Sept. 10, 1940. S. RUBEN 2,213,969

ELECTRICAL RESISTANCE ELEMENT

Filed Feb. 23, 1937 2 Sheets-Sheet 1

Fig. 1

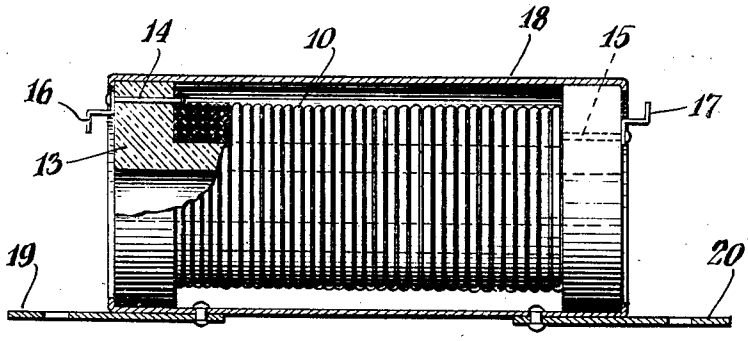


Fig. 2

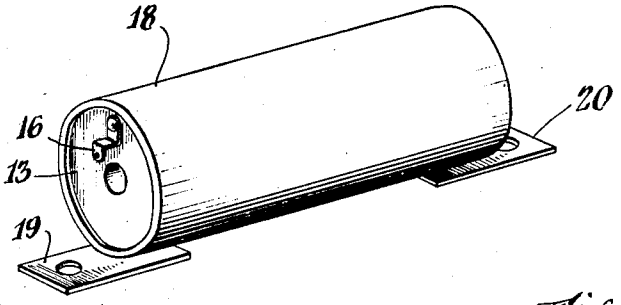


Fig. 5

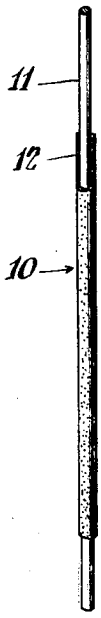


Fig. 3

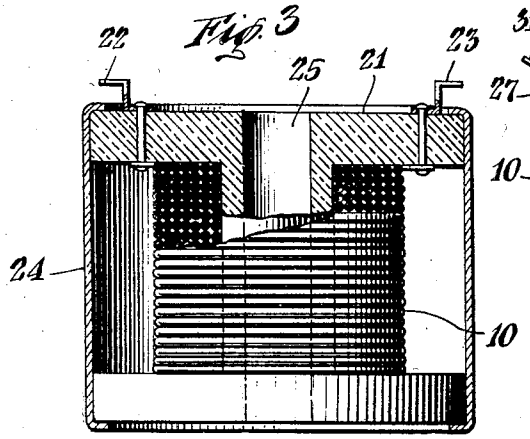
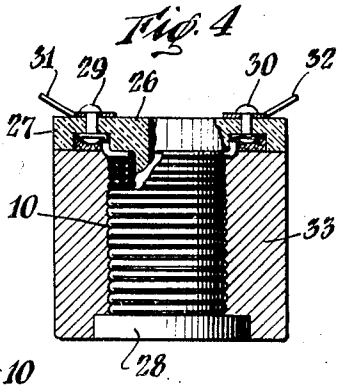


Fig. 4



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Fig. 6

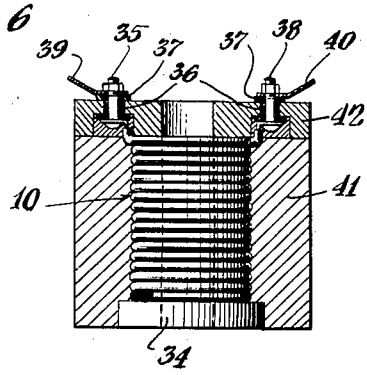
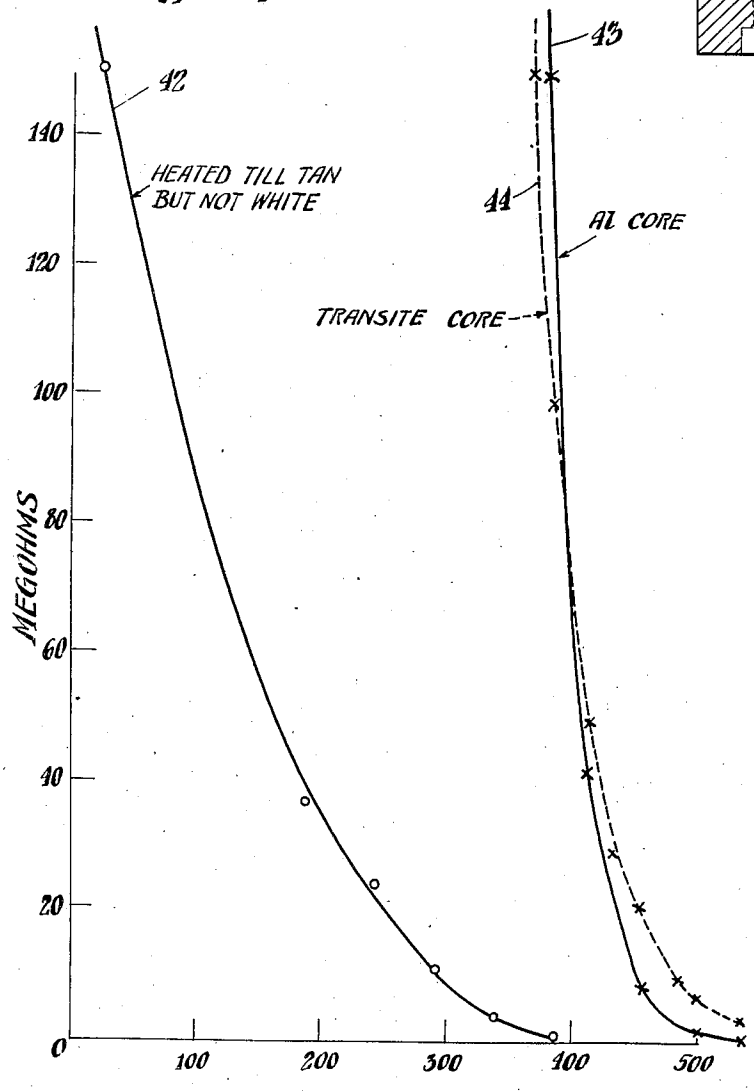


Fig. 7

Effect of Oxidation



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ELECTRICAL RESISTANCE ELEMENT

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Application February 23, 1937, Serial No. 127,101

10 Claims. (Cl. 201—67)

This invention relates to resistance elements and methods of making the same. This application is a continuation in part of my copending application Serial No. 71,365, filed March 28, 1936.

The general object of the invention is to provide a new and improved insulated multi-layer wire wound resistance element and a method for making the element.

Particularly it is desired to provide a resistance element formed from refractory wire having an intimate, adherent, indestructable, inorganic, thin, hard insulating layer of uniform thickness composed of inorganic insulating material capable of providing a rapid heat transference from the wire; which may be easily and economically produced and which lends itself to the manufacture of industrial resistor and heating appliances of novel design and high efficiency.

Other objects of the invention will be apparent from the following description and accompanying drawings taken in connection with the appended claims.

The invention comprises the features of construction, combination of elements, arrangement of parts, and methods of manufacture and operation referred to above or which will be brought out and exemplified in the disclosure hereinafter set forth, including the illustrations in the drawings.

In the drawings—

Figure 1 is a side elevation, partly in section, of a multi-layer resistance element made according to the invention;

Figure 2 is a perspective view of the element;

Figure 3 is a longitudinal section through a modified element;

Figure 4 is a section through another modification; and

Figure 5 is a view of a section of coated resistance wire with part of the coating removed;

Figure 6 is a section through another modification of the invention, and

Figure 7 is a graph showing effect of oxidation of the coating in respect to increase in resistivity.

While a preferred embodiment of the invention is described herein, it is contemplated that considerable variation may be made in the method of procedure and the construction of parts without departing from the spirit of the invention. In the following description and in the claims, parts will be identified by specific names for convenience, but they are intended to be as generic in their application to similar parts as the art will permit.

Heretofore, in the commercial manufacture of resistance elements, several methods have been employed. In one, the wire was wrapped with a layer of thick insulating fibrous material such as asbestos; in another, the wire was embedded in a mass of plastic cement after which the mass was baked to dry and harden the cement; a third means of obtaining insulation was to wind the bare wire on an insulating form with sufficient spacing between turns to avoid short-circuiting contact between them.

Units of the above types could not conveniently or efficiently be made in multi-layer coil form. It will be appreciated that the asbestos or cement coverings of the type described are inherently and necessarily relatively thick or massive resulting in excessive heat insulation. This produces a high temperature differential between the inside and outside of the element. The element is thus not as quickly responsive to electric current through the wire nor can high current values be safely handled by the element without danger of burn-outs. Likewise the space occupied by the insulation seriously limits the amount of wire which can be contained in an element of a given size. The space factor is also very poor in a bare wire element and added precautions are necessary to avoid danger of contact with the bare wire.

In my application Serial No. 71,365 I describe a flexible, high-temperature, electrical heating element comprising a wire of refractory metal coated with a thin, hard and adherent insulating layer of uniform thickness, the layer being hard, adherent and non-conductive at temperatures at which the heating element is operated. The layer is composed of inorganic insulating material and a much smaller amount of organic resinous binder, the percentage of latter material present being insufficient to render the insulating layer conductive at temperatures beyond its carbonization point. The coating is applied by making the wire the anode in a bath of aqueous shellac solution which has in suspension finely divided inorganic insulating material, the container for the bath, acting as the cathode. When current is discharged through the assembly, inorganic insulating material and shellac are simultaneously deposited upon the wire, a round, smooth, uniform coating being obtained.

In the present invention there is no organic material present in the coating of the element as used, the preferred coating consisting of finely divided inorganic insulating material and bentonite, or its equivalent. Instead of using a res-

inous solution in which to suspend the insulating materials during their application to the wire, I prefer to use an inorganic suspension medium. Perhaps the most important improvement is the use of a high temperature heat treatment to sinter or fire the coating upon the wire, either before the wire is wound into the form of a resistor element or after it has been so wound. This firing treatment is preferably carried out at a temperature of from 700° to 1100° C.

In applications where maximum insulation resistivity is necessary between the wire and the exterior and where maximum mechanical bonding of the insulation to the wire is desirable, I have found it preferable to avoid the use of any organic binder in the coating bath. In place of such organic binder, I use a hydrated silicate, such as bentonite, which, when mixed with water, will allow suspension of the finely divided insulating materials, for instance kaolinite and talc, to be maintained in the solution and which forms an adhering gel in suspension. The effect of the bentonite, especially when the coated wire has been fired as above described, is to make the coating denser and more adherent to the wire.

I have found it desirable to use only enough bentonite to afford necessary suspension of the solids, to impart sufficient conductivity to the bath and to bring about the required coating density. The percentage of bentonite is preferably held down for the reason that the insulation resistance of the coating at high temperatures with an excess amount of bentonite is poor. The best percentage seems to be about 10% by weight of the total insulating solid materials used, the useful limits appearing to be from 5% to 20%. Preferably, the bentonite used is of 600 mesh size or finer.

Finely divided hydrated materials of the kaolinite and talc type are the most desirable insulating compounds, due to the fact that they are excellent suspension materials in the electrolytic method of coating used and also because they are highly suitable for the firing and sintering operation. While kaolinite alone may be used with the bentonite, the presence of the talc increases the smoothness of the coating and increases its resistivity at high temperatures. Finely divided chromium oxide, beryllium oxide or titanium oxide may be substituted for the talc or kaolinite with less satisfactory results, the latter being superior. The most desirable combination appears to be a mixture of kaolinite and talc in bentonite. For coating small size wires, I use a mixture of 45% by weight of kaolinite, 45% by weight of talc and 10% by weight of bentonite, the bentonite having previously been mixed with distilled water to form a hydrogel. About 300 grams of solid are used to 1200 grams of water. Before the mixture is applied to the wire, it is ballmilled for about twenty-four hours in order to eliminate any possible large particles and to insure a fine grain deposition. It is important that the materials after being ground should have a grain size not larger than 400 mesh and preferably smaller.

The wire used for the resistance element may be of any suitable composition, such as nickel-chromium, iron-chromium, tantalum-iron-chromium, etc., and of any desired size. The invention makes it possible to use very fine wire, as low as 0.001 inch in diameter and the coating may, of course, also be deposited upon larger wires of all commercial sizes.

The coating is applied to the wire in the manner described in my copending application Serial No. 123,759, filed February 3, 1937, the wire coating first being electro-deposited on the wire, next heated and dried at a temperature of about 350° C. and thereafter passed through a firing or sintering oven maintained at a temperature of about 1000° C. at which temperature the individual particles sinter together to form a coating of great strength and durability. The high firing temperature completely dehydrates the coating, eliminates the combined water of hydration, increases the coating density and causes the insulation to be bonded to the base. At this point the coated wire is in the form illustrated in Fig. 5, the resistance element 10 comprising nickel chromium wire 11 and coating 12. For some purposes the wire may be used in this form but where considerable handling is required and where the coated wire is to be wound upon mandrels of relatively small diameter it is desirable to apply a temporary flexible top coating, such as methyl methacrylate, cable lacquer, etc. Accordingly, the sintered wire may be directly passed through a solution of 7% methyl methacrylate polymer in acetone and thereafter dried at a temperature of about 150° C. and spooled for future use. The wire so produced is sufficiently tough and flexible to be wound or bent into any form ordinarily required in the finished element without danger of chipping or cracking. It is likewise resistant to mechanical shocks and abrasion so that the coated wire may be handled by a winding machine. In the manufacture of resistance units, the organic top coating is expelled as a gas or vapor from the finished unit, either immediately after the wire has been wound into form or where a metal casting is used, at the time of or prior to the application of the metal to the unit.

The selection of a proper top coating, where one is used, is of importance in connection with the ultimate resistivity of the unit. The top coating should be adherent, abrasive and flexible and when the unit is heated to a sufficient temperature, the top coat should volatilize without leaving any carbon residue. I have tried many materials for this purpose, such as ethyl cellulose, cellulose acetate, nitro cellulose, glycerol phthalate lacquers, fixed oil compounds, etc., but none had the desirable properties provided by a solution of methyl methacrylate polymer in a solvent such as acetone. I have found that the methyl methacrylate holds tenaciously to the sintered inorganic coating providing a smooth and tough surface which allows rough mechanical handling. When heated to a temperature of 400° C. instead of carbonizing and leaving a residue, tending to lower the resistivity of the unit, it completely dissociates and volatilizes without carbonizing. The solution is made by dissolving the polymer methyl methacrylate in acetone in suitable proportions, for instance, six ounces of the polymer to one gallon of acetone. The drying of the top coating at 150° eliminates the acetone and leaves the resin plastic and adherent, at the same time imparting a smooth and tough binding layer to the insulating coating.

The coated wire having the characteristics above described may be used to form resistance elements of various types and for various purposes such as fixed resistors for radio circuits and the like heating elements, soldering iron elements, hot plates, energy dissipating units and the like. It may be wound on forms of metal or ceramic either in ordinary spiral or in non-inductive form.

Figures 1 and 2 show a fixed resistor for use in general circuit applications. This comprises a spool or form 13 of insulating material such as porcelain, lavite, isolantite, sillimanite or the like. The coated wire 10 is wound without spacing between turns on form 13 in multi-layer fashion without the interposition of any extra insulating layers and the ends are scraped clean of coating material and electrically connected to terminal rivets 14 and 15, respectively, which pass through the end flanges of form 13, the electrical connection being made by a mechanical riveting operation or by welding. A pair of terminal lugs 16 and 17 are secured to the ends of form 13 by the respective rivets and form the electric terminals of the element.

If greater rigidity and higher abrasive resistance is desired in the finished element it can be obtained by applying a glazing material prior to any of the above heat treatments. For example the wound element, before heating, can be sprayed, dipped or painted with a hydrolyzed ethyl silicate solution, preferably with finely divided kaolinite and talc suspended therein. A suitable mixture consists of 50% kaolinite and 50% talc added to an equal weight of hydrolyzed ethyl silicate. This glazing layer gives the coating a smooth surface and bonds adjacent turns of the winding together into a rigid integral unit. Upon heat treatment the organic ethyl silicate is decomposed leaving a silica binder. Methyl or glycol silicate can be substituted for ethyl silicate. Likewise a water solution of sodium silicate may be applied if high voltages are not encountered. The best glazing effects can be obtained by heating at least to 1000° C.

The element of Figures 1 and 2 may be covered and protected by a metal sleeve 18 of aluminum or other metal which fits over the flanges on form 13 and has its ends spun down over the ends of the form thereby completely enclosing the winding 10. A pair of lugs 19 and 20 secured to sleeve 18 serve as mounting means for the element.

Figure 3 shows an element of different shape, the coated wire 10 in this case being wound without spacing between turns on a shorter insulator form or spool 21 the wire being connected to terminal lugs 22 and 23. A metal sleeve 24 fits over spool 21 and is spun down over its ends. This form is adapted to be mounted on a bolt passing though central hole 25 in spool 21.

Figure 4 shows an element having a cast metal sheath. In this case the coated wire 10 is wound without spacing between turns on an insulating form 26 having a large diameter flange 27 at one end and a small diameter flange 28 at the other. The wire is connected to rivets 29 and 30 whose heads are countersunk in the inner face of flange 27. The countersunk bores are filled with alundum cement after the wires are attached to insulate the connections. A pair of terminal lugs 31 and 32 are held by rivets 29 and 30 on the end of form 26. A metal sheath 33 is cast over the winding after the element has been heated as described to eliminate organic material. This may be done by placing the wound element into a mold and casting the metal about it. The metal sheath may be made flush with the outer edge of flange 27 as shown. The metal is cast directly against the coated wire winding. Due to the prior elimination of the volatile organic material the casting will be free of blow holes.

A suitable alloy for the cast sheath where low temperatures only are to be encountered consists of:

	Per cent
Aluminum	4.1
Magnesium	.1
Copper	2.7
Zinc	93.1

which alloy melts at about 390° C. For higher temperatures I prefer an alloy containing approximately 98% aluminum and having a melting point in the order of 650° C. Other metals and alloys, such as copper alloys, can be used where still higher temperatures are to be met or where other properties such as higher conductivity are desired.

Figure 6 shows a resistor somewhat similar to the one shown in Figure 4. In the unit illustrated, the coated wire 10 is wound in multi-layer form on an aluminum spool having small diameter flange 34 at one end and a larger diameter flange 42 at the other end. The wire is connected to screws 35 and 38 extending through and insulated from the spool by insulating members 36 and terminals are provided by lugs 39 and 40 held in place by nuts 35 and 38 and insulated from the spool by washers 37. If desired, the unit can be constructed in plug-in form, prongs being substituted for the terminals shown. An aluminum sheath 41 has been cast directly over the winding to protect the unit and to afford a rapid heat transference. This heat transference may be further improved and the unit can be made capable of dissipating higher wattage by etching or otherwise roughening the outer surface of the casting and also by blackening the casting.

The coating described so far and its method of application, with the exception of the top coating materials, have dealt solely with the use of inorganic materials. It is possible, however, and for some purposes desirable to use a type of coating in which shellac or other organic binder is substituted for the bentonite. When thus used the shellac may be removed by a subsequent heating operation and the finished coating will consist solely of inorganic materials.

The most practical working limits for shellac are 10% to 30%. The preferred proportions of shellac will vary somewhat, however, with different sizes of wire. Thus with 1 and 2 mil wire the preferred amount of shellac is 10%, with 4 to 6 mil wire 16% and with 10 mil wire about 22%.

Other organic binders than shellac can be used such as the various resins (natural or synthetic) for example, rosin, copal and the like, the various gums, for instance, dammar, Arabic, tragacanth, and rubber latex and certain oils such as tung oil and linseed oil. However, none of these have been as satisfactory as shellac.

When shellac is used in place of bentonite, it is desirable in most cases to employ the high temperature heating only after the wire has been wound on the resistance element. In such cases the high temperature 1000° oven is not required, the resistance element being heated up to 1000° C. after the wire has been wound into final form.

For use where low voltage insulation only is required it may only be necessary to heat the winding above the volatilizing or decomposition temperature of the shellac or other organic binder. For shellac a temperature of about 420° C. may be sufficient. At this temperature the shellac appears to decompose, the majority of the product going off as vapor and only a small amount of non-volatile residue remaining, probably in the

form of carbon. If the unit is to be used in this form it is to be preferred that the original coating shall have a lower percentage of binder so that the amount of carbon left in the coating will be insufficient to cause any material current leakage. For a shellac binder, the percentage of shellac originally in the coating should preferably be 30%. The heating may be carried on in an oven or by passing current through the winding and may take place in air or in an inert gas atmosphere.

While the above heating may be sufficient for low-voltage operation it will generally be preferred especially where high-voltage will be encountered to heat the element to a higher temperature, namely one at which the residue (carbon) will burn out leaving a coating free from organic matter. For this purpose the temperature should be raised to 455° C. or above. The resulting coating is highly resistant to current leakage, the resistance normally amounting to several megohms per linear inch of coated wire. This coating is suitable for high-voltage high-temperature use. A metal sheath can be cast directly against the coated wire if desired in which case the coating will fully insulate the wire from the cast sheath. In this case it is of advantage, however, to keep the percentage of shellac originally in the coating to a minimum (preferably below 5% to keep down the porosity in the final coating from which the organic material has been volatilized and oxidized out.)

When a greater abrasion resistance is desired, as where the coated wire is to be used without any protective sheath, it is preferred that the wire element be sintered and fired at 1000° C. The resulting sintered element is ready for use without further treatment either with or without a protective sleeve or a cast metal sheath. The sintering temperature can be reduced by adding a small percentage of fusible borates or silicates to the coating material before applying to the wire but for minimum leakage at high temperatures the use of such additional agents is not desired.

The preceding description of the various possible heat treatments which may be employed when an organic binder is used may be briefly summarized as follows: The wire is first provided with a coating consisting of a finely divided inorganic insulating material and an organic binder whereby a coated wire is produced of sufficient flexibility to enable winding or otherwise forming into a resistance element of desired shape by hand or with a winding machine or other forming apparatus. The wound (or formed) element can be used in this form where low temperatures only are to be encountered. Where higher temperatures are to be encountered the coated wire element is given a heat treatment which changes the composition and physical properties of the coating. The composition is thus changed so as to reduce or eliminate the organic material which could not stand up under the higher temperatures which the element is expected to encounter during the coating of the metal sheath or in subsequent use. The physical characteristics are changed by the heat treatment to produce a more rigid, less flexible coating which would ordinarily be chipped or cracked if it were attempted to manipulate or rewind the coated wire in this condition. However, since the element has already been formed or wound prior to the heat treatment it is unnecessary to apply any further manipulations after treatment and hence the coating is preserved intact.

The heat treatment, as described above, may extend to one of the following temperatures:

(1) Volatilizing temperature at which the volatile constituents of the organic binder are driven off. Suitable for low-voltage operation at high temperatures preferably with metal sheath, 375° C.

(2) Oxidizing temperature at which any residual carbon left by the organic binder is burned out. Suitable for high voltage 450° C. operation at high temperatures preferably with cast metal sheath.

(3) Sintering temperatures at which the particles of inorganic material are sintered together. Suitable for high voltage operation at high temperatures with or without any protective sleeve or sheath.

The effect of the heat treatments and resultant oxidation of the shellac binder wire coating is illustrated in Figure 7 which is a graph, the curves of which show resistivity of insulation on units formed from resistance wire having a 0.003" thick insulating coating and in which the total contacting area of the insulation is 4.6 sq. in. Curve 42 shows the resistivity of such a unit, the insulating coating of which has been heated only up to the point at which the coating becomes tanned. Curve 44 shows the result of heating such a unit to a temperature where the coating becomes white due to oxidation and/or elimination of any carbonaceous material, the heating temperature being in excess of 450° C. The insulated wire, the characteristics of which are shown in curve 44, was wound on a transite core. Curve 43 illustrates the resistivity of a coated wire identical with that referred to in curve 44, excepting that in this case the wire was wound on an aluminum core.

It will be seen that the present invention provides an insulated resistance wire element in which the insulation, fired in situ upon the wire, is thin, hard, uniform, continuous, adherent, indestructible, of sufficient flexibility to permit of its being wound into coil form, which may be constructed in compact multi-layers without danger of short-circuiting between turns and which conveniently allows the casting of a protective and heat-radiating hard metal sheath directly against and around the insulated wire without damage to the wire.

What is claimed is:

1. An electrical heating element comprising a metal resistance wire having sintered on its surface a thin hard coating of finely divided inorganic insulating material, said coating consisting of finely divided silicates of the kaolinite and talc type and a relatively small amount of bentonite, said coating being continuous, round and uniform throughout the length of said wire, said wire being wound without spacing between turns upon a mandrel in multi-layer form, the coating on said wire for all practical purposes being substantially indestructible by heat and being capable of maintaining a high resistivity at temperatures in excess of the normal operating temperatures of said heating element, said unit having no substantial leakage between turns under all operating conditions.

2. An electrical resistor adapted to operate at high temperatures comprising a wound coil of resistance wire, said wire having over substantially its entire surface a thin, hard, round, uniform, non-softening, adherent coating of inorganic insulating material of the group comprising high heat resistant silicates and oxides, said coating

being fired to the surface of said wire, said coating containing a relatively small percentage of an inorganic hydrogel, at least in the order of 5% said insulated wire being unseparated between the turns of the coil.

3. An electrical resistor adapted to operate at high temperatures comprising a wound coil of resistance wire, said wire having over substantially its entire surface a thin, hard, round, uniform, non-softening, adherent coating of inorganic insulating material of the group comprising high heat resistant silicates and oxides, said coating being fired to the surface of said wire, said coating containing from 5 to 20% bentonite, said insulated wire being unseparated between the turns of the coil.

4. An electrical resistor adapted to operate at high temperatures comprising a wound coil of resistance wire, said wire having over substantially its entire surface a thin, hard, round, uniform, non-softening, adherent coating of inorganic insulating material of the group comprising high heat resistant silicates and oxides, said coating being fired to the surface of said wire, said coating containing a relatively small percentage of bentonite to increase the density thereof and adherence of the coating to the wire, said insulated wire being unseparated between the turns of the coil.

5. An electrical resistor adapted to operate at high temperatures comprising a closely wound coil of resistance wire, said wire having over substantially its entire surface a thin, hard, round, uniform, non-softening, adherent coating derived from high temperature resistant inorganic insulating material of the group comprising high heat resistant silicates and oxides of a fineness of at least 400 mesh, said coating being fired to the surface of said wire, said coating containing a relatively small percentage of a hydrated inorganic silicate to increase the density thereof and adherence of the coating to the wire, the turns of said coil being unseparated except for the insulating coating above described, said resistor being substantially completely sealed by metal cast directly on the insulated wire.

6. An electrical resistor adapted to operate at high temperatures comprising a wound coil of resistance wire, said wire having over substantially its entire surface a thin, hard, round, uniform, non-softening, adherent coating of inorganic insulating material of the group comprising high heat resistant silicates and oxides, said coating being fired to the surface of said wire, said coating containing a relatively small percentage of an inorganic hydrogel, at least in the order of 5% said insulated wire being unseparated between the turns of the coil and an aluminum casing over said resistor.

7. An electrical resistor adapted to operate at high temperatures comprising a wound coil of resistance wire, said wire having fired to its surface over substantially the entire area thereof, a thin, hard, round, uniform, non-softening, adherent coating of inorganic insulating material consisting substantially of finely divided high heat resistant silicates of the aluminum and magnesium silicate type and a relatively small proportion of a hydrated inorganic silicate, said wire being unseparated between the turns of the coil, except for the above described insulating coating thereon.

8. An insulated electrical resistor as described in claim 7, characterized in that the inorganic insulating coating on the resistor has an additional top coat of organic insulating material thereover.

9. An insulated electrical resistor as described in claim 7, characterized in that it has an additional coating of inorganic insulation thereover.

10. An insulated electrical resistor as described in claim 7, characterized in that said resistor is in multi-layer form and has a metal casing thereover.

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