

- [54] **HIGH VOLTAGE RESISTOR**
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- [73] Assignee: **CTS Corporation**, Elkhart, Ind.
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- [52] U.S. Cl. **338/257, 29/612, 174/DIG. 8, 338/51, 338/274, 338/276, 338/315, 338/325**
- [51] Int. Cl. **H01c 1/14**
- [58] Field of Search **338/51, 256, 257, 338/273, 274, 276, 315, 325, 329; 174/52 PE, DIG. 8; 29/612**

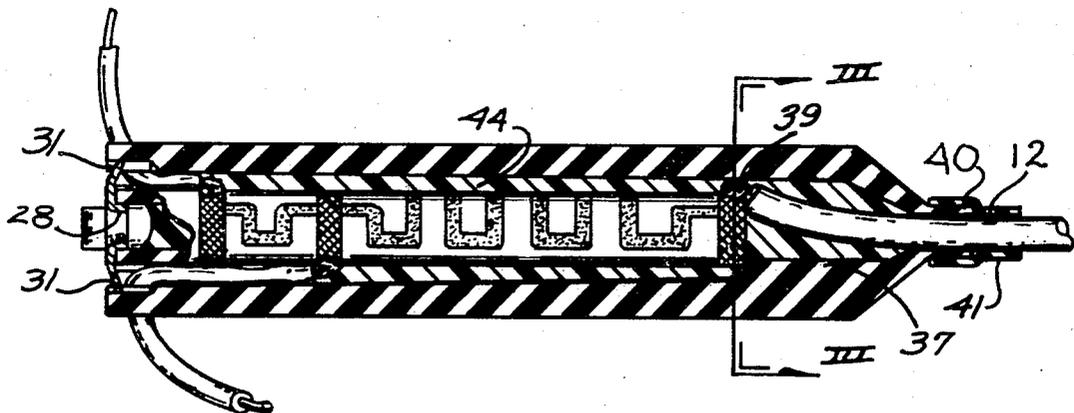
Primary Examiner—E. A. Goldberg
 Attorney—John J. Gaydos et al.

[57] **ABSTRACT**

A high voltage electrical resistor comprises a resistive path supported on a dielectric hollow cylindrical substrate, termination means electrically connected to the resistive path, an insulation system and a heat dissipation system. The high voltage end of the substrate is spaced from the wall of an insulative jacket by means of projections extending radially inwardly from the wall. The low voltage end of the substrate is spaced from the wall of the jacket by means of a heat dissipating mounting member. The termination means include insulated lead wires electrically connected to the resistive path with a lead wire adjacent the high voltage end of the substrate passing through a tubular projection of the jacket. A heat shrunk sleeve forms a tight seal between the tubular projection and the lead wire. Dielectric material fills the space between the substrate and the jacket forming a moisture impervious barrier around the resistive path and improving the dielectric strength of the resistor.

- [56] **References Cited**
- UNITED STATES PATENTS**
- 2,914,600 11/1959 Smith 174/52 PE
- 3,012,273 12/1961 Lewis 174/52 PE
- 3,048,914 8/1962 Kohring 338/273 X

23 Claims, 4 Drawing Figures



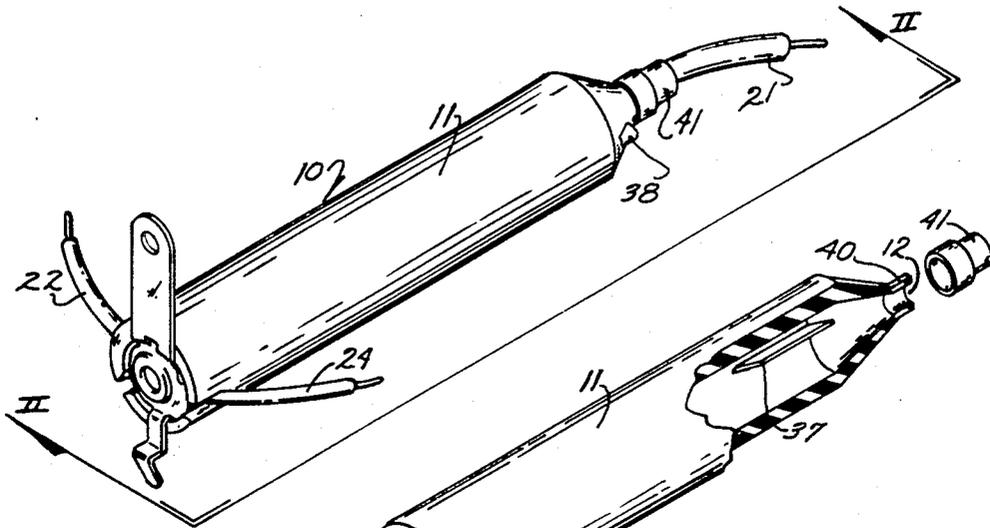


FIGURE-1

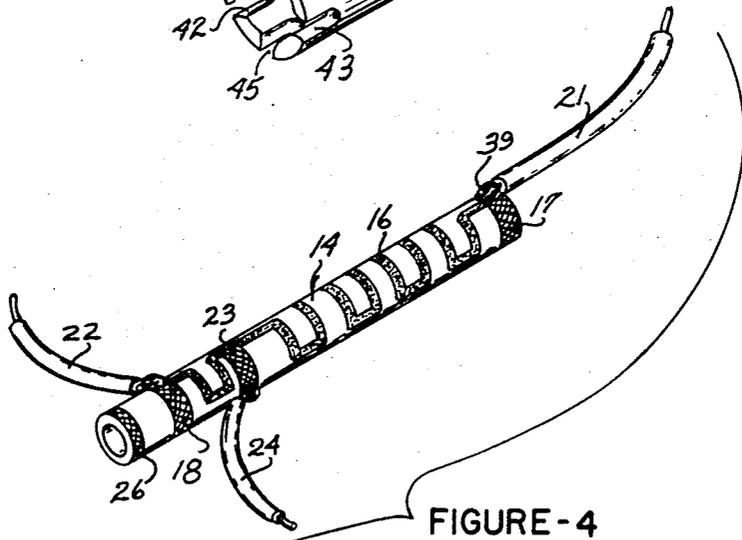
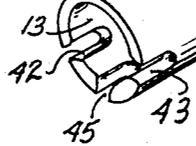


FIGURE-4

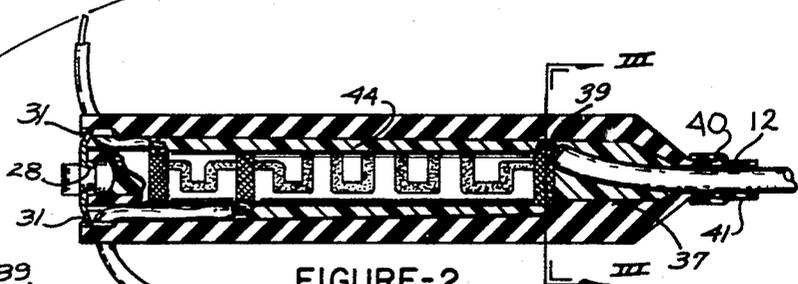
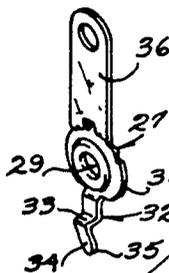


FIGURE-2

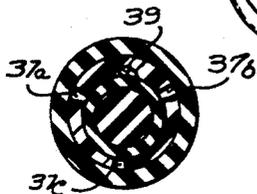


FIGURE-3

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HIGH VOLTAGE RESISTOR

This application is an improvement over commonly assigned application Ser. No. 23,267, filed Mar. 11, 1971, which is a division of application Ser. No. 809,655 filed Mar. 24, 1969, now U.S. Pat. No. 3,579,819 incorporated herein by reference. The present invention relates to an improved high voltage resistor having improved characteristics for use in a high voltage electrical circuit and a method of manufacturing such a resistor.

As discussed in the above-identified applications, the prior inventions sought to replace the typical prior art circuit arrangement wherein a resistor module comprising a plurality of series connected fixed volume electrical resistors had been connected across a power supply of 20,000 or more volts. The inventions of the above-identified applications eliminated the need for separate resistors by providing a single discrete high ohmic value resistor for use in a high voltage circuit application such that the precision, stability and quality thereof was determined by the characteristics of a single continuous resistive path. While the inventions of the above-identified applications have met with a great degree of commercial success and have satisfied rigid engineering requirements, it would be desirable to fabricate an improved high voltage resistor capable of discharging 20,000 or more volts and provide taps along the resistive path on a single substrate in a smaller package with higher initial and long term dielectric strength.

In the construction of the inventions of the above-identified applications a great deal of time and effort was spent in centering the substrate relative to a heat dissipating mounting member in order to provide for uniform distribution of the primary insulating material, e.g., polyurethane, between the jacket and substrate. The effort in precisely centering the substrate relative to the heat dissipating mounting member can be minimized if means are provided for positively spacing the high voltage end of the substrate from the jacket. It would therefore be desirable to provide an improved high voltage resistor having improved centering means for centering the substrate and particularly for positively spacing the high voltage end of the substrate from the jacket.

Accordingly, it is an object of the present invention to provide a new and improved high voltage resistor and method of manufacturing same. Another object of the present invention is to provide an improved resistor to which potentials of 20,000 or more volts may be applied and which is provided with means of preventing the occurrence of high voltage corona. An additional object of the present invention is to provide improved centering means for spacing the high voltage end of the resistor relative to the insulating jacket. A further object of the present invention is to provide improved mounting means for a high voltage resistor. Yet another object of the present invention is to provide a method for bottom filling of the insulation to insure maximum density of the insulation at the high voltage end of the resistor. Still another object of the present invention is to provide a tapped resistor wherein the substrate provides a continuous heat transfer path through the taps. Further objects and advantages of the present invention will become apparent as the following description proceeds and the features of novelty characterizing the invention will be pointed out with

particularity in the claims annexed to and forming a part of this specification.

Briefly, the present invention is concerned with an improved high voltage electrical resistor comprising a resistive path supported on a ceramic substrate, termination means electrically connected to the resistive path, and an insulation system. The substrate provides a uniform and continuous heat dissipation path between the ends of the resistive path. In order to promote the rapid transfer of heat away from the substrate, a thermally conductive heat dissipating mounting member is arranged in close proximity to the surface of the substrate. An insulative jacket having an aperture in one end and an opening in the other end surrounds the substrate. The termination means include an insulated lead wire electrically connected to the resistive path adjacent the high voltage end which projects through the aperture and substantially seals the aperture. A plurality of projections extend from the interior wall of the housing into engagement with the substrate to maintain the resistive path at the high voltage end spaced from the wall of the housing. The point of electrical connection between the insulated lead wire and the resistive path is also spaced from the wall of the housing by positioning the point relative to the projections. The thermally conductive heat dissipating member provides means for maintaining the resistive path at the low voltage end spaced from the wall of housing. Dielectric material is positioned between the resistive path and the wall of the housing thereby providing a moisture impervious barrier around the resistive path. The material also surrounds the termination thereby providing strain relief and means for preventing high voltage corona when the termination is connected to a high potential in the range of 20,000 volts or more.

For a better understanding of the present invention reference may be made to the accompanying drawings wherein the same reference symbols have been applied to like parts and wherein

FIG. 1 is an isometric view of the high voltage resistor made in accord with the present invention;

FIG. 2 is a sectional view taken on the line II—II of FIG. 1;

FIG. 3 is a sectional view taken on the line III—III of FIG. 2 assuming FIG. 2 to be shown in full; and

FIG. 4 is an exploded isometric view of the high voltage resistor shown in FIG. 1 with parts broken away to better disclose features of the present invention.

Referring now to the drawings the preferred embodiment of the present invention comprises a high voltage resistor 10 comprising a jacket or cylindrical housing 11 of a dielectric material such as polypropylene having an aperture 12 in one end and an opening 13 in the other end. A hollow cylindrical substrate 14 formed of a ceramic type material such as steatite or alumina is disposed within the housing 11 and has resistance means in the form of resistance material 16 defining a serpentine resistive path deposited by a printing or other suitable process onto an outer surface of the substrate 14. The resistive path is comprised of an intersticed mass of inert electrically nonconductive particles uniformly distributed throughout the resistive path and a conductive phase forming an interstitial mass within the intersticed mass of the inert electrically nonconductive particles. The uniformly spaced inert electrically nonconductive particles typically have an average size of 0.1 to 10 microns with the conductive phase fill-

ing the spaces between adjacent ones of the inert electrically nonconductive particles. A binder bonds together the inert electrically nonconductive particles and the conductive phase. In a preferred embodiment the resistive path has a resistivity of 1 megohm per square and a voltage coefficient of 400 parts per million per volt per square of resistive path. Preferably the resistance composition used in making the resistive path is similar to the resistance composition disclosed in the co-pending application Ser. No. 803,688 filed on Mar. 3, 1969, by L. J. Brady and entitled Electrical Resistance Elements, Their Composition, and Method of Manufacture. It will, however, be understood that resistance compositions other than those being disclosed in said co-pending application may also be used in the practice of the present invention.

The illustrated termination means includes two solderable conductive pads 17, 18 deposited adjacent the ends of the resistive path in electrical connection therewith and having insulated lead wires 21, 22 soldered thereto. When it is desired to provide a tap intermediate the ends of the resistor, a third or additional solderable conductive pad 23 is deposited on the substrate intersecting the resistive path to provide the desired ratio between the resulting two portions of resistive path and an insulated lead wire 24 is soldered to the pad. In the preferred embodiment the end of the substrate having the lead wire 17 secured thereto is referred to as the high voltage end whereas the other end of the substrate is referred to as the low voltage end. An additional solderable conductive pad 26 is deposited adjacent the low voltage end and positioning means in the form of a heat dissipating mounting member 27 is connected thereto by a deposit of solder. This construction enables the heat dissipating mounting member 27 to dissipate relatively large amounts of heat away from the substrate during use of the resistor. It will be appreciated that the resistive path could be electrically connected to the solderable conductive pad 26 secured to the heat dissipating mounting member 27 whereby the heat dissipating mounting member 27 could also serve as termination means. The heat dissipating mounting member 27 is provided with tubular centering means 28 defining the walls of a central aperture 29 projecting into the interior of the hollow substrate 14 to thereby center the substrate relative to the heat dissipating mounting member 27. Frictional gripping means 31 extend from the heat dissipating mounting member into engagement with the interior wall of the cylindrical housing 11 to position the substrate 14 relative to the housing.

In order to secure the resistor to a not shown mounting panel incorporating the resistor, a latching tab 32 projects outwardly from the tubular centering means 28 having an angled portion 33 bent at an angle to the heat dissipating mounting member 27 and a lateral portion 34 extending outwardly of the housing from the angled portion 33. A screw tab 36 also extends from the heat dissipating mounting member 27 having a hole therein for receiving a bolt or screw to secure the resistor to the mounting panel. In order to ensure a good heat transfer interface between the heat dissipating mounting member 27 and the mounting panel the tip 35 of the lateral portion 34 is disposed such that the distance between the tip 35 and a plane through the interface of the heat dissipating mounting member is less than the thickness of the mounting panel. Thus when

the latching tab 32 is inserted in a slot in the mounting panel with the tip 35 of the lateral portion 34 positioned adjacent the underside of the panel the screw tab 36 is spaced from the top surface of the panel whereby a bolt passing through the hole of the screw tab 36 draws the heat dissipating mounting member 27 into tight abutting relationship with the mounting panel.

In order to ensure proper spacing of the resistive path from the walls of the housing, positioning means in the form of a plurality of projections or fins 37 extend from the interior wall of the housing adjacent the aperture 12 into engagement with the substrate 14 adjacent the high voltage end. A locating lug 38 projects from the exterior of the housing to enable external determination of the position of the fins 37. In the preferred embodiment as shown in FIG. 3 two of the fins 37a, 37b project from the housing a distance greater than the distance a third fin 37c projects therefrom. During the assembly of the resistor the high voltage end of the substrate is inserted into the housing with the point of electrical connection 39 between the insulated lead wire 21 and the solderable conductive pad 17 being positioned between the two fins 37a, 37b, thus ensuring spacing between the point of electrical connection 39 and the wall of the housing. The aperture 12 in the end of the housing is defined by a tubular projection 40 and is substantially sealed by introducing the insulated lead wire 21 therethrough. In order to provide ease of assembly it is necessary to have some tolerance between the tubular projection 40 and the insulated lead wire 21. Thus a heat shrinkable sleeve 41 is disposed over the tubular projection 40 and insulated lead wire 21 and heat shrunk to tightly seal the aperture. Alternatively, the tubular projection 40 can be spin welded to the insulation of the insulated lead wire 21 in order to tightly seal the aperture.

As the substrate 14 is inserted into the housing during assembly, the insulated lead wire 24 forming the tap and the insulated lead wire 22 secured to the low voltage end of the resistor are disposed in the space between the substrate 14 and the housing wall and inserted into individual lead break outs 42, 43, 45 adjacent the opening in the housing. By directing the lead wires 22, 24 radially of the housing, strain relief is provided since a force exerted on the lead wires 22, 24 will be in a direction different from the direction in which the lead wires 22, 24 are secured to the solderable conductive pads 18, 23. Since each of the lead wires 22, 24 has a separate break out, the possibility of shorting between the lead wires 22, 24 is minimized due to their physical separation. When the high voltage end of the substrate 14 is positioned in engagement with the fins 37, the heat dissipating mounting member 29 is disposed with its frictional gripping means 31 frictionally engaging the wall of the housing, thus positioning the substrate 14 so as to provide a space between the resistive path and the wall of the housing.

Once the substrate is positioned in the housing with the heat shrinkable sleeve 41 shrunk into tight engagement with the tubular projection 40 and the insulated lead wire 21, dielectric material 44 such as a polyurethane is inserted through the aperture 29 in the heat dissipating mounting member 27 whereby the material passes through the center of the substrate and fills the space between the resistive path and the walls of the housing 11. The lead break outs 42, 43, 45 provide

vents for the escape of gases forming during insertion of the dielectric material 44. Since the point of electrical connection 39 between the insulated lead wire 21 and the solderable conductive pad 17 at the high voltage end of the substrate is spaced from the wall of the housing, the dielectric material also surrounds the point of electrical connection 39. Once the dielectric material cures it forms a rigid moisture impervious barrier around the resistive path and insulated lead wires. In surrounding the insulated lead wires, the dielectric material adheres to the insulation of the lead wires and provides strain relief. The dielectric strength of the resistor 10 can be increased by tapering the cross-sectional width of the housing wall such that the width of the wall is greater at the high voltage end.

The voltages applied to the high voltage end of the resistor during operation are sufficiently high to cause high voltage corona to occur around the resistive path in the absence of some corona prevention means. In the presence of corona, atmospheric nitrogen will combine with water vapor to form nitrous acid and atmospheric oxygen will form ozone. Since both of these materials are extremely chemically active with materials such as the resistance material and insulation, it is necessary to provide some means for both preventing the formation of high voltage corona around the resistive path and eliminating the formation of nitrous acid and ozone in the event corona does occur. By providing a uniform voltage gradient along a resistive path devoid of abrupt changes, the likelihood of corona occurring is reduced. Additionally, the dielectric material 44 serves as a dielectric barrier between adjacent turns of the serpentine path further reducing the likelihood of corona occurring. Even if corona occurs the dielectric material 44 forms a moisture impervious barrier around the resistive path thus preventing the presence of atmospheric nitrogen and oxygen in the area where corona occurs. Since the dielectric material is filled from the low voltage end of the substrate 14, it will be appreciated that the maximum density of the material will be at the high voltage end of the substrate thus reducing the possibility of gas pockets forming adjacent the high voltage end and improving the dielectric strength at the high voltage end which is desirable as the likelihood of corona occurring is greatest at the high voltage end.

The preferred embodiment of the inventive method of the present invention comprises depositing a resistance material 16 in a serpentine path on a cylindrical dielectric substrate 14 thereby defining a resistive path. Solderable conductive pads 17, 18 are deposited on the substrate 14 in electrical connection with the resistive path and insulated lead wires 21, 22 are soldered to the pads. Additionally, a solderable conductive pad 26 is deposited on the low voltage end of the substrate and a heat dissipating mounting member 27 having an aperture 29 therein is soldered to the solderable conductive pad 26 with the aperture 29 in communication with the interior of the substrate 14. Once the insulated lead wires 21, 22 are secured to the conductive pads 17, 18 and the heat dissipating mounting member 27 is secured to the low voltage end of the substrate, the subassembly is positioned in a cylindrical housing of dielectric material with the lead wire 21 adjacent the high voltage end being disposed in an aperture 12 in the housing. The point of electrical connection 39 between the insulated lead wire 21 at the high voltage end of the substrate and the solderable conductive pad 17 is accu-

rately positioned relative to fins 37 projecting from the inner wall of the housing by means of a locating lug 38 projecting outwardly from the exterior of the housing. Thus the point of electrical connection 39 is guaranteed to be centered between two of the projections 37 and spaced from the wall of the housing. A heat shrinkable sleeve 41 is positioned over a tubular projection 40 defining the aperture 12 and over the insulated lead wire 21 and heat shrunk into tight engagement with the tubular projection and insulated lead wire. Alternatively, the tubular projection can be spin welded to the insulation of the insulated lead wire 21. Dielectric material 44 is then injected into the housing through the aperture in the heat dissipating mounting member 27 whereby the material passes through the hollow substrate and enters the space between the resistive path and the housing.

While there has been illustrated and described what is at present considered to be a preferred embodiment of the present invention, it will be appreciated that numerous changes and modifications are likely to occur to those skilled in the art, and it is intended in the appended claims to cover all those changes and modifications which fall within the true spirit and scope of the present invention.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A high voltage resistor comprising a cylindrical housing of dielectric material having an inner wall extending longitudinally of the housing, a high heat resistant dielectric cylindrical substrate disposed within said housing, the substrate being provided with a cylindrical opening extending longitudinally through the substrate, a resistive path supported on the substrate, termination means electrically connected to the resistive path, said resistive path having a high voltage end and a low voltage end, positioning means for maintaining said high voltage end of the resistive path spaced from the wall of said housing, said positioning means being provided with at least one opening between said high voltage end of said resistive path and the wall of said housing, the cylindrical opening in the substrate communicating with the one opening, and dielectric material disposed between said resistive path and the wall of said housing and forming a moisture impervious barrier around said resistive path.

2. The high voltage resistor of claim 1, wherein said positioning means comprises a plurality of projections extending from said housing into engagement with said substrate.

3. The high voltage resistor of claim 2, wherein second positioning means spaces the resistive path at said low voltage end from the wall of the housing.

4. The high voltage resistor of claim 3, wherein said second positioning means comprises a mounting member bearing against said substrate and engaging the wall of said housing.

5. The high voltage resistor of claim 4, wherein said mounting member has a latching tab projecting outwardly from said housing and a screw tab having an aperture therethrough extending outwardly from said housing for securing said resistor to a mounting panel.

6. The high voltage resistor of claim 5, wherein said latching tab has an angled portion bent at an angle to said mounting member and a lateral portion extending outwardly of said housing from said angled portion.

7. The high voltage resistor of claim 4, wherein a thermally conductive bonding material secures the mounting member and substrate in fixed assembled relationship, said bonding material providing a thermally conductive path for dissipating heat from the substrate to the mounting member.

8. The high voltage resistor of claim 1, wherein said housing has an aperture in one end and an opening in the other end, said termination means including an insulated lead wire electrically connected to said resistive path adjacent said high voltage end and projecting through said aperture, said lead wire substantially sealing said aperture.

9. The high voltage resistor of claim 8, wherein said housing is provided with a tubular projection defining said aperture, and a sleeve is disposed over said projection and engages said insulated lead wire to completely seal said aperture.

10. The high voltage resistor of claim 8, wherein said housing is provided with a tubular projection defining said aperture, and said tubular projection is welded to the insulation of said insulated wire.

11. The high voltage resistor of claim 8, wherein second positioning means is provided for maintaining the resistive path at said low voltage end spaced from the wall of said housing and comprises a mounting member electrically connected to said resistance path.

12. The high voltage resistor of claim 2, wherein said termination means includes an insulated lead wire electrically connected to the resistive path adjacent said high voltage end, the point of electrical connection between the insulated lead wire and the resistive path being positioned between two of said projections.

13. The high voltage resistor of claim 1, wherein said termination means includes a tap comprising an insulated lead wire electrically connected to the resistive path intermediate the high voltage end and the low voltage end, said substrate providing a continuous heat transfer path from said high voltage end to said low voltage end.

14. The high voltage resistor of claim 13, wherein said insulated lead wire is disposed adjacent said resistive path and passes between the wall of the housing and said low voltage end.

15. The high voltage resistor of claim 2, wherein said termination means includes an insulated lead wire electrically connected to said resistive path adjacent said high voltage end, said projections spacing the point of electrical connection between the lead wire and the resistive path from the wall of the housing, said dielectric material surrounding the point of electrical connection.

16. The high voltage resistor of claim 15, wherein said housing has an indicator lug projecting therefrom indicating the position of said projections whereby said insulated lead wire is accurately positioned relative to said projections.

17. A high voltage resistor comprising a cylindrical housing of dielectric material, a high heat resistant dielectric cylindrical substrate disposed within said housing, a resistive path supported on the substrate, termination means electrically connected to the resistive path, said substrate having a high voltage end and a low voltage end, said housing having an aperture in one end and an opening in the other end, a plurality of projections extending from said housing adjacent said one end into engagement with said substrate adjacent said high voltage end whereby said resistive path at said

high voltage end is spaced from the wall of the housing, said termination means including an insulated lead wire electrically connected to said resistive path adjacent said high voltage end, said insulated lead wire passing through and substantially sealing said aperture, a mounting member bearing against said low voltage end and frictionally engaging the housing adjacent said other end maintaining the resistive path at said low voltage end spaced from the wall of the housing, and dielectric material positioned between said resistive path and the wall of said housing, said dielectric material forming a moisture impervious barrier around said resistive path.

18. The method of manufacturing a high voltage resistor comprising the steps of:

depositing a resistance material on a hollow dielectric cylindrical substrate thereby defining a resistive path,

applying termination means to said resistive path, securing a mounting bracket having an aperture therein to one end of said substrate with said aperture being in communication with the interior of said substrate,

centering said substrate relative to the walls of a cylindrical housing of dielectric material having an aperture in one end and an opening of sufficient size to receive said substrate in the other end,

positioning said substrate within said housing with said one end of said substrate adjacent said opening, said mounting bracket being in frictional engagement with said housing, said resistive path being spaced from the walls of said housing, sealing substantially the aperture in said housing, and injecting a dielectric material through the aperture in said mounting bracket whereby said material passes through said substrate and enters the space between the resistive path and the walls of said housing.

19. The method of claim 18, wherein the step of applying termination means to said resistive path comprises securing an insulated lead wire to the other end of said substrate in electrical connection with said resistive path.

20. The method of claim 19, wherein the step of centering the substrate relative to the walls of a cylindrical housing comprises nesting the other end of the substrate against a plurality of projections in the housing with said insulated lead wire disposed between two of said projections.

21. The method of claim 19, wherein the step of sealing substantially the aperture in said housing comprises placing said lead wire through the aperture in said housing.

22. The method of claim 21, wherein the housing is provided with a tubular projection defining said aperture in the one end of the housing, and including the additional steps of applying a heat shrinkable tubing over said lead wire and the projection, and shrinking said tubing into engagement with the tubing and the lead wire to seal the aperture.

23. The method of claim 21, wherein the housing is provided with a tubular projection defining said aperture in the one end of the housing, and including the additional step of welding said projection to the insulation of said insulated lead wire.