United States Patent

Rosema et al.

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[54] HIGH VOLTAGE RESISTOR

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[21] Appl. No.: **123,267**

Related U.S. Application Data

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[52] **U.S. Cl.** **338/256,** 338/51, 338/262, 338/268, 338/308, 338/315, 338/329, 174/DIG. 5

[51] **Int. Cl.** **H01c 1/02**

[58] **Field of Search**.....338/257, 256, 262, 263, 267, 338/268, 269, 308, 315, 329, 331, 332, 330, 51

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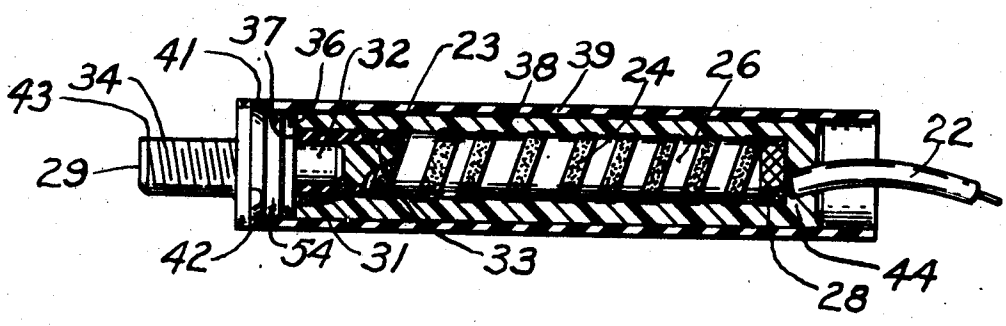
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[57] **ABSTRACT**

High voltage circuit arrangement includes a load connected to a power supply of at least 20,000 volts, and a single discrete high voltage electrical resistor connected to the power supply and load. The high voltage resistor comprises a spiral resistive path supported on a ceramic substrate which provides a uniform and continuous heat dissipation path between the ends of the resistor. A heat dissipating mounting member forms an electrical termination for the resistor, rapidly transfers heat away from the substrate, and includes a substrate alignment surface and seat in close proximity to a surface of the substrate. A threaded portion of the heat dissipating member is useful for mounting the resistor on a supporting surface and insulative means including an insulative jacket surrounds the substrate. High voltage corona inhibiting means include an insulative body that extends one-half inch beyond an end of the resistive path and embeds a lead wire connected to the resistive path. The resistive path is a cermet film type material having resistivity of 5 megohms per square, a voltage coefficient of less than 400 parts per million per volt per square, and a voltage withstanding ability of 3,000 volts per inch of resistive path. The resistive path itself comprises an intersticed mass of inert particles and a conductive phase forming an interstitial mass within the intersticed mass.

5 Claims, 7 Drawing Figures



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SHEET 1 OF 2

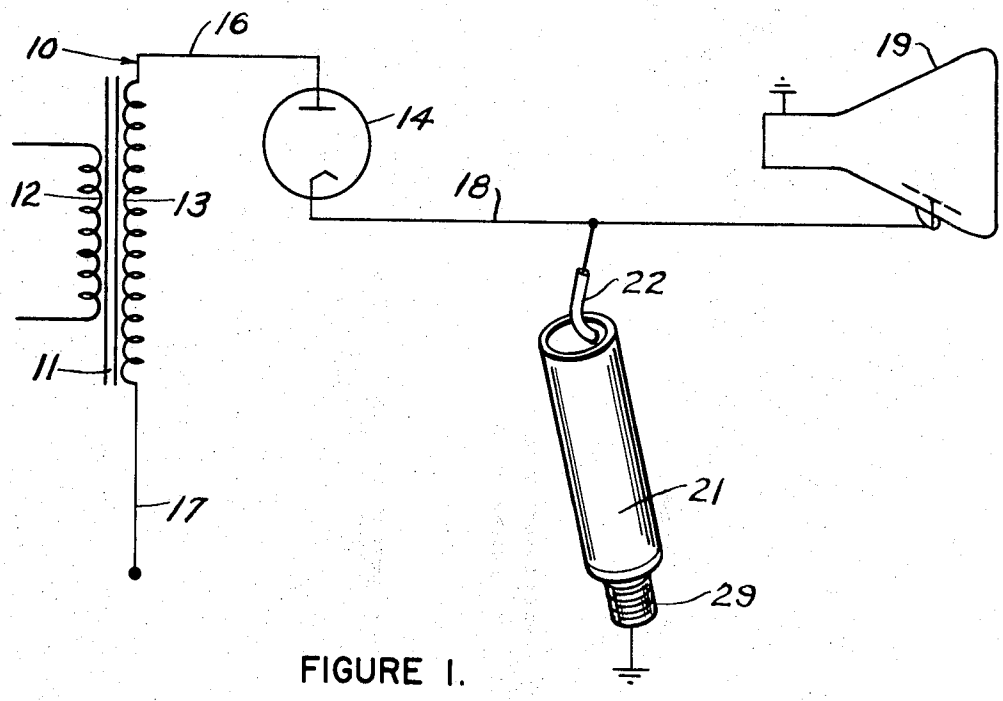


FIGURE 1.

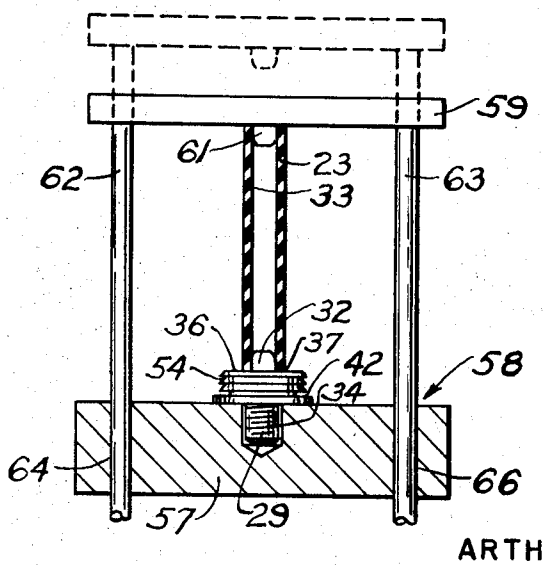


FIGURE 2.

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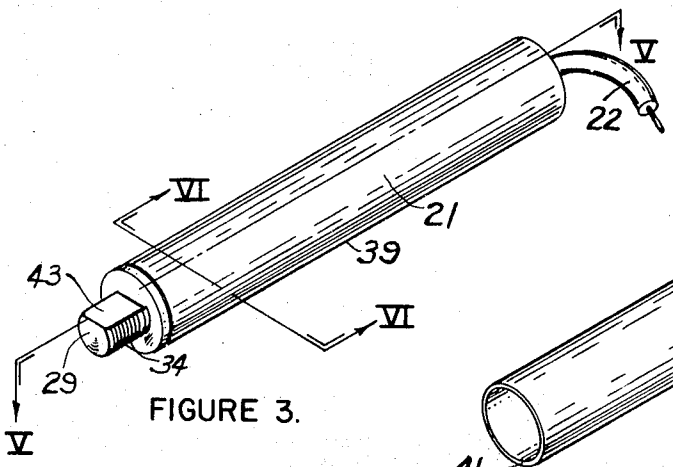
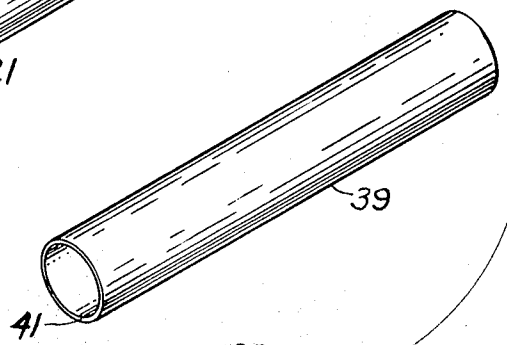


FIGURE 3.



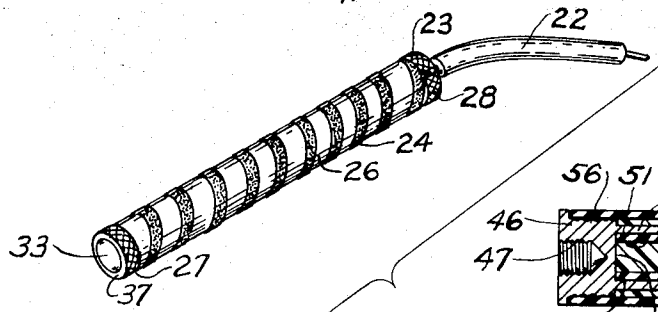
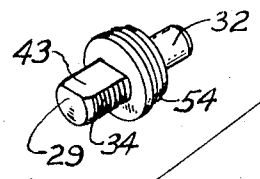


FIGURE 4.



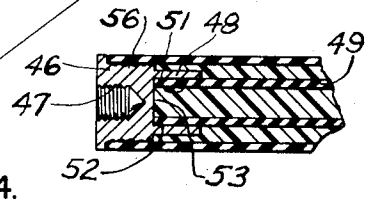


FIGURE 7.

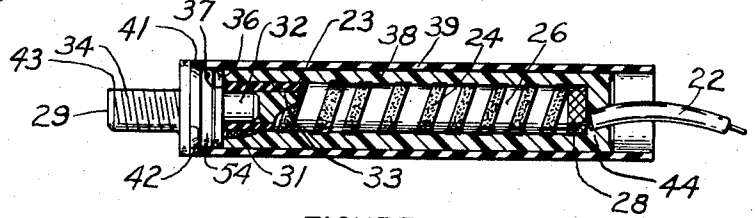


FIGURE 5.

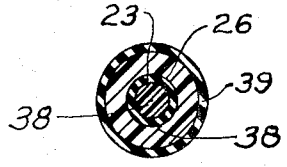


FIGURE 6.

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HIGH VOLTAGE RESISTOR

This is a division of application Ser. No. 809,655 filed Mar. 24, 1969 now U.S. Pat. No. 3,579,819.

The present invention relates to an improved high voltage electrical circuit arrangement and, more particularly, to such arrangements and high voltage resistors having improved characteristics for use therein.

As used herein, "electrical circuit arrangement" is meant to refer to the physical arrangement of tangible electrical and electronic circuit components as distinguished from a symbolic schematic representation of such components. Heretofore, high voltage circuit arrangements of the type used in oscilloscopes, X-ray equipment, television sets, voltmeters, and various types of industrial and military equipment have included a plurality of series connected resistors to which a total potential of 20,000 or more volts have been applied. Schematic diagrams of these circuit arrangements have sometimes symbolically represented such resistors as a discrete single resistor, but in actual physical embodiments of these circuits, such resistors have comprised a plurality of series connected discrete resistors. This approach has usually been taken so that the voltage drop across each of the series connected resistors would be about 600 volts, the commonly accepted working voltage of fixed volumetric resistors.

In a typical prior art circuit arrangement, a resistor module comprising 34 series connected fixed-volumetric resistors has been connected across a power supply of 20,000 or more volts in order to avoid the expense of mechanically mounting and electrically connecting each one of the individual resistors into the circuit arrangement. Such modules are relatively expensive and not altogether satisfactory because a relatively large amount of heat is generated within such modules and is difficult to dissipate during operation. In addition, the precision, stability, and quality of such modules are dependent on a relatively large number of variables, i.e., the characteristics of each one of the series connected resistors.

In some high voltage circuit applications, such as those found in solid state color television receivers, high voltage, high ohmic value impedances must be used in order to prevent damage to the cathode-ray tube when the receiver is disconnected from a power source. An example of one such receiver is Color TV Chassis CTC40A/B manufactured by Radio Corporation of America. An electrical schematic diagram of this receiver appears in a PHOTOFACT Folder (Set 984, Folder 15-S) published by Howard W. Sams & Co., Inc. of Indianapolis, Indiana. When the power switch is turned off in this type of receiver, the horizontal drive for the color cathode-ray rube is substantially instantaneously stopped. Because of this, a high potential of about 25,000 volts remaining on the cathode-ray tube may cause "spot-burning" on the face of the tube if a high voltage, high ohmic value resistor were not used to provide a discharge path for the decaying voltage in the power supply and on the tube. In view of these problems, it would be desirable to provide a single discrete high ohmic value resistor for use in high voltage circuit applications so that the precision, stability, and quality thereof would be determined by the characteristics of a single continuous resistive path. More particularly, it would be desirable for such high voltage resistor to be a cermet film type resistor supported on a continuous heat dissipation path extending between the ends thereof.

Efforts have been made heretofore to develop film type resistors generically referred to as "metal oxide glaze" resistors for use in high voltage applications, but such efforts have not been successful in developing single discrete resistors that would withstand a voltage gradient, per inch of resistive path, of from 2,000 to 3,000 volts and higher. In other words, there has been little or no success in developing a competitive resistor of reasonably small physical size that may be reliably used in a high voltage circuit arrangement with a potential thereacross of 20,000 or more volts. Therefore, it would be desirable to devise a new and improved high voltage electrical circuit arrangement wherein a cermet film type single discrete resistor includes a single continuous heat dissipating member extending between the ends thereof, is provided with means for dissipating heat away from such member, and has a potential of 20,000 or more volts applied thereacross. In order to provide stable operation, such resistor should desirably have a voltage coefficient of resistance of 400 parts or less per million per square of film at voltage gradients of 2,000 or more volts per inch of resistive path.

In addition to withstanding high voltage gradients and dissipating relatively large amounts of heat, resistors used in high voltage circuit arrangements must be provided with means for either preventing high voltage corona or withstanding the corrosive effects of ozone and nitrous acid which are the normally encountered by-products of high voltage corona in the earth's atmosphere. Thus, it would also be desirable to provide corona inhibiting means for discrete resistors used in high voltage circuit arrangements.

Accordingly, it is an object of the present invention to provide a new and improved high voltage electrical circuit arrangement. Another object of the present invention is to provide a new and improved resistor for use in high voltage circuit arrangements. A further object of the present invention is to provide a new and improved electrical resistor that will withstand voltage gradients of 2,000 of more volts per inch of resistive path. An additional object of the present invention is to provide an improved resistor that is provided with means for rapidly dissipating heat from the resistor. A more specific 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 for preventing the occurrence of high voltage corona at the high potential end thereof. Still another object of the present invention is to provide an improved resistor wherein a member useful for transferring heat away from the resistor may be used as an electrical termination for the resistor. A still further object of the present invention is to provide an improved high voltage resistor having a substrate and means for transferring heat from such substrate that may also be used to support the resistor. Yet a further object of the present invention is to provide means for transferring heat away from a resistor that includes means for maintaining proper alignment of the resistor and that may include a threaded means for mounting the resistor to a supporting surface. Still an additional object of the present invention is to provide a high voltage resistor for use in high voltage circuit arrangements wherein a

uniform and continuous heat dissipation path is provided between the ends of the resistor. 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 circuit arrangement including a high voltage power supply providing a potential of at least 20,000 volts; a load, such as a cathode-ray tube, connected to the high voltage power supply; means connected to the high voltage power supply and load in the form of a single discrete high voltage electrical resistor comprising a spiral 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 and, in order to promote the rapid transfer of heat away from the substrate, a thermally conductive heat dissipating member is arranged with a substrate alignment surface in close proximity to a surface of the substrate so as to facilitate the transfer of heat therebetween and a seat adjacent to the substrate alignment surface which bears against the substrate. The heat dissipating member also includes a threaded portion that is used to mount the resistor to a supporting surface for the high voltage electrical circuit arrangement and a shoulder that is cooperable with an insulative jacket surrounding the substrate. Insulative material fills the space between the substrate and the insulative jacket and surrounds a termination in the form of a lead wire soldered to one end of the resistive path. By surrounding the lead wire in this manner, means are provided for preventing high voltage corona when the lead wire is connected to a high potential, i.e., 20,000 or more volts.

The resistive path is formed of a cermet film resistive material having a resistivity of 5 megohms per square, a voltage coefficient of resistance of less than 400 parts per million per volt per square and a voltage withstanding ability of 3,000 volts per inch of resistive path. The cermet resistive path itself is comprised of an intersticed mass of uniformly distributed inert nonconductive particles and a conductive phase forming an interstitial mass within the intersticed mass. Preferably, the heat dissipating mounting member is electrically connected to one end of the resistive path and may be used to complete an electrical connection, such as a ground connection, to one end of the resistive path.

For a better understanding of the present invention, reference may be had to the accompanying drawings wherein the same reference numerals have been applied to like parts and wherein: FIG. 1 is a representation, with parts shown schematically, of a high voltage electrical circuit arrangement including a high voltage resistor and embodying the present invention; FIG. 2 is a diagrammatic representation of parts of the high voltage resistor shown in FIG. 1 and a fixture that may be used in the practice of the inventive method; FIG. 3 is an enlarged isometric view of the high voltage resistor shown in FIG. 1; FIG. 4 is an exploded isometric view of the high voltage resistor shown in FIG. 3 with parts omitted; FIG. 5 is a sectional view taken on the line V—V of FIG. 3 with parts shown in full; FIG. 6 is a sectional view taken on the line VI—VI of FIG. 3; and FIG. 7 is a view similar to FIG. 5, with parts broken away, of another embodiment of the invention.

Referring now to the drawings, and more particularly to FIG. 1, the electrical circuit arrangement 10 includes a high voltage power supply comprising a transformer 11 having a primary winding 12 connected to a not shown suitable alternating current voltage source and a secondary winding 13, and a conventional solid state or tube type half-wave rectifying means 14. An alternating current high voltage, i.e., a voltage of approximately 25,000 volts, appears across the lead 16, connected to one side of the secondary winding 13 of the transformer, and the low potential lead 17 of the transformer. The rectified voltage produced by the power supply is supplied through a lead 18 to the high voltage electrode of a load illustrated as an externally grounded color cathode-ray tube 19 of the type used in a color television receiver. Additional details of the power supply 10, the cathode-ray tube 19, the interconnections therebetween, and other circuitry used in the operation of the cathode-ray tube 19 are not here shown or described since they are not necessary to an understanding of the invention and are completely described in the above referred to publication of Howard W. Sams & Co., Inc., the contents of which are specifically incorporated herein by reference. Still having reference to FIG. 1, a high voltage resistor 21 is connected by means of an insulated lead wire 22 to the high voltage power supply and provides a bleeder path to ground potential for the high voltage appearing across the load. The resistor 21 prevents the high voltage on the cathode-ray tube 19 from being dissipated across the face of the tube after the horizontal drive circuitry for the tube has been de-energized and thus prevents spot burning within the tube.

Now having reference to FIGS. 3 through 6, the resistor 21 comprises a hollow cylindrical substrate 23 formed of a ceramic type material such as steatite or alumina; resistance means comprising a spiral resistive path 24 deposited by a printing or other suitable process onto an outer surface 26 of the substrate; a plurality of termination means, two of which define the ends of the resistive path; and an insulation system. The resistive path 24 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 inert particles. The uniformly spaced inert particles are submicron in size and typically have an average size of 0.1 to 10 microns with the conductive phase filling the spaces between adjacent ones of the inert particles. A binder bonds together the inert particles and conductive phase. The resistive path 24 has a resistivity of 5 megohms per square and a voltage coefficient of 400 parts per million per volt per inch of resistive path. Because of these characteristics, the resistor 10 will readily withstand applications of 30,000 volts across the ends thereof when the substrate 23 is only 3 inches long and 0.375 inches in diameter and the developed resistive path 24 has an effective length of about 10 inches. Preferably, the resistance composition used in making the resistive path 24 is similar to the resistance composition disclosed in the copending

application, U.S. 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 disclosed in said copending application may also be used in the practice of the present invention. Although the pitch of the spiral path **24** is illustrated as being uniform throughout the length thereof, it will also be understood that the pitch between adjacent turns of the spiral may be varied along different portions of the substrate **23**.

The illustrated termination means comprise two solderable conductive pads **27** and **28** deposited on the ends of the resistive path, a heat dissipating member **29** soldered to pad **27**, and the lead wire **22** soldered to pad **28**. The heat dissipating member **29** is connected to the solderable pad **27** by means of a deposit of solder **31** and, since it is necessary to dissipate relatively large amounts of heat away from the substrate **23** during use of the resistor **21**, the mounting member is provided with a surface **32** in close proximity to the internal surface **33** of the substrate and is preferably formed of a material such as brass having good thermal conductivity so that heat generated during use of the resistor will be conducted through the heat dissipating mounting member **29** to a not shown chassis of the electrical equipment incorporating the electrical circuit arrangement **10**. Although a single resistive path has been illustrated and the substrate **23** provides a uniform continuous heat dissipation path between the ends of the resistive path **24**, it will be appreciated that when two or more unconnected resistive paths are supported on the substrate **23**, the substrate will transfer heat from all of such resistive paths and the mounting member **29** will in turn transfer such heat away from the substrate **23**.

The heat dissipating member **29** preferably includes a threaded portion illustrated as a threaded stud **34** and by means of such threaded member is mountable on the previously mentioned chassis. When used in this manner, the heat dissipating member **29** supports the substrate **23** and also provides a ground path for the resistive path **24**. In order to facilitate the transfer of heat from the substrate **23** to the heat dissipating member **29**, and in order to provide a rigid structural connection between such member and the substrate, the member **29** includes a seat **36** for the end **37** of the substrate as well as the substrate alignment surface **32**. In addition to providing the just described advantages, the seat **36** and alignment surface **32** are extremely useful during the practice of the inventive method as will be more fully described hereinafter. It will be understood that the alignment surface **32** can be either an external surface as illustrated in FIGS. **4** and **5** or an internal surface as will be presently described in connection with the description of FIG. **7**.

The insulation system surrounding the resistive path **24** may be any suitable material and in the preferred embodiment is comprised of a polyester based polyurethane material **38** and a jacket **39** having an end **41** bearing against a shoulder **42** on the heat dissipating member **29**. Although the jacket **39** could be metallic so as to further enhance the heat transfer characteristics of the resistor **21**, a plastic insulative material is preferably used in order to maximize the amount of electrical insulation around the high voltage end of the resistive path. In order to prevent objectionable amounts of torque from being applied to the jacket **39** when a not shown nut is threaded onto the stud **34**, the stud is provided with a flat **43** that will cooperate with a keyway in a chassis and prevent turning of the stud relative to the chassis. The voltage is applied to the high potential end of the resistor **21** during operation are sufficiently high to cause high voltage corona to occur around the resistor in the absence of corona prevention means. In the presence of corona, as will be understood, atmospheric nitrogen will combine with water vapor to form nitrous acid and atmospheric oxygen will form ozone. Both of these materials are extremely chemically active with organic materials, and accordingly means **44** for preventing high voltage corona around the resistor **21** is provided. Preferably, such means is in the illustrated form of insulation surrounding the end of the resistive path and the high potential lead wire **22**. It is preferred that the insulative material **38** extend one-half inch beyond the end of the resistive path and embed the lead wire **22** in order to prevent high voltage corona.

FIG. **7** illustrates an embodiment of the invention wherein a heat dissipating mounting member **46** is provided with a threaded portion in the form of a tapped hole **47**, and a sleeve **48** is disposed in close proximity to a surface of a substrate **49** so as to facilitate the transfer of heat therebetween. The internal surface **51** of the sleeve **48** comprises a substrate alignment surface cooperating with the substrate. When the substrate **49** and mounting member **46** are assembled together, the end **52** of the substrate bears against a seat **53** on the mounting member. The end portion of the substrate **49** and the sleeve **48** are tinned prior to assembly and then, after the substrate has been inserted into the sleeve, heat is applied to the sleeve so that the sleeve and substrate will be sweated together. In the embodiments of both FIG. **5** and FIG. **7** the heat dissipating mounting members are provided with barbed or stepped tapered surfaces **54** and **56**, respectively, in order to facilitate assembly of the jacket and mounting member. Since the surfaces **54**, **56** are tapered, the mounting members may be easily wedged into the jackets and thereafter the barbs or steps on such surfaces resist separation of the mounting members and jackets.

Now having reference to FIG. **2**, the inventive method comprises the steps of nestedly positioning the heat dissipating mounting member **29** on a nest **57** supported at a work station **58** with the substrate **23** engaging the seat **36** and the substrate alignment surface **32** of the heat dissipating mounting member. After the substrate and mounting member have been approximately positioned relative to each other, a substrate centering means comprising a movable platen **59** carrying a pin **61** overlying the nest is moved toward the nest by a pair of supporting arms **62**, **63** slidably supported in sleeve bearings **64**, **66**. Then, while the substrate and mounting member are compressively held between the nest and substrate centering means, the mounting member and substrate are secured together by applying molten solder to the mounting member and solderable pad **27** on the substrate. After the molten solder has solidified, the platen **59** is raised and the substrate and mounting member are removed from the work station.

As will be understood, the thermal characteristics and large mass of the heat dissipating mounting member **29** make it difficult to perform the soldering operation. Therefore, it is preferable to control the rate of heat transfer relative to the heat dissipating member. This may be accomplished by forming the nest **57** of a thermally insulating material but is preferably accomplished by placing heating elements in the work station which heat the work station and preheat the heat dissipating mounting member **29** prior to the application of molten solder thereto. When the work station is heated, it is necessary that the temperature of the station and nest be maintained below the solidus temperature of the solder so that molten solder can quickly solidify after being applied to the substrate and mounting member. After the heat dissipating mounting member has been positioned on the preheated nest, the temperature of the heat dissipating member is raised to a point below the solidus point of the solder. Then, as the heat dissipating mounting member is heated with a soldering iron or other suitable tool, the temperature of the heat dissipating mounting member is quickly raised to a temperature such that solder applied thereto will become molten and wet the heat dissipating mounting member and the solderable pad **27** on the substrate **23**. While the molten solder is being applied, the transfer of heat away from the heat dissipating mounting member is controlled since the temperature gradient between the heat dissipating mounting member and the nest is relatively low. However, when the soldering tool is removed from the heat dissipating mounting member, the temperature of the heat dissipating member will drop to about the temperature of the nest and the molten solder will solidify. Thereafter, the movable platen **59** is raised to the dotted position shown in FIG. **2** and the assembled substrate and heat dissipating mounting member are removed from the nest. It will be understood that this method may also be used to secure together the heat dissipating mounting member **46** and substrate **49** illustrated in FIG. **7**, although it would then be desirable to modify the nest **57** so as to accommodate the member **46**.

While there has been illustrated and described what is at present considered to be a preferred embodiment of the present invention and a method of making the same, it will be appreciated that numerous changes and modifications are likely to occur to those skilled in the art, that a plurality of independent resistive paths could be supported on a single substrate, and that any one of such resistive paths could be provided with a plurality of voltage tap terminals. Therefore, 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 resistor for use in a high voltage circuit wherein a potential of at least 20,000 volts is applied to said resistor, said resistor comprising a high heat resistant electrically nonconductive cylindrical substrate, a spiral cermet film resistive path supported on the substrate, terminations electrically connected to the resistive path, and a heat dissipating mounting member having a substrate alignment surface in close proximity to a surface of the substrate and a seat adjacent to the substrate alignment surface bearing against the substrate, said substrate providing a single continuous heat transfer path between the ends of the resistor, said mounting member providing a thermally conductive path for dissipating heat from the substrate.

2. The resistor of claim **1** wherein the heat dissipating mounting member is electrically conductive and a deposit of solder electrically connects the heat dissipating mounting member to the resistive path and provides a path for the transfer of heat from the substrate to the mounting member.

3. The resistor of claim **1** wherein the heat dissipating mounting member includes a threaded portion thereby to facilitate mounting of the resistor on a supporting surface.

4. The resistor of claim **2** wherein a jacket is secured to said mounting member, said jacket encircles said substrate and is spaced therefrom, and an insulative material is disposed between said jacket and said substrate.

5. The resistor of claim **4** wherein said heat dissipating mounting member supports the substrate and the jacket in spaced relationship.

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