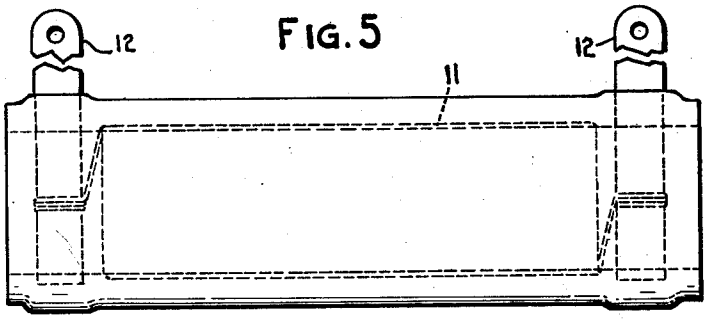


FIG. 6

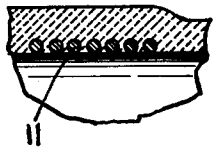


FIG. 7

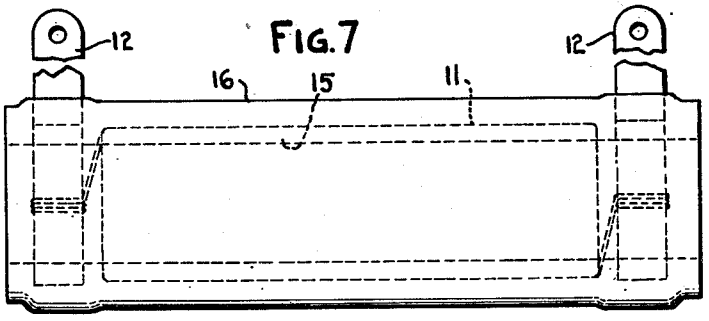
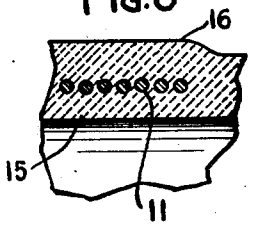


FIG. 8



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RESISTOR

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Application August 16, 1950, Serial No. 179,659

11 Claims. (Cl. 201—64)

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This invention relates to wire wound resistors and to a method of producing such a resistor, as well as to the use of a novel composition particularly well suited for use under high temperature and severe humidity conditions. More particularly, this invention relates to a resistor of the embedded type, i. e., in which the coil of resistor wire is coated with an electrically insulating and heat resisting coating which becomes the support for the wire coil.

The characteristics of a resistor according to my invention are such that they are especially adapted for use as "power" resistors, that is, where relatively large amounts of heat are dissipated as I^2R loss, although my resistors are naturally not limited to such uses and may be used equally well where the heat dissipated is relatively insignificant.

Among the objects of my invention are:

To produce a resistor which is lighter in weight and smaller than other embedded resistors of the same rating;

To provide such a resistor having a greater heat dissipation capacity per given area than other such resistors;

To provide such a resistor which will dissipate more power per unit area for a predetermined temperature rise, or, conversely, one which will operate at a lower temperature for predetermined power dissipation, and which can be made physically smaller;

To provide such a resistor allowing efficient operation at higher temperatures, and in which the maximum wattages for this temperature are considerably increased; and

To provide a resistor which will reach its rated load in a considerably shorter time than other embedded resistors of the same resistance value.

Still other objects and advantages of my invention will be apparent from the specification.

The features of novelty which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its fundamental principles and as to its particular embodiments, will best be understood by reference to the specification and accompanying drawing, in which—

Figure 1 is a view of a resistor according to my invention after the first impregnating step;

Fig. 2 is a fragmentary enlarged detail section thereof;

Fig. 3 is a view similar to Fig. 1, after the secondary impregnations;

Fig. 4 is a fragmentary enlarged detail section thereof, similar to Fig. 2;

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Fig. 5 is a view similar to Fig. 1 after destruction of the paper or cardboard core;

Fig. 6 is a fragmentary enlarged section thereof, similar to Figs. 2 and 4;

Fig. 7 is a view similar to Fig. 1 of the complete resistor, and

Fig. 8 is a fragmentary enlarged section thereof, similar to Figs. 2, 4 and 6.

Referring now to the drawings, I prefer to produce my resistor by starting with an oxidizable core, as a paper or cardboard tube 10, of the desired size and strength, on which the resistor wire 11 is wound and, after calibration, is secured to suitable terminals, such as clamping metal bands 12. One method of effecting termination is shown in my application Ser. No. 179,660, now Patent No. 2,636,963, filed concurrently herewith.

In production, the wire winding is done on a rotating mandrel and I presently prefer to immediately apply a preliminary coating 13 of ceramic material to the outside of the wire wound core and terminals by spraying the coating material thereon as the core is rotated, so as to thinly cover the wire and fill the spaces therebetween, and also to cover the portions of the terminal bands which surround the core. This coating is allowed to set and partially dry, air drying being sufficient.

The open ends of the tube 10 are temporarily plugged with suitable closures 10*a*, which may be wood or cardboard plugs frictionally held in place, after which the unit is dipped in a liquid ceramic slip to further coat the same. This coating is allowed to partially dry in the air, and the coating process of dipping and drying is preferably repeated twice more, although the number of dippings may be changed if desired. The resistor will then be in the form shown in Figs. 3 and 4, the added coatings being indicated at 14.

The composition of the ceramic slip and coating material is also of importance in obtaining my results, and will hereafter be discussed in detail.

After thorough drying of the unit following these first dippings, which may be accelerated by heating in an oven to get rid of the mechanically held water, the end closures 10*a* are removed from the unit and the unit is then heated in an oven at a controlled temperature, until the paper or cardboard tubular core 10 is burned away, leaving the wire and terminals adhering to the inner portion of the shell, which now has sufficient strength and rigidity for handling as a unit. The resistor will now have the form shown in Figs. 5 and 6. The burning temperature will vary according to

the material of the core. Paper tubes are sufficiently oxidized at 1250° F., while cardboard tubes require higher temperatures, approaching 1600° F.

After oxidation of the core, the inside of the shell is cleaned to remove residual ash, and the unit is again dipped in the ceramic slip, so as to coat both the inside and the outside of the shell, as indicated at 15 and 16 respectively, after which the coating is desirably dried, first in the air and then in the oven. Usually a single dipping is sufficient at this point, but the dipping and drying may be repeated until the coating has built up to the thickness desired. The finally coated unit is again placed in the oven and fired at a temperature of preferably 1600° F., which sets all the coatings into a homogeneous solid mass. The unit now is as shown in Figs. 7 and 8.

The resistor may now be impregnated or surface coated as desired, in any known and suitable manner, and I have found a silicone resin impregnation preferable.

In making the ceramic slip compound, I presently prefer to employ commercial grade products, of approximately 300 screen mesh, as follows:

	Parts by weight
ZrO_2	300 to 450
Kyanite clay	100 to 200
MnO_2	100 to 200

with aluminum sesqui-phosphate added as required for desired viscosity.

Kyanite clay is a commercially obtainable product understood to be approximately 60 per cent Al_2O_3 and 40 per cent SiO_2.

Aluminum sesqui-phosphate may be prepared by mixing 1.37 parts by weight of $Al(H_2PO_4)_3$ and 0.63 part by weight of $Al_2(HPO_4)_3$, and adding 33 per cent of water to give the mixture the form of a tacky mucilage.

Satisfactory results are obtained by first forming a heavy paste while stirring the above ingredients, after which the mixture is mechanically agitated until a creamy mixture results. The mixture should then age for a period of about seventy-two hours after which it is thinned to the desired consistency by the addition of distilled water.

One trouble with cast ceramic resistors in the past has been the tendency of the coating to develop bubbles and striations leading to hot spots and failure under load. With my coating, I find that the firing seems to produce a sintering, without fusing, or a chemical reaction which turns the coating into a homogeneous mass, apparently free from bubbles and striations, as far as may be observed under the microscope, and in spite of the multiple coating process by which it is made. The surface is free from checks and cracks.

The composition for the ceramic material may be changed, as circumstances warrant. For some purposes, satisfactory compositions to produce a resistor according to the above process may omit either the Kyanite clay or the manganese dioxide from the above recited mix. In other instances, the manganese dioxide in the above formulation has been replaced by ferric oxide, with and without the Kyanite clay. In all these cases, the proportions of the ingredients are within the ranges recited above. It also has been found that useful results are obtained when adding one per cent of ferric oxide

to the manganese dioxide in the above formulation.

Zirconium oxide has the desirable property of a low co-efficient of expansion and the co-efficients of expansion of the composition, the wire and the terminals are such that no cracking of the hardened composition results when the resistor is in use. It presently appears that other refractory oxides also may be useful in some circumstances in place of the manganese dioxide in the above formula, such as the oxides of titanium, silicon, chromium, iron, cobalt and nickel, in commercial grades, and similar amounts.

A suitable material for impregnating the finished resistor to render the same suitable for use even in severe moisture and humidity conditions is one of the silicone resins, selected according to characteristics desired, or a blend thereof. While any suitable method may be employed in this impregnation, I presently prefer to preheat the finished resistor at 100° C., followed by a vacuum impregnation with the silicone. After air drying for approximately one hour and oven drying for another hour at about 120° C., the unit is baked for several hours while raising the oven temperature to 250° C. After the unit returns to room temperature the impregnation procedure is repeated, except that the final baking temperature is increased to 325° C., after which the resistor can withstand all operating temperatures encountered.

In the specification, I have explained the principles of my invention and the best mode in which I have contemplated applying those principles, so as to distinguish my invention from other inventions; and I have particularly pointed out and distinctly claimed the part, improvement or combination which I claim as my invention or discovery.

While I have shown and described certain preferred embodiments of my invention, it will be understood that modifications and changes may be made without departing from the spirit and scope thereof, as will be clear to those skilled in the art.

I claim:

1. A resistor comprising a layer of wire embedded in a hardenable plastic composition comprising, by weight, zirconium oxide 300 to 450 parts, clay 100 to 200 parts, an additional refractory oxide 100 to 200 parts, and sufficient aluminum sesqui-phosphate to provide a suitably viscous consistency prior to firing, said composition being fired to a solid mass.

2. A resistor according to claim 1 further comprising one per cent of ferric oxide.

3. A resistor according to claim 1, such resistor being impregnated with a silicone resin.

4. A resistor according to claim 1, the hardened composition being impregnated with a moisture proofing coating.

5. The method of producing a resistor which comprises coating a wire with a compound of MnO_2, ZrO_2, clay, and aluminum sesqui-phosphate to provide a desired viscosity of said compound, and firing to produce a solid mass.

6. The method of producing a resistor which comprises coating a wire with a compound comprising, by weight, zirconium oxide 300 to 450 parts, clay 100 to 200 parts, an additional refractory oxide 100 to 200 parts, and aluminum sesqui-phosphate, and firing to produce a solid mass.

7. The method of producing a resistor which

comprises repeatedly coating a wire with a binder made up of ZrO_2, clay, MnO_2, and aluminum sesqui-phosphate to provide a desired viscosity of said compound, drying said binder between applications of coating, and firing the coated resistor to produce a solid mass.

8. The method of producing a resistor which comprises coating a wire with a compound of ZrO_2, clay, MnO_2, and aluminum sesqui-phosphate to provide a desired viscosity of said compound, and firing the coated wire at a temperature of the order of 1600° F. to produce a solid mass.

9. The method of producing a tubular resistor which comprises winding a wire on an oxidizable tube, coating the exterior only of said tube with a ceramic slip compound, drying the coated tube, firing said tube to destroy said oxidizable tube and leaving a shell of ceramic coated wire, coating both the interior and the exterior of said shell, and firing the shell to produce a solid mass.

10. The method of producing a resistor which comprises coating a wire with a compound made up by weight of ZrO_2, 300 to 450 parts, clay, 100 to 200 parts, MnO_2, 100 to 200 parts, and aluminum sesqui-phosphate to provide a desired viscosity of said compound, and firing the coated wire at a temperature of the order of 1600° F. to produce a solid mass.

11. The method of producing a resistor which comprises repeatedly coating a wire with a composition comprising, by weight zirconium oxide 300 to 450 parts, clay 100 to 200 parts, an additional refractory oxide 100 to 200 parts, and sufficient aluminum sesqui-phosphate to provide a desired viscosity of said composition, drying said composition between applications of coating, and firing the coated resistor to produce a solid mass.

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