Sept. 25, 1945. E. HEDIGER ET AL 2,385,702

ELECTRICAL RESISTOR

Filed Sept. 24, 1942

Fig. 1.

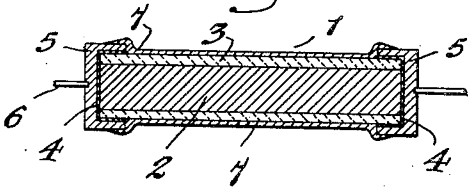


Fig. 2.

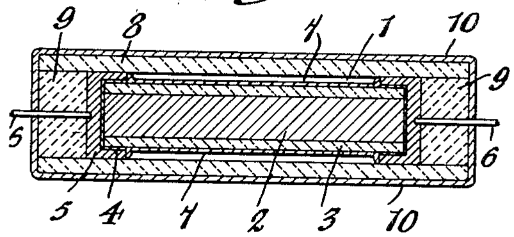


Fig. 3.

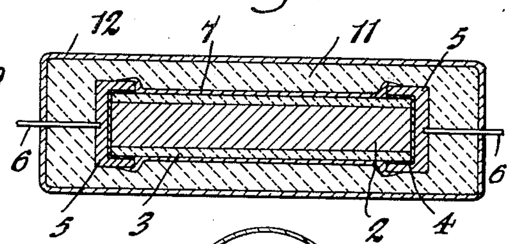


Fig. 4.

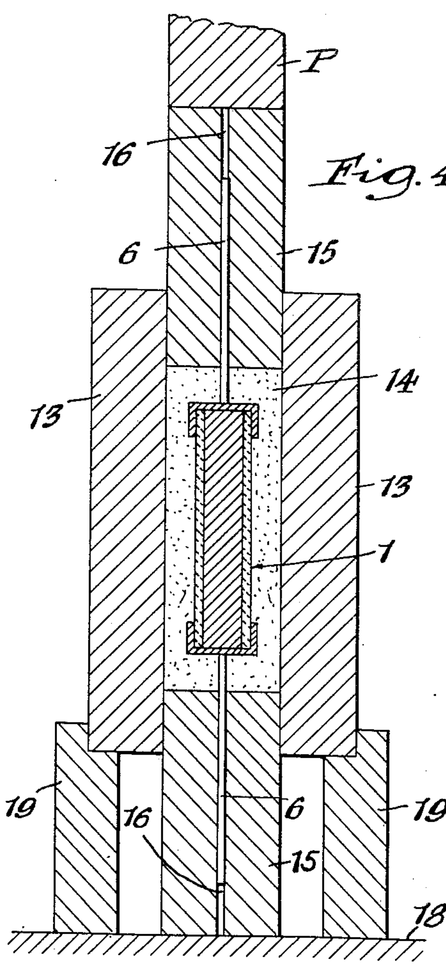
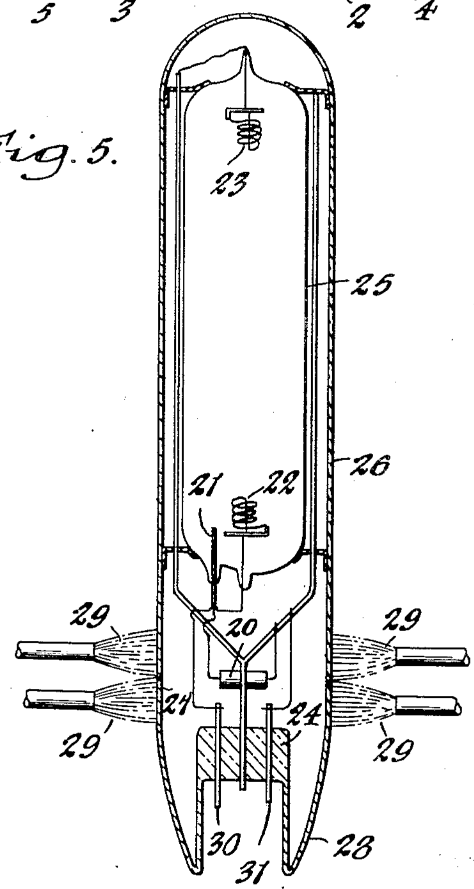


Fig. 5.



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ELECTRICAL RESISTOR

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Application September 24, 1942, Serial No. 459,514

16 Claims. (Cl. 201—67)

This invention relates to electrical resistance elements. Electrical resistance elements comprehended within the present invention are useful in many different applications. Because of their resistance to deterioration at high temperatures, they are particularly useful where high temperatures are encountered during their operation. They are also stable in ohmage values at ambient elevated temperatures, thus making unnecessary any provision for compensating for changes in resistance of the resistor with its length of service.

The resistor of the present invention, although not limited to such use, is particularly advantageous in applications where fairly high resistance is required and the space available for the resistor is limited. Wire wound resistors are large because of the ohmage values required, which may be, in the case of the starting resistor for mercury arc lamps, between 20,000 and 50,000 ohms. To attain such ohmage values in a wire wound resistor small enough to fit into the limited space available, the wire used must be very small in diameter and the insulation light. Because of such inherent limitations in design, wire wound resistors of this type frequently develop open circuits or short circuits.

Composition resistors have been employed for such purpose, but those used before the present invention have not performed satisfactorily because they changed in resistance value as their length of service increased. Furthermore, because of the high temperature at which they were operated, they tended to burn out and thus open circuit after a relatively short period of use.

The present invention overcomes the above difficulties and others encountered with the use of wire wound resistors and the prior art composition resistors where they are operated at high temperatures for long periods of time or encounter still higher temperatures for short periods of time. The invention will be more readily understood by reference to the accompanying drawing, which is for purpose of illustration only, in which

Fig. 1 is a view in cross-section of a resistor element embodying one form of the invention,

Fig. 2 is a view in cross-section of a modification of the resistor of the present invention,

Fig. 3 is a view in cross-section of another modification of the resistor,

Fig. 4 is a cross-sectional view of an apparatus employed in the making of the resistor shown in Fig. 3, and

Fig. 5 shows, in cross-section, a mercury arc lamp in which the resistor may be employed.

The resistance element shown in Fig. 1 is made up of a resistance member denoted generally by the reference character 1, which consists of a resistance core member 2 composed of an electrical conducting material such as carbon distributed in a vitrified insulating matrix, and a rigid ceramic jacket 3 surrounding the core and vitrified into an integral mass with the core. No novelty is claimed for the resistance member 1 per se. Such resistance member and its method of manufacture are disclosed and claimed in U. S. Patent No. 2,060,393, issued November 10, 1936, to A. H. Heyroth. Briefly, such member 1 is made by forming a mix containing carbon, a clay binder, and a filler of poor electrical conductivity in comparison with carbon, such as silicon carbide, flint, or zircon. The mix is moistened with sufficient water to impart plasticity thereto and is then extruded or otherwise formed into rods, or other desired shapes, and dried. The formed shapes are then given an oxidation treatment by heating at 900° F. or over in an oxidizing atmosphere to oxidize the conducting material in the outer portions thereof, after which they are hardened by firing at a higher temperature to effect at least a partial vitrification of the clay binder or a sintering of the resistor into a strong coherent mass. A length of such product is then cut off sufficient to form member 1, or if individual resistor members were formed, the ends are cut off to expose the conducting core 2 at the ends of the resistor member 1.

Electrical connection is made with the conducting core 2 by metal spraying the ends of member 1 with a coating 4 of nickel or iron or other suitable metal, such coating extending down the sides of the member for a substantial distance, as shown in Fig. 1. Over this coating 4 at each end of the resistor member 1 is forced a metal cap 5 equipped with lead wires 6. In one instance the caps 5 are made of nickel or iron and the lead wires 6 are composed of iron or of Monel metal, an alloy composed of 60 parts nickel and 40 parts copper. It is obvious that caps and lead wires made of different metals may be employed if desired.

For the purpose of sealing the resistance from the atmosphere and thus making it capable of operation at fairly elevated temperatures without damaging the resistor core or altering its electrical characteristics by reason of oxidation of the conducting core, the member 1 is coated, in accordance with the present invention, with a glaze 7 which extends over the edges of the caps as shown. To enable the glaze to maintain an airtight seal with caps 5 and shell 3, it must possess a coefficient of thermal expansion substantially the same as that of caps 5 in the range between room temperature and the highest temperature under which the resistor operates or to which it is subjected in installation. Various glazes which meet this requirement may be employed for coating 7. As an example, a glaze having the following composition has been found highly satisfactory where caps 5 are made of nickel or iron:

	Per cent
Na_2O	6.46
PbO	59.17
B_2O_3	14.53
SiO_2	19.84

It is to be understood that this glaze is illustrative only, and that it is capable of variation, and that other glazes may be used instead of it. The glaze mixed with water to form a paste or slurry is coated on to the resistor element 1 and over the ends of caps 5. The resistor is heated at 190–250° F. until the glaze is dried, and is then fired for from 1 to 2 minutes at from 1400 to 1700° F. to cause the glaze to melt and flow. When cool the glaze seals the caps to the resistor member and seals the resistor member itself, making them impervious to the atmosphere, and preventing oxidation of the resistance material and the end contacts.

The resistor shown in Fig. 1 is useful where moderately high temperatures are encountered in service. Because it is sealed it also has a long life when used at ordinary temperatures, the resistance core 1 retaining its initial resistance despite long usage, as it is unaffected by atmospheric conditions.

Where the resistor must operate under high temperature conditions or must be subjected to high temperatures during its installation in operating position in a device in which it is to be used, as for instance, in lamps such as mercury arc lamps, it is preferred to use a resistor still further sealed and protected. Such resistor is shown in one modification in Fig. 2 and in another modification in Fig. 3.

The resistor shown in Fig. 2 consists essentially of the element shown in Fig. 1 with a further outer ceramic shell around it and a second glaze on said outer ceramic shell. It is made by assembling the resistor element 1 with wet unfired glaze coating 7 thereon into the prefired ceramic tube 8, which in one example is of substantially the same composition as the outer layer 3 of the resistor member. The open ends of tube 8 are then plugged with plugs 9 of a suitable material, for example a vitrifiable material. One such substance is a mixture of 80% of the same composition as tube 8 and 20% of a frit of the following composition:

	Per cent
Na_2O	3.68
CaO	4.41
PbO	30.46
B_2O_3	12.60
Al_2O_3	3.41
SiO_2	42.82
ZrO_2	2.30

It is obvious that such plugging material may be varied in composition and that other mixtures may be employed.

The resistor is then heated at 190–250° F. to dry the plugging mixture, after which it is fired for from 1 to 2 minutes from 1400 to 1700° F.

After firing, the resistor is cooled and then coated with a glaze mixed with water to make a paste or slurry. One such outer glaze which is satisfactory is composed of the following components:

	Parts by weight
Jasper flint	4
Bentonite clay	4
Zirconium oxide	8

and 80 parts by weight of a frit which is composed of

	Per cent
Na_2O	3.68
CaO	4.41
PbO	30.46
B_2O_3	12.60
Al_2O_3	3.41
SiO_2	42.82
ZrO_2	2.30

The outer or over glaze coating is dried by heating the resistor to a moderate temperature, for instance 190–250° F., after which the resistor is fired for from 1 to 2 minutes at from 1700 to 2000° F. to melt the glaze and cause it to flow completely and uniformly around the resistor as shown at 10.

Ceramic tube 8, plugs 9, and over glaze 10 prevent oxidation of the body of the resistor and prevent the under glaze 7 from gassing when the resistor becomes highly heated as an incident to its operation at high temperatures or its being assembled into a lamp or other device.

In the modification of the resistor shown in Fig. 3 the outer protective jacket 11 is applied by molding a suitable mixture around the resistor member shown in Fig. 1 and then firing to vitrify it. An over-glaze 12 is then applied over the jacket in the same manner as described in connection with Fig. 2. The molding of the jacket may be done in a variety of ways, as well as by hand. The apparatus shown in Fig. 4 has been found convenient for accomplishing such molding. This apparatus consists of a die block 13 of metal having a bore 14 therethrough of the desired size of the resistor jacket. Two plugs or pistons 15 which closely fit the bore 14 are provided, one for each end of the bore. These pistons have small coaxial bores 16 through them to receive the lead wires 6 from the resistance element 1.

In operation, one piston 15 is placed in bore 14, and the die block positioned vertically, with piston 15 resting on the bottom support 18 of a power press. A member 19, which is U shaped in cross section to allow its removal by being moved laterally, is placed under die 13 to support it temporarily. A measured quantity of the mixture to form the outer jacket, which may be of the same composition as used for plugs 9 in the modification shown in Fig. 2, is placed in the die bore 14 and evenly distributed on the assembled bottom piston 15. A resistor element 1 is then placed coaxially in the bore with the bottom lead wire 6 extending into bore 16. A measured quantity of the same mixture to form the jacket is poured around the resistor and on top of it. The second piston 15 is then assembled in the die bore 14 with lead wire 6 extending into bore 16. Top piston 15 is pressed downwardly by press plunger P with a predetermined moderate force, after which temporary support 19 is removed and plunger P then advanced to exert a predetermined final molding pressure on the resistor. The resistor is ejected by moving bottom piston 15 over an opening in the press bed or support 18, large enough to allow the jacketed resistor to pass through it supporting die 14 by support 19, and pressing the resistor out by force exerted on the top piston 15.

After packet 11 has been fired, over-glaze 12 is applied to the resistor and fired, as described in connection with the application of the over glaze to the resistor in Fig. 2.

As has been previously explained, the mounting of resistors in certain types of apparatus entails their exposure to high temperatures. This is true in the case of mercury arc lamps of the type illustrated in Fig. 5, in which the arc starting mechanism employs a series resistance located near the base of the lamp. This resistance, shown at 20 in Fig. 5, is connected in series with the starting arc between starting electrode 21 and the bottom main electrode 22 when the lamp is connected to a suitable source of electric current. When the mercury in the tube becomes sufficiently vaporized and ionized, an arc is established between electrodes 22 and 23, which are connected in parallel with the starting electrodes. Because the resistance of the main arc is now much less than that through resistance 20 and the starting arc, the starting arc is extinguished and no current flows through the starting circuit.

The lamp shown in Fig. 5 is assembled by welding the lead and support wires in the press 24 to the lead wires projecting from the electrodes in the inner sealed glass sheath 25. This assembly is then slipped into the outer glass sheath which terminates at point 27. Press 24 has the bottom portion 28 of the outer sheath integrally connected to it. In order to unite the bottom portion of sheath 26 to part 28 the bottom of sheath 26 and the top of part 28 are heated as by gas flames 29 while being suitably turned in a vertical position. When sufficiently heated the glass necks in slightly at the bottom of sheath 26 and when the part 28 is pressed against the bottom of sheath 26 a sealed joint results. A conventional lamp base, not shown, is connected to the lamp lead wires 30 and 31 and cemented to part 28 of the outer glass sheath to complete the lamp.

This heating of the outer glass sheath for the lamp, such as illustrated, after becoming highly heated as from operation for a considerable period of time is shut off for any reason such as power failure for even a fraction of a cycle, it will not again function to establish an arc between electrodes 22 and 23 until the lamp has cooled down so that pressure within sheath 25 becomes materially lowered, which may take as long as five or ten minutes. If power is re-established during this period, the starting arc then is created and maintained between starting electrode 21 and main electrode 22. This causes resistor 20 to carry a considerable current for a substantial length of time. When a mercury arc light source of the type shown in Fig. 5 is employed in certain ultra violet lamps, the outer glass sheath is made of glass which passes only ultra violet light. Such sheath absorbs or reflects all radiant energy from the arc except the ultra violet, and thus the interior of the outer-sheath and consequently the resistor becomes very hot.

Resistor 20 thus is subjected to very severe treatment during its installation in the lamp and during operation of the lamp. It has been found that resistors such as shown in Figs. 2 and 3 withstand this severe installation and operation conditions, and yield long trouble-free service. The resistance remains substantially constant throughout the life of the lamp, since it is completely sealed from the atmosphere and other gases which might deleteriously affect it.

The remarkable constancy of resistance value of the resistor of the present invention under high temperature conditions in an oxidizing atmosphere is shown by the results of a test involving repeated cycles of heating and cooling resistors such as shown in Figs. 2 and 3. The resistors were put into an electrical furnace at 1300° F., with air as the atmosphere, and left for 10 minutes. They were taken out, allowed to cool, and their resistance value determined. The resistors were subjected in all to seven such heating and cooling cycles. At the end of the test the average change in resistance of the twelve resistors was 10.8%. In the following table the original resistance, resistance after each cycle, and change in resistance from the original after each cycle is given for each of twelve resistors numbered 1 to 12.

Repeated temperature test of resistors, heating to 1300° F. for 10 min. and cooling

No.	Original resistance	Resistance cycle #1	Percent	Cycle #2	Percent	Cycle #3	Percent	Cycle #4	Percent	Cycle #5	Percent	Cycle #6	Percent	Cycle #7	Percent
1	18,600	18,900	1.6	19,500	4.84	19,500	4.84	19,500	4.84	20,200	8.6	20,200	8.6	20,600	10.7
2	17,700	18,000	1.69	18,600	5.08	18,900	6.77	18,900	6.77	19,500	10.2	19,500	10.2	19,800	11.9
3	17,700	18,000	1.69	18,600	5.08	18,900	6.77	18,900	6.77	19,500	10.2	19,500	10.2	19,800	11.9
4	18,300	18,600	1.64	19,200	4.92	19,200	4.92	19,500	6.55	20,200	10.4	20,200	10.4	20,200	10.4
5	18,600	18,900	1.61	19,500	4.83	19,500	4.83	19,800	6.45	20,200	8.6	20,200	8.6	20,600	10.7
6	17,700	18,000	1.76	18,300	3.39	18,900	6.78	19,200	8.47	19,500	10.2	19,800	11.9	19,800	11.9
7	17,700	18,000	1.76	18,600	5.08	18,900	6.76	18,900	6.76	19,200	8.47	19,500	10.2	19,500	10.2
8	17,700	18,000	1.76	18,600	5.08	18,600	5.08	18,900	6.76	19,200	8.47	19,500	10.2	19,500	10.2
9	17,700	18,300	3.39	18,600	5.08	18,900	6.76	19,200	8.47	19,200	8.47	19,200	8.47	19,500	10.2
10	17,700	18,000	1.76	18,600	5.08	18,900	6.76	19,800	10.7	19,500	10.2	19,500	10.2	19,800	10.7
11	17,100	17,400	1.75	17,700	3.50	18,000	5.26	18,300	7.02	18,900	10.5	18,900	10.5	18,900	10.5
12	17,700	18,000	1.76	18,300	3.39	18,300	3.39	18,600	5.08	18,900	6.76	18,900	6.76	19,500	10.2

purpose of sealing it subjects the mechanism inside it, including resistor 20, which is about opposite the zone of maximum temperature of the sealing flames to intense heat, in the order of 1300° F., for several minutes. Furthermore, during normal operation the temperature inside sheath 26 rises to about 600° F. When a mercury

This test demonstrates, besides the substantial constancy of electrical resistance of such resistors, their ability to withstand heat shock, since as above pointed out, each cycle involved the placing of cold resistors directly into a furnace at 1300° F., with no preliminary warming up.

While the resistor has been illustrated and described specifically in connection with a mercury arc lamp, it is obvious that it is useful in other types of lamps such as sodium arc lamps and neon lamps. Furthermore, the resistor is useful in all applications where high temperatures are encountered in its installation or operation, and/or atmospheres are encountered at normal temperatures which without the fully sealed construction of the resistor would destroy it or substantially change its resistance value.

It is therefore to be understood that the details herein described with respect to the resistor may be variously changed and modified without departing from the spirit and scope of the invention except as pointed out in the annexed claims.

We claim as our invention:

1. An electrical resistor comprising a resistance core of electrical conducting material in a rigid jacket surrounding the core, metal caps on the ends of the resistor making electrical connection with the resistance core, and a vitrified glaze on the outside of the jacket adjacent the caps and extending over the inner ends of the caps and making an air-tight joint with the caps, said glaze being of substantially the same thermal coefficient of expansion as the metal caps.

2. An electrical resistor comprising a resistance core of electrical conducting material in a rigid ceramic jacket surrounding the core, metal caps on the ends of the resistor making electrical connection with the resistance core, and a continuous vitrified glaze on the outside of said jacket and overlying the inner ends of the caps and making an air-tight joint with the caps, said glaze being of substantially the same thermal coefficient of expansion as the metal caps.

3. An electrical resistor comprising a resistance core of electrical conducting material distributed in a vitrified insulating matrix, a rigid ceramic jacket surrounding the core and vitrified into an integral mass with said core, metal caps on the ends of the resistor making electrical connection with the resistance core, and a continuous vitrified glaze on the outside of said jacket and overlying the inner ends of the caps and making an air-tight joint with the caps, said glaze being of substantially the same thermal coefficient of expansion as the metal caps.

4. An electrical resistor comprising a resistor core of electrical conducting material in a rigid jacket surrounding the core, metal caps equipped with lead wires on the ends of the resistor making electrical connection with the resistance core, a vitrified glaze on the outside of the jacket adjacent the caps and extending over the ends of the caps, said glaze being of substantially the same thermal coefficient of expansion as the metal caps, an outer sheath of ceramic material enclosing the jacketed resistor core, the cap lead wires extending through such outer sheath, and a vitrified glaze covering the outer sheath and sealing it from the atmosphere.

5. An electrical resistor comprising a resistance core of electrically conducting material in a rigid ceramic jacket surrounding the core, metal caps equipped with lead wires on the ends of the resistor making electrical connection with the resistance core, a continuous vitrified glaze on the outside of said jacket and overlying the ends of the caps, said glaze being of substantially the same thermal coefficient of expansion as the metal caps, an outer sheath of ceramic material enclosing the jacketed resistor core, said sheath comprising a prefired ceramic tube fitted over the resistor and ceramic plugs filling the ends of the tube, the lead wires extending through the outer sheath, and a vitrified glaze covering the outer sheath and sealing it from the atmosphere.

6. An electrical resistor comprising a resistance core of electrically conducting material in a rigid ceramic jacket surrounding the core, metal caps equipped with lead wires on the ends of the resistor making electrical connection with the resistance core, a vitrified glaze on the outside of the jacket adjacent the ends of the caps and extending over the ends of the caps, said glaze being of substantially the same coefficient of expansion as the metal caps, an outer sheath of ceramic material molded around and enclosing the jacketed resistor core, the cap lead wires extending through such outer sheath, and a vitrified glaze covering the outer sheath and sealing it from the atmosphere.

7. An electrical resistor comprising a resistance core, high temperature resistant insulating material on the core, metal caps equipped with lead wires on the ends of the resistor making electrical connection with the resistance core, a vitrified glaze on the outside of the jacket adjacent the ends of the caps and extending over the ends of the caps, said glaze being of substantially the same coefficient of expansion as the metal caps, an outer sheath of ceramic material enclosing the insulated resistor, the lead wires extending through the outer sheath, and a vitrified glaze covering the outer sheath and sealing it from the atmosphere.

8. An electrical resistor comprising a resistance core of electrical conducting material in a jacket surrounding the core, metal caps on the ends of the resistor making electrical connection with the resistance core, and a vitrified glaze on the outside of the jacket adjacent the caps and extending over the inner ends of the caps and making an air-tight joint with the caps, said glaze being of substantially the same thermal coefficient of expansion as the metal caps.

9. An electrical resistor comprising a resistance core of electrically conducting material, a jacket surrounding the core, means at the ends of the resistor making electrical connection with the resistance core, and a vitrified glaze on the outside of the jacket adjacent the electrical connector means extending into intimate contact with the connector means and making an air-tight joint therewith, the said glaze being of substantially the same thermal coefficient of expansion as the electrical connector means.

10. An electrical resistor comprising a resistance core of electrically conducting material, a jacket surrounding the core, metal electrical connector means at the ends of the resistor making electrical connection with the resistance core, and a vitrified glaze on the outside of the jacket adjacent the electrical connector means extending into intimate contact with said connector means and making an air-tight joint therewith, said glaze being of substantially the same thermal coefficient of expansion as the electrical connector means.

11. An electrical resistor comprising a resistance core of electrically conducting material, a rigid jacket surrounding the core, metal electrical connector means at the ends of the resistor making electrical connection with the resistance core, and a vitrified glaze on the outside of the jacket extending into intimate contact with the electrical connection means and making an air-tight joint therewith, said glaze being of substantially

the same thermal coefficient of expansion as the metal electrical connector means.

12. An electrical resistor comprising a resistor core of electrical conducting material in a jacket surrounding the core, electrical connector means equipped with electrically conducting leads at the ends of the resistor making electrical connection to the resistance core, a vitrified glaze on the outside of the jacket adjacent the electrical connector means extending into intimate contact with the connector means and making an air-tight joint therewith, said glaze being of substantially the same thermal coefficient of expansion as the electrical connector means, an outer sheath of ceramic material enclosing the jacket resistor core, the electrically conducting leads extending through such outer sheath, and a vitrified glaze covering the outer sheath and sealing it from the atmosphere.

13. An electrical resistor comprising a resistor core of electrically conducting material in a jacket surrounding the core, electrical connector means equipped with electrically conducting leads at the ends of the resistor making electrical connection with the resistance core, a continuous vitrified glaze on the outside of said jacket extending into intimate contact with the electrical connector means and making an air-tight joint therewith, said glaze being of substantially the same thermal coefficient of expansion as the electrical connector means, an outer sheath of ceramic material enclosing the jacketed resistor core, said sheath comprising a prefired ceramic tube fitted over the resistor and ceramic plugs filling the ends of the tube, the electrically conducting leads extending through the outer sheath, and a vitrified glaze covering the outer sheath and sealing it from the atmosphere.

14. An electrical resistor comprising a resistor core of an electrically conducting material in a jacket surrounding the core, electrical connector means equipped with electrically conducting leads at the ends of the resistor making electrical connection with the resistance core, a vitrified glaze on the outside of the jacket extending into intimate contact with the connector means and making an air-tight joint therewith, said glaze being of substantially the same coefficient of expansion as the electrical connector means, and an outer sheath of ceramic material molded around and enclosing the jacketed resistance core, the electrically conducting leads extending through such outer sheath, and a vitrified glaze covering the outer sheath and sealing it from the atmosphere.

15. An electrical resistor comprising a central resistance core of electrically conducting ceramic material, a jacket surrounding the core, means at the end of the resistor making electrical connection with the resistance core, and a vitrified glaze on the outside of the jacket adjacent the electrical connector means extending into intimate contact with the connector means and making an air-tight joint therewith, said glaze having substantially the same thermal coefficient of expansion as that of the electrical connector means.

16. An electrical resistor comprising a rigid central resistance core of electrically conducting vitrified ceramic material, a rigid ceramic jacket surrounding the core, means at the end of the resistor making electrical connection to the resistance core, and a vitrified glaze on the outside of the jacket and adjacent the electrical connector means and extending into intimate contact with the connector means and making an airtight joint therewith, the said glaze having substantially the same thermal coefficient of expansion as that of the electrical connector means.

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