

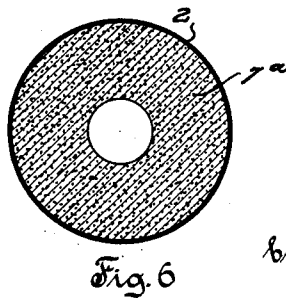
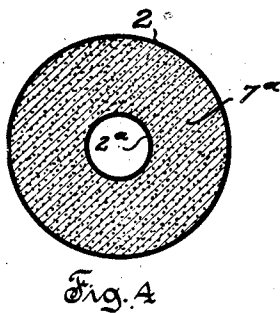
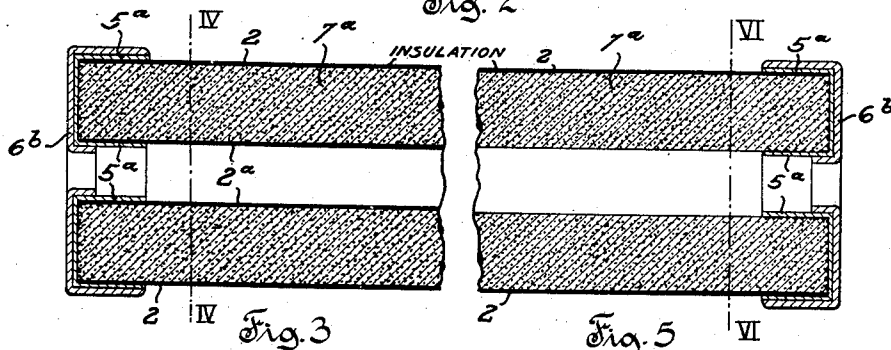
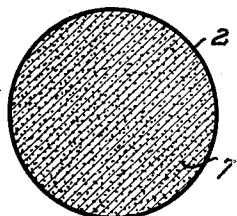
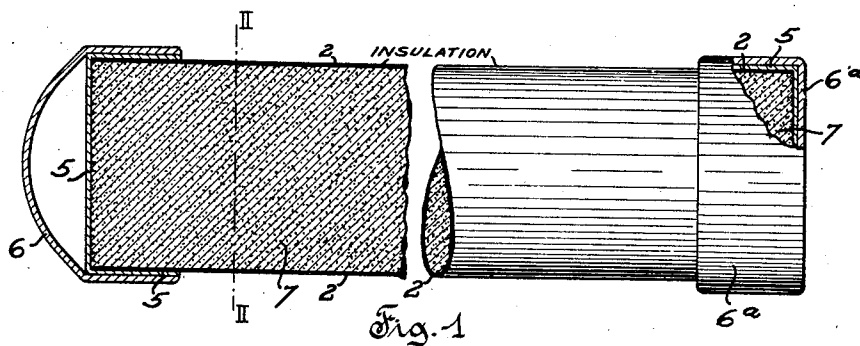
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ELECTRICAL RESISTANCE ELEMENT AND PROCESS OF MANUFACTURING THE SAME

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ELECTRICAL RESISTANCE ELEMENT AND PROCESS OF MANUFACTURING THE SAME

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This invention relates to the production of electrical resistance materials or elements, more particularly such as are used for various current limiting and regulating purposes and for the production of heat of various degrees.

In the production of composition resistance elements formed from a mixture of comminuted materials of different specific resistances, it has been difficult to secure a reasonably satisfactory degree of commercial uniformity, as to mechanical and electrical characteristics, without involving the rejection of a relatively large number of elements, with a consequent increase in cost of production of such resistance elements. Likewise, where a protective shell or seal is provided for the purpose of protecting the element and maintaining the resistance of the element at a reasonably constant figure, such provision of an effective covering or seal of this character has involved considerable additional handling and consequent expense and further difficulty in providing for a commercially satisfactory union or electrical connection between the body of the resistance element and highly conductive terminals of such a character as to insure proper and ready connection of the resistance element in a line circuit, with its resistance of the desired value.

The present invention contemplates the production of a resistance element of an improved character in the form of a heat-treated composition product made from a mixture of a relatively conductive material and a relatively insulating material, the product being produced in commercial quantities and at reduced cost by a process which insures a high degree of uniformity as to the physical and electrical characteristics of the product throughout the ordinary handling and commercial life thereof; and as a more particular feature, the invention contemplates the production of a resistance element from material having as an ingredient a substance possessing among its desirable properties the capability of producing a highly desirable surface seal of a protective character on the finished resistance element.

I have discovered that through the use of certain clay-like substances, particularly ben-

tonite or an ingredient thereof, as a substance of insulating properties in the original mixture from which the resistance element is formed, particularly desirable results are attained, among which is the fact that a highly satisfactory seal or covering for the resistance element may readily be produced on the resistance element merely through a heating operation which may be a part of that used for hardening or adjusting the resistance of the product.

It is an object of the present invention to produce an improved resistance element of the composition type including as ingredients materials of different specific resistance and which may be commercially produced in a relatively simple and inexpensive manner.

A further object of the present invention is the production of a resistance element of this general character from a comminuted mixture including as an ingredient a material of relatively high specific resistance which, in addition to its other properties, is capable of producing a glaze-like coating on the element which effectively seals the surface thereof, thus insuring constancy of electrical and physical characteristics thereof.

It is a further object of the present invention to produce an electrical resistance element of the character described above, wherein the relatively conductive medium of the resistance element includes a carbon-containing substance, and, more particularly, to produce a resistance element of this character which includes silicon carbide as an essential ingredient thereof.

These and other objects and advantages are attained by the present invention, various novel features of which will be apparent from the description and drawings herein, disclosing embodiments of the invention, and will be more particularly pointed out in the claims.

In the drawings:

Fig. 1 is a broken elevation, partly in section, of an electrical resistance element embodying or produced in accordance with features of the present invention.

Fig. 2 is a sectional view in the plane of the line II—II of Fig. 1.

Figs. 3 and 4 are views similar to Figs. 1 and 2, respectively, of a modified embodiment of the invention, Fig. 4 being in the plane of the line IV—IV of Fig. 3.

5 Figs. 5 and 6 are views similar to Figs. 1 and 2, respectively, of a further modified embodiment of the invention, Fig. 6 being in the plane of the line VI—VI of Fig. 5.

10 In the embodiment of the invention shown in Figs. 1 and 2 of the drawing, 7 indicates the body of a resistance element of rod-shape. This resistance element is produced from a mixture of suitable ingredients by molding the same under pressure, as by means of the
15 process of squirting a more or less doughy mass of the mixture under relatively high pressure through a die of desired conformation. The mass from which the element is formed includes a comminuted mixture of
20 a conductive material, either silicon carbide alone or with a suitable proportion of a more conductive material, such as carbon or graphite, or a mixture of the same and a metal, and a clay-like material which is of rela-
25 tively great electrical resistance and suitably resistant to a fairly high degree of heat, that is, to temperatures above those to which the element is liable to be subjected under conditions of ordinary operation.

30 As indicated in the drawings, the resistance element includes an outer skin or shell 2 which is of an insulating character and in the form of a glaze of suitable thickness and which effectively seals the element from the
35 effects of moisture or other foreign materials which might in any way affect the resistance of the element. Within the annular outer skin or shell 2 is the main body or core portion 7 which is formed of the mixture of the
40 clay-like insulating material and the carbonaceous or conductive material entering into the original mixture as the relatively conductive ingredient thereof, but in a fired or heat-hardened condition, with its consequent
45 effects.

5 indicates a coating of highly conductive material applied to the exposed end of the resistance element, this conductive coating being in particularly intimate electrical and
50 mechanical connection with the body portion 7 of the element, and it preferably extends over the outer sides or surface, that is, outside of the insulating glaze-like shell 2, of the element to an appreciable extent. 6
55 and 6^a indicate types of a metallic sleeve or cap of suitable conformation pressed upon the end of the resistance element with an ample area of the inner surface thereof in intimate electrical engagement with the con-
60 ductive coating 5 at the end or along the outer cylindrical surface, or both, of the resistance element. Direct contact engagement between the cap 6 or 6^a and the coating 5 may be relied on for the desired electrical and
65 mechanical connection of the cap to the end

of the resistance element, or these parts may be united by fusion of metal, either direct or through an intermediate brazing or soldering strip or coating.

I have discovered that certain clay-like materials which are of relatively great electrical resistance, in fact more nearly of an insulating character, and are reasonably resistant to heat, and more particularly, a clay-like material known as bentonite, are of particularly desirable characteristics as an ingredient of a mixture from which to form resistance elements of the general type with which the present invention is concerned. This material, which is readily obtainable in powdered or colloidal form, when present in a substantial amount, particularly in the latter form, as an ingredient of the insulating material of the mixture, increases to a considerable degree the plasticity and workability of the mixture; and it permits most thorough intermingling of the relatively conductive and insulating ingredients of the mixture. Further, because of its composition, bentonite is capable of readily producing a glaze-like skin or covering of a vitreous and permanent nature and high dielectric strength upon a formed body containing the material in a substantial amount, by heating to a suitable temperature in air, and this glaze thus
70 formed effectively seals the surface of the body.

For the ingredient of a relatively conductive nature in the mixture, particularly desirable results may be attained when using silicon carbide alone to produce resistance elements of relatively high specific or unit resistance, or in combination with carbon or graphite, with or without an additional conductive material, to produce resistance elements of lower specific or unit resistance.

In accordance with a desirable process of practicing the present invention, such as may be used in producing resistance elements of relatively small physical dimensions and of fairly high ohmic resistance, and adapted to produce or withstand appreciable heating effects, a comminuted mixture may be produced containing 70 percent of silicon carbide, 5 percent of carbon, and 25 percent of bentonite, preferably in the colloidal state. A sufficient amount of water may be added to form a doughy mixture of the most desirable consistency to permit squirting the comminuted mixture under high pressure through
110 a die of suitable conformation to produce thereby a rod-shaped element of desired cross-sectional area and form, usually circular.

The properties of bentonite which distinguish it from other clays appear in general to be due to its physical constitution rather than to its chemical composition. Its chemical composition is characterized by a high silica content (54% to 63.2%), a high alkali
125 130

plus alkaline earth content (2.46% to 9.69%), and a high iron oxide content (2.46% to 3.97%). This chemical composition results in a rather low softening point (cones 1-14).

5 The great majority of the particles found in bentonite vary from a lower limit of 0.1 micron or less to an upper limit of 0.2 to 0.5 micron. To explain the very high absorptive properties of bentonite it has been suggested
10 that the particles exist in the form of flakes which have dimensions visible under the microscope parallel to the flakes, but have a third smaller dimension perpendicular to the flakes. When suspended in water bentonites often
15 swell to six times their original volume. This hydrophylic quality is one of the principal physical characteristics of bentonite. The fine state of division and the large water content of bentonite result in good lubricating
20 properties which make it easy to extrude the resistor rods such as the applicant makes. The fine state of division is also conducive to coating of the silicon carbide grains with a thin coating of bond which shrinks a great
25 deal during curing. This condition is such that small electric arcs may pass between the silicon carbide grains through the thin coatings or through the cracks formed during the curing.

30 After being formed to shape under pressure, as by being squirted under pressure through a die, the formed elements, in any desired length to permit ready and economical handling, may be received on plates or
35 trays and dried in the presence of air at a temperature ranging from 200° F. to 300° F. These rod-shaped elements, more particularly if they are of relatively great cross-sectional area, may be more or less completely
40 embedded, during this drying operation, in relatively coarse sand or the like which will afford suitable support for the rods against distortion, while still permitting the passage of air and gases at a suitably gradual or retarded rate, insuring a uniform drying
45 throughout. The period of drying need be only sufficient to remove all moisture from the elements, and this period will depend upon the cross-sectional area of the element
50 and the freedom with which moisture may be driven therefrom.

After these rods or other shaped bodies or elements have been suitably dried, they may be heated or fired in neutral or inert, that is,
55 non-oxidizing, atmosphere or surroundings, at a sufficiently high temperature and for a sufficient period of time to thoroughly consolidate the particles of and to heat-harden the element. A satisfactory temperature for
60 this operation is 1800° F. although fairly satisfactory results may be secured with temperatures ranging between 1500° F. to 2200° F. or slightly higher; and the period of heating may range from a very slight period to
65 a considerable period, depending upon the

cross-sectional area and somewhat upon the desired final resistance of the element. For elements of three-eighths inch in diameter formed from the above described mixtures, heating at a temperature of 1800° F. for approximately twenty-five minutes gives satisfactory results. With this heating operation carried on in a neutral atmosphere, there is no resultant oxidation of the carbon or other oxidizable ingredient of the mixture from which the element is formed, and thus any lack of uniformity in the resistance of the final products due to differences in the degree to which oxidation has occurred, is avoided.

Having been heated to the desired extent in the manner described, the formed element, after cooling, may be calibrated to determine its specific or unit resistance; and if the resistance value suitably corresponds to that desired for the final resistance product, the resistance element may then be heated in the presence of air for a short interval at a temperature of approximately 2150° F. to 2450° F., five minutes heating at this temperature being ordinarily sufficient to fire or cause the production of a glaze-like shell or covering on all exposed surfaces of the element, this effect being an incident of heating the body formed of the original mixture from which the element is formed, more particularly the relatively insulating ingredient. This glaze constitutes a very effective sealing envelope which protects the enclosed body of the resistance element from further change in resistance due to oxidation or absorption of any material or substance which might affect the resistance of the element.

A modification of the above described process of heat-hardening or firing the resistance element, and one which in many respects is preferable from the standpoint of economical commercial production, involves the single step of heating in oxidizing surroundings the formed and dried element at a temperature sufficiently high to produce the desired surface glaze or vitreous seal thereon, a temperature approximately 2200° F. to 2500° F. being quite satisfactory for this purpose. Continued heating at this temperature produces during the first stages the surface glaze-like coating and then the desired consolidation and heat-hardening of the particles of the mixture from which the element is formed, the incidental effect of continued heating being to reduce the resistance of the formed element at a decreasing rate. For the satisfactory production of heating elements of the specific physical and electrical characteristics mentioned hereinabove, heating at the temperature specified for a period of approximately 30 to 40 minutes is satisfactory, and gradual application of full heat is desirable.

The heat-hardened resistance elements provided with the vitreous seal over all ex-

posed surfaces may be calibrated after removing the insulating glaze-like seal from the ends of the element, as by a suitable abrading operation. The resistance elements of the desired length thus produced may then be provided at their ends with a conductive coating, indicated at 5 in the drawings, preferably by forcing a stream of metal particles, more desirably in a molten condition, into intimate mechanical and electrical engagement with the ends of the element, this conductive coating preferably being applied in such a manner as to have a portion thereof extending to a suitable extent over the insulating glaze or shell on the outer surface of the elements. This conductive terminal coating thus applied may be of any desired thickness, and it may be relied upon as the only conductive terminal serving to connect the resistance element to a line circuit or, as indicated in the drawings, a separate conductive terminal sleeve or cap 6 or 6^a may be secured over the end of the resistance element, with the conductive coating 5 thereon, by pressing the cap directly into intimate electrical and mechanical engagement with the conductive coating; and likewise, the conductive terminal cap may be connected to the conductive coating 5 by direct fusion of these metal parts or by fusion through an intermediate brazing or soldering material.

In Figs. 3 and 4, there is shown a modification of the resistance element shown in Figs. 1 and 2, and wherein the resistance element is in the form of a hollow tube having an annular body portion 7^a provided with a glaze-like seal 2 on its outer surface and 2^a on its inner surface. A resistance element of this form may be pressed or squirted from the original mixture in substantially the same manner as described hereinabove in connection with the resistance element of circular cross-section shown in Figs. 1 and 2. Of course, a core of suitable form must be provided in the molding or the squirting operation to insure the desired hollow center of the final element. Likewise, the original drying and heating operation in connection with an element of this form may be the same as described hereinabove, independently of whether the heating operation is one wherein the desired heat-hardening and consolidation of the particles of the mixture are secured initially and the vitreous glaze is then fired upon the surface of the element, or the firing of the vitreous glaze is an initial incident of the heat-hardening operation at the temperatures mentioned hereinabove. With the ends of the bore of the formed element open to the passage of air therethrough, the inner surface of the element will be provided with the vitreous glaze which is produced thereon subsequent to heat-hardening in accordance

with the process first described hereinabove or is automatically produced on the resistance element during the initial part of the heat-hardening operation later described hereinabove.

Subsequent to the completion of the heat-hardening or firing operation to produce an element of the desired characteristics, the formed element, with its insulating glaze-like interior and exterior coating thereon, has a conductive coating 5^a, of any desired thickness, applied to its ends in the manner described hereinabove in connection with the resistance element of Fig. 1, this conductive coating preferably extending to some degree over the surface of insulating or glaze-like shells 2 and 2^a; and this conductive coating, by itself, may serve as the finished terminal device for the resistance element, or an additional sleeve or cap 6^b may be provided, this cap extending across the entire end of the heating element, as in the case of that shown in Fig. 1, or being centrally apertured as more particularly indicated in Fig. 3.

In Figs. 5 and 6, there is shown a resistance element embodying the external insulating glaze-like shell or covering sleeve 2 about an annular body portion 7^a of the same character as that of the resistance element of Figs. 3 and 4; but the inner surface of the element of Figs. 5 and 6 is not provided with any vitreous seal or glaze, corresponding to that indicated at 2^a in Fig. 3, the material at this inner surface being of substantially the same composition as the remainder of the body portion 7^a of the resistance element.

A resistance element of this character is formed in the manner described hereinabove in connection with the resistance element of Figs. 3 and 4, except that prior to the heat-hardening or firing operation, the ends of the bore are closed by the insertion therein of a small portion of some plastic mixture, which may be of substantially the same constitution as the body of the resistance element, or by pinching the ends of the formed annular body while the same is in plastic condition. With the bore thus effectively sealed during the heat-hardening operation, there is no oxidation from the inner surface and there is no formation of the glaze or vitreous seal thereon. At the termination of the heat-hardening operation of the general character described above, the end seals or closures of the bore in the element may be removed; and the conductive coating 5^a is then applied as described hereinabove, along with the metal cap 6^b which may be secured in position in the manner heretofore described.

An element of the character of that shown in Figs. 5 and 6 has particular utility as a variable resistance element, one terminal, corresponding to that formed by a conductive coating 5^a and metallic cap 6^b thereon constituting a line terminal connection, and a

contact device being disposed within the bore of the element and adjustable so as to contact with any point on this inner surface, the contact being insulated from all parts of the resistance element except that which bears upon the inner surface at the desired point, constituting or being connected to the other line terminal. It will be apparent that by adjustment of the inner contact, any desired resistance may be included between the terminals.

While the oxidation of any conductive particles at the surface of the formed body may be an incident of the formation of a most effective insulating glaze on the surface of the resistance element, nevertheless, where the firing or heat-hardening is done at a temperature substantially below 2200° F., there is danger of this sealing skin or shell not being produced upon the formed body quickly enough to prevent oxidizing to too great an extent the carbon or other oxidizable conductive medium near the surface of the formed body. And if the firing is done at too high a temperature the insulating glaze or skin produced on the formed body is liable to become sticky and too highly fluent, which may cause the production of a rather rough and uneven surface which is not particularly desirable from a commercial standpoint.

The specific or unit resistance of electrical resistance elements produced in accordance with the present invention may be varied at will throughout a considerable range. For the higher resistance values, the amount of carbon may be very small and practically zero, the silicon carbide being relied upon as the conductive ingredient of the composition, and the bentonite varying from a minimum of about 25 percent to any value desired, although there is no ordinary occasion of exceeding 40 percent. For lower specific or unit resistances of the final product, the percentage of bentonite may be reduced below 25 percent and the carbon, or carbon plus some other conductive material may be increased to 25 percent or more, with silicon carbide making up the balance of the mixture. However, I have found that generally satisfactory commercial results are more difficult of attainment, particularly in the matter of a suitable degree of plasticity or workability of the mixture and the most ready formation of a satisfactory sealing surface or shell on the element, if the amount of bentonite is reduced materially below 25 percent; and most desirable mechanical characteristics are not readily imparted to the final resistance element if the proportion of carbon in the mixture is in excess of about 20 percent. Further, by varying the size of the grains of the silicon carbide used in the mixture, further variation in the resistance of the final product may be secured.

The conductive ingredients of the original mixture from which the resistance element is formed may be so selected that certain of such ingredients compensate for the negative resistance coefficient imparted to the final product by the carbon or silicon carbide, to the end that the final product may have approximately zero resistance coefficient.

The conductive coating such as 5 or 5^a, alone or with the cap 6, 6^a or 6^b, may be extended from one or both ends toward the middle of the element, as to length, to any desired extent, and thus considerable capacitance may be introduced into the circuit by reason of the condenser effect of the outer conductive shell and the inner relatively conductive body portion 7 or 7^a, with the intermediate di-electric separator in the form of the insulating sleeve 2.

In subjecting the formed elements to heating at temperatures corresponding to those required to produce the desired consolidation of particles and heat-hardening of the element, it is desirable that the latter be brought up to such temperatures gradually, so as to avoid any strains or rupture that might occur if the elements were suddenly subjected to the higher temperatures.

It is noticeable that where the proportion of carbon is relatively large, or the proportion of bentonite is relatively small, most desirable results are secured by firing or heat hardening the elements at the higher temperatures within the range specified; and vice versa, with smaller proportions of carbon and larger proportions of bentonite, satisfactory results may be secured at the lower temperatures within the specified range.

During the heat-hardening or firing operation, it is possible that certain of the desirable results produced in the final product are due to the probable action of the bentonite, or some constituent thereof, as a catalyst, possibly because of the highly aluminous nature of bentonite, to promote breaking down of a portion of the silicon carbide throughout the resistance element, resulting in the production of material of greater conductivity; and, possibly, there is some further re-arrangement of the particles of silicon carbide in the fusion of bentonite, or a constituent thereof, resulting in decreased resistance of the element.

Resistance elements produced in accordance with the invention described hereinabove are characterized particularly by the great facility with which a commercial degree of uniformity of the elements may be initially secured, and stability of the characteristics of the element in handling and commercial use may be insured. While the invention has been described hereinabove more particularly in connection with resistance elements of rod or tubular shape, it will be apparent that the invention may be readily utilized in connec-

tion with resistance elements of plate, disk, helical or any other desired shape.

It should be understood that the invention claimed is not limited to the exact details of construction and features of processes shown and described herein, for obvious modifications will occur to persons skilled in the art; and the invention includes such modifications of features herein disclosed as come within the scope of the appended claims.

It is claimed and desired to secure by Letters Patent:

1. A heat-hardened electrical resistance element formed of a mixture containing a silicon carbide and carbon and bentonite, the latter being present in an amount equal to from 20 to 45 per cent, the body portion of said element being of a substantially homogeneous nature throughout, and said element having an outer insulating and sealing shell which is a reaction product of said bentonite.

2. The method of manufacturing electrical resistance elements which comprises forming a shaped body from a mixture including a carbon-containing conductive material and a relatively insulating self-fluxing clay-like material in finely divided form, and heating said element at a temperature between 2100° F. and 2500° F. under oxidizing surroundings for a sufficient time to insure the formation of an insulating sealing shell in the form of a reaction product of said clay-like material upon the surface of said element and the heat-hardening and consolidation of interior particles of said element.

3. The method of manufacturing rod-shaped electrical resistance elements, which comprises forming a shaped body from a mixture including a carbon-containing conductive material and a relatively insulating self-fluxing clay-like material in finely divided form, heating said element at a temperature between 2100° F. and 2500° F. under oxidizing surroundings for a sufficient time to insure the formation of an insulating shell upon the surface of said element and to insure the heat-hardening and consolidation of interior particles of said element, applying a conductive coating to the ends of said heating element in the form of a pressure spray of minute molten particles of metal into intimate mechanical and electrical union with the body portion of said element and over the side surfaces of a portion of said insulating shell.

4. The method of manufacturing a heat-hardened electrical resistance element, which comprises forming a shaped body of a mixture including silicon carbide between 75 and 45 percent, carbon between zero and 20 percent, and bentonite between 25 and 45 percent, heating said formed body at a temperature between 2100° F. and 2500° F. for a period of time sufficient to insure the produc-

tion on the surface of said element of an insulating sealing shell which is a reaction product of one or more of the ingredients of the body, and continuing said heating operation for a period sufficient to consolidate and heat-harden interior portions of said element.

5. The method of manufacturing electrical resistance elements, which comprises forming a shaped body from a mixture including silicon carbide as a main constituent and a relatively insulating self-fluxing clay-like material in finely divided form, and heating said element at a temperature between 2100° F. and 2500° F. under oxidizing surroundings and for a sufficient time to insure the formation of an insulating sealing shell in the form of a reaction product of said clay-like material upon the surface of said element and the heat-hardening and consolidation of interior particles of said element.

6. The method as described in claim 5 in which the silicon carbide is admixed with a more conducting material and the clay-like material is bentonite.

7. A method of producing resistors in large quantities which comprises making a comminuted mixture of finely divided silicon carbide, a more conductive material, bentonite and water; extruding the mixture onto trays under conditions which will keep the extruded portions straight; drying the extruded bodies in air at approximately the normal boiling-point of water under conditions which preclude distortion; firing the dried rods at a temperature exceeding 1500° F. to heat-harden the said rods and to adjust their specific resistance; and further firing the rods at temperatures exceeding 2100° F. for a relatively much shorter period to glaze the exterior surface.

8. The method described in claim 7 in which the glazed rods are cut into suitable lengths, impregnated as to their terminal portions with fused metal which is driven into the pores of said terminal portions, and finally capped with metal sleeves which are in intimate contact with said terminal metal impregnations.

In witness whereof I affix my signature hereto.

ALBERT H. HEYROTH.