United States Patent

Harnden, Jr.

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[54] **ELECTRICAL RESISTANCE HEATER**

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[73] Assignee: **General Electric Company**

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[51] **Int. Cl.** **H05b 3/08**

[58] **Field of Search**......219/510, 523, 544, 541, 553, 219/381; 338/229, 240, 241, 274, 326

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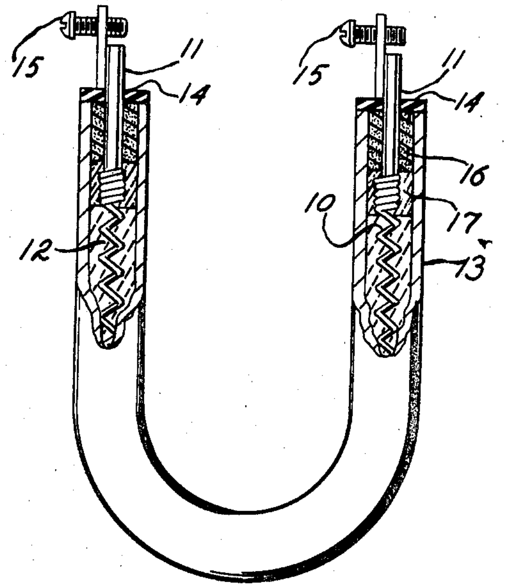
[57] **ABSTRACT**

The material in the space between the lead-in sections and outer metallic sheath of an electrical resistance heater is a densely packed sintered metal oxide material for transient voltage suppression to prevent incipient breakdown and subsequent arcing between the heater wire and sheath. The sintered metal oxide material in less densely packed form may also be included alone or with conventional heat resistant, electrically insulating material along the entire length of the coiled heater wire to provide further transient voltage suppression. The sintered metal oxide material has varistor characteristics.

22 Claims, 4 Drawing Figures



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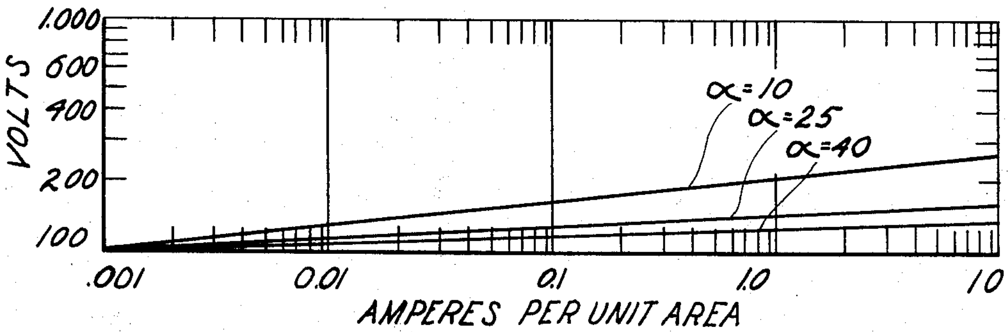


Fig. 1

Fig. 3

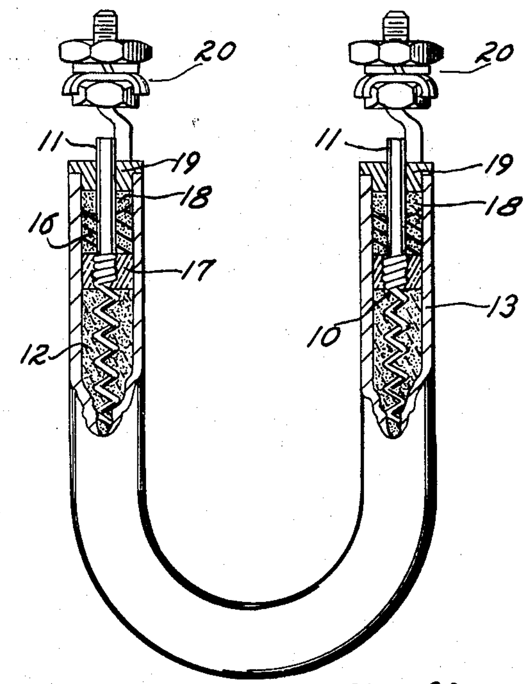
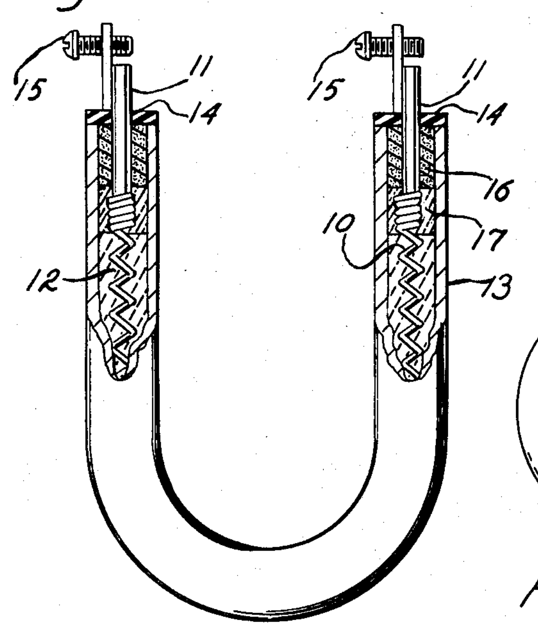


Fig. 2



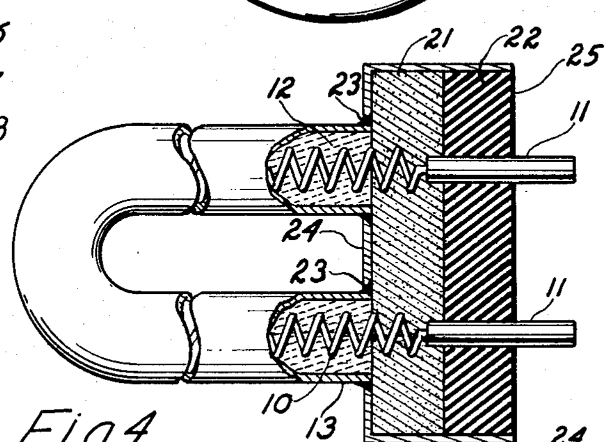


Fig. 4

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ELECTRICAL RESISTANCE HEATER

My invention relates to a resistance heater utilizing metal oxide varistor material for transient voltage suppression, and in particular, to utilizing the metal oxide varistor material between the lead-in sections of the heater and outer metallic sheath for preventing arcing between the heater wire and sheath when the heater is subjected to other than normal design voltage.

Various types of electrical resistance heaters such as the well known CALROD heater, a trademark of the General Electric Company, are utilized in household appliances such as electric flat irons, percolators, soldering irons and the like, and may be of the liquid immersible or nonimmersible type. The conventional sheathed electrical resistance heater comprises an inner electrical conductor having lead-in sections at the terminal ends of the heater and a helically coiled heater wire interconnected intermediate such lead-in sections, and being surrounded by an outer metallic sheath which is generally adapted to be grounded. A heat resistant, electrically insulating material (i.e. a ceramic insulating material) such as magnesia (magnesium oxide) is confined and compacted in the space between the inner conductor and outer sheath such that the heating coil is embedded therein. The heater is conventionally fabricated by connecting the heating coil, which is generally a nickel-chromium alloy such as nichrome, to the lead-in sections and placing such arrangement within an oversized metallic tubing which will become the outer sheath. The ceramic magnesia material in powder form is then poured into the tubing which is compressed and drawn in order to moderately confine and compact the magnesia in the space between the conductor and outer sheath to a moderate density and thereby form an integral but bendable structure, or may be more firmly compacted to form a rigid structure. The compacting step, however, often causes incipient damage to the heating coil thereby resulting in a weakened region (lower dielectric strength) at a point along the wire and, or a region wherein the wire is closer to the sheath than along other sections thereof. The generally high operating currents in electrical resistance heaters cause continual stressing of the magnesia material, and the application of a transient voltage of sufficient voltage magnitude and energy content can cause a break-down and arcing at the weak point or most closely spaced point between the heating coil wire and outer sheath and result in failure of the heater at such point. The electrical resistance heater is also exposed to moisture in many applications, and moisture penetration of the magnesium oxide insulation lowers such insulation level and thereby again may cause early failure of the heater in the presence of a voltage transient at the weak point in the system.

Therefore, one of the principal objects of my invention is to provide an improved electrical resistance heater which provides improved life through immunity to transient voltages or stresses other than rated conditions.

There are a few known materials which exhibit nonlinear resistance characteristics and which require resort to the following equation to relate quantitatively current and voltage:

$$I=(V/C)^{\alpha}$$

where V is the voltage between two points separated by a body of the material under consideration, I is the current flowing between the two points, C is a constant and α is an exponent greater than 1. Both C and α are functions of the geometry of the body formed from the material and the composition thereof, and C is primarily a function of the material grain size whereas α is primarily a function of the grain boundary. Materials such as silicon carbide exhibit nonlinear or exponential resistance characteristics and have been utilized in commercial silicon carbide varistors, however, such nonmetallic varistors typically exhibit a alpha (α) exponent of no more than 6.

A new family of varistor materials having alphas in excess of 10 within the current density range of 10^{-3} to 10^{2} amperes per square centimeter has recently been produced from metal oxides although very few applications have been disclosed for this new metal oxide varistor material. Although the alpha of the metal oxide varistor, also known as MOV, a trademark of the General Electric Co., materials in which range the alpha remains substantially constant are identified by the current density range of 10^{-3} to 10^{2} amperes per square centimeter, it is appreciated that the alphas remain high also at higher and lower currents although some deviation from maximum alpha values may occur. The MOV material is a polycrystalline ceramic material formed of a particular metal oxide with small quantities of one or more other metal oxides being added. As one example, the predominant metal oxide is zinc oxide with small quantities of bismuth oxide being added. Other additives may be aluminum oxide, iron oxide, magnesium oxide, and calcium oxide as other examples. The predominant metal oxide is sintered with the additive oxide(s) to form a sintered ceramic metal oxide body. Since the MOV is fabricated as a ceramic powder, the MOV material can be pressed into a variety of shapes of various sizes. Being polycrystalline, the characteristics of the MOV are determined by the grain (crystal) size, grain composition, grain boundary composition, and grain boundary thickness, all of which can be controlled in the ceramic fabrication process.

The nonlinear resistance relationship of the MOV is such that the resistance is very high (up to at least 10,000 megohms) at very low current levels in the microampere range and progresses in a nonlinear manner to an extremely low value (tenths of an ohm) at high current levels. The resistance is also more nonlinear with increasing values of alpha. These nonlinear resistance characteristics result in voltage versus current characteristics wherein the voltage is effectively limited, the voltage limiting or clamping action being more enhanced at the higher values of the alpha exponent as shown in FIG. 1. Thus, the voltage versus current characteristics of the MOV is similar to that of the Zener diode with the added characteristic of being symmetrically bidirectional and over more decades of current. The conduction mechanism of the MOV is not yet clearly understood but is completely unlike the avalanche mechanism associated with Zener diodes, a possible theoretical explanation of its operation being that of space charge limited current. The "breakdown" voltage of an MOV device is determined by the particular composition of the MOV material and the thickness to which it is pressed in the fabrication process. The MOV involves conduction changes at grain boundaries resulting in the advantage of bulk phenomenon allowing great flexibility in the design for specific applications simply by changing the dimensions of the body of MOV material. That is, the current conduction in the absence of closely spaced electrodes along one surface of the MOV body is through the bulk thereof. The bulk property of the MOV also permits a much higher energy handling capability as compared to junction devices. Thus, since an MOV device can be built up to any desired thickness, it is operable at much higher voltages than the Zener diode junction device and can be used in a range from a few volts to several kilovolts. The voltage changes across a silicon carbide varistor device are much greater than across an MOV device for a given current change and thus the silicon carbide varistor has a much smaller voltage operating range thereby limiting its applications. The thermal conductivity of MOV material is fairly high (approximately one-half that of alumina) whereby it has a much higher power handling capability than silicon carbide, and it exhibits a negligible switching time in that its response time is in the subnanosecond domain. Finally, the MOV material and devices made thereof can be accurately machined, soldered, used as a hermetic enclosure, and operated at very low voltages, capabilities not possible for the larger grained silicon carbide.

Therefore, another principal object of my invention is to provide a compacted body of metal oxide varistor material in the heater to obtain uniformly long life through superior transient voltage suppression.

A further object of my invention is to provide the compacted body of metal oxide varistor material along the lead-in sections of the heater.

A still further object of my invention is to include generally less densely compacted metal oxide varistor material alone or with other insulating material along the entire length of the heating coil in the heater.

In accordance with my invention, I provide an improved electrical resistance heater wherein a body of metal oxide varistor material having an alpha exponent in excess of 10 is densely compacted in the space between the lead-in sections connected to the heating wire and an outer metallic sheath. The nonlinear resistance characteristic of the metal oxide varistor material limits the voltage between the lead-ins and sheath when a high transient voltage is applied to the heater terminals to thereby provide transient voltage suppression and resultant protection of the heating wire. During the period of voltage limiting, the MOV material provides a low resistance path from lead-in to sheath to thereby dissipate the transient and prevent incipient breakdown and subsequent arcing between heating wire and sheath. The metal oxide varistor material exhibits a high resistance during normal voltage operation of the heater and thus at such time functions in a dual role as an electrical insulator. The metal oxide varistor material can also be included alone or with conventional heat resistant, electrically insulating material along the length of the heating wire to provide further protection against transient voltages.

The features of my invention which I desire to protect herein are pointed out with particularity in the appended claims.

The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawing wherein like parts in each of the several figures are identified by the same reference character and wherein:

FIG. 1 is a graphical representation of the nonlinear resistance and resultant voltage limiting characteristics of the MOV material for different values of the exponent alpha plotted in terms of volts versus amperes on a log-log scale;

FIG. 2 is an elevation view, partly in section, of an electrical resistance heater in accordance with my invention wherein a body of densely packed MOV material is located along the lead-in sections of the device;

FIG. 3 is an elevation view, partly in section, of the heater illustrated in FIG. 2 and further including less densely packed MOV material along the length of the coiled heater wire; and

FIG. 4 is an elevation view, partly in section, of a second embodiment of the heater illustrated in FIG. 2 wherein the lead-in conductors are in a common terminating body.

The volts versus amperes characteristics plotted in FIG. 1 of the drawings illustrate the nonlinear or exponential resistance characteristics exhibited by MOV material, and in particular, indicate the increasing nonlinearity and enhanced voltage limiting obtained with increased values of the exponent alpha (α). The VOLTS abscissa is in terms of the voltage between the heater conductor and outer grounded sheath and the CURRENT ordinate is in terms of current or current density. Although the use of linear scales on the graph would show the decreasing slopes (decreasing resistance values) with increasing currents, such curves can be readily manipulated by the choice of scales, and for this reason, log-log scales are chosen to obtain a family of lines each of which remains substantially straight within the indicated current range. It can be seen from the FIG. 1 plots that the resistance exhibited by the MOV material is quite high at low current levels and becomes increasingly smaller in a nonlinear exponential manner with increasing current levels, and such nonlinearity is greater for greater values of the exponent alpha. Extension of the plots to lower and higher current levels would obviously indicate correspondingly much higher and lower resistances, respectively, and operation of the subject electrical resistance heater may very likely extend into such current levels (especially the higher current level) depending upon the particular application and size of the heater and its electrical source.

Referring now in particular to FIG. 2, there is shown a first embodiment of my invention wherein the electrical resistance heater is shown as including a heating wire 10 which may be a helical coil of nichrome wire as one example, and lead-in electrical conductor sections 11 which are connected to the ends of the heater wire 10 and which form the terminals of the heater. Lead-in conductors 11 are generally solid and made of a high temperature steel. The outer ends (i.e. the terminals) of lead.in conductors **11** may be connected to suitable threaded stud-type terminals, bushings, or other terminating elements **15** as required by the particular heater application and which is well know. The particular terminating element **15** illustrated in FIG. **2** is a screw-type end projection-welded terminal commonly used in residential kitchen electric ranges. The heater wire **10** is embedded in a conventional heat resistant, electrically-insulating material such as powdered fused magnesium oxide **12**, such ceramic insulating material being confined and moderately compacted around the heater wire **10** by an outer metallic sheath **13** which is at a different potential than the heater wire and is generally adapted to be grounded. Sheath **13** may be made of a stainless steel and it should be evident that lead-in conductors **11** and sheath **13** are fabricated of materials appropriate to the temperature and atmosphere in which the heater will function, realizing that the nichrome temperature may be in the order of **1,400°F** and the sheath temperature in the order of **800°F** in some applications. Suitable electrical insulation **14** such as mica washers, glass seals or the like are provided for enclosing the open ends of sheath **13**. Elements **10–15** are the conventional parts of an electrical resistance heater which may be somewhat flexible or rigid as a function of the degree of compaction of material **12**.

In accordance with my invention, I provide a dense body **16** of metal oxide varistor material at each end region of sheath **13** in place of the heat-resistant, electrical insulating material **12** which is disposed only along the heater wire **10** portion of the heater. Thus, the metal oxide varistor (MOV) material **16** is located in the unheated portions of the heater and is limited to the space between sheath **13** and lead-in conductors **11** in the FIG. **2** embodiment. The MOV bodies provide a significant moisture barrier, and if sufficiently compacted, form hermetic seals due to their high density.

My heater may be fabricated in any of a number of ways, a convenient method being as follows: The helical heating coil conductor **10** is concentrically positioned within an oversized electrically conductive metallic tubing which will form the outer sheath **13**. The ceramic insulating material **12** in powder form is then poured into the space between conductor **10** and the tubing to occupy all of the space between heating coil **10** and the tubing except along the end portions of the coil. The tubing is then compressed and drawn (as by swaging or roll-reducing) to approximately one-third of its original outside diameter to thereby confine and moderately compact the ceramic insulating material **12**. As a separate step, the metal oxide varistor material is sufficiently compacted around the central portions of lead-in conductors **11**, and sintered, to form dense hollow cylindrical bodies **16** of the metal oxide varistor material. The uncoiled ends of the heating coil **10** are then spot-welded or otherwise united to the inner ends of lead-in conductors **11**. A quantity of a glass frit (particles) **17** is then slightly compacted in the two spaces surrounded by sheath **13** in the region of the heater wire **10**-lead-in conductor **11** junctures. Each lead-in conductor and MOV body assembly (**11, 16**) is then slid into a respective end region of sheath **13** with a rotary motion to coil the ends of heating coil **10** around the inner ends of the lead-in conductors, and until such assembly contacts the glass frit material. The assemblies (**11, 16**) are then pressed in slightly to further compact the glass frit material. The electrically insulating mica (or other material) washers **14** (or other type electrically insulating elements) are then fastened to the end surfaces of sheath **13** for enclosing it. Finally, the suitable terminal elements **15** are welded or otherwise attached to the outer ends of lead-in conductors **11**. Since the glass frit material **17** is a heat resistant, electrically insulating material, it should be obvious that MOV material can be substituted therefor in powder form and subsequently sintered.

The MOV material **16** by being located between the lead-in sections **11** and outer sheath **13** of the heater is thereby positioned between the heating coil **10** and source of power which is supplied to the heater through the outer ends of the lead-in conductors **11** (via terminal elements **15**). Thus, in the event of a transient voltage of sufficient magnitude and energy content being impressed on the power line as can happen, for example, in the home from operation of mercury wall switches, thermostat devices, range ovens, oil burners, and other ignition devices, the extremely nonlinear resistance characteristics of the MOV material **16** suppresses such transients and thereby protects the heating coil **10** from such transients. The above-described transients can have voltage peaks up to 3,000 volts and are not to be confused with lightning-induced surges as to their occurrence and incidence, although my invention also provides lightning surge suppression.

The thickness and density of the hollow cylinders **16** of MOV material is selected in accordance with the normal operating voltage of the heater whereas the density determines the moisture permeability of the MOV material. Thus, the thickness is such that at normal operating voltage the "leakage" current to the grounded sheath **13** will not exceed a predetermined value such as 0.1 milliampere. At such low leakage current level the MOV bodies **16** exhibit a very high resistance in the order of about one megohm and thereby function as electrical insulators. However, as can be seen from the FIG. **1** plots, a sudden increase in the voltage level in the power supply lines as is produced by a voltage transient, causes a dramatic decrease in the resistance of the MOV material. This sudden decrease in resistance results in limiting the voltage between the lead-in sections **11** and outer sheath **13** such that a high transient voltage in the order of say 1,000 volts may be limited to a range between 10 and 100 volts above the quiescent operating voltage depending on the value of the alpha exponent. The subnanosecond response time of the MOV material prevents any significant voltage build-up of the transient (i.e. rate effect) and in combination with the voltage limiting capability and decrease in resistance, the MOV material provides a low resistance path from lead-in to sheath to shunt the transient to ground and thereby dissipate it. The resultant transient voltage suppression and virtual elimination thereof prevents incipient breakdown and subsequent arcing between heating element **10** and sheath **13**.

The FIG. **3** embodiment is similar to that illustrated in FIG. **2** with the exception that the heat resistant, electrically insulating material **12** moderately compacted between outer sheath 13 and heating coil 10 additionally includes at least some MOV material such that the composition of material 12 may be a mixture of magnesium oxide, for example, and the MOV material. The percentage by volume of the MOV material may be in the range from 1 to 100 percent, that is, the material 12 may be all MOV material which is compacted (and sintered) to the same or a lesser degree than the end MOV material bodies 16 located along the lead-in sections 11 of the heater. In the FIG. 3 embodiment, the MOV material in the intermediate space 12 provides both further heating coil turn-to-sheath arc protection from voltage surges as well as serving as an improved heat transfer medium for conducting to the sheath 13 the I^2R heat generated in the normal operating mode of the heater. The FIG. 3 embodiment also illustrates a structure having hermetically sealed terminals which could also be applied to the FIG. 2 embodiment. In particular, a plastic resin 18 of the epoxy or vinyl type is used to provide a moisture seal at the outer ends of the bodies of MOV material 16 (a glass frit would provide a hermetic seal), and ceramic bushings 19 enclose the ends of the sheath 13. A conventional threaded study-type terminal 20 is spot-welded along the outer end of each lead-in conductor 11 as an example of an alternate form of the terminating element 15 in FIG. 2. The use of silicone in place of the plastic resin is utilized for applications wherein the maximum terminal operating temperature is 550°F (the plastic resins are limited to 250°F maximum terminal operating temperatures), although the silicone does not provide a true hermetic seal but is merely a good moisture barrier. A ceramic-to-metal sealed terminal would be used for terminal operating temperatures in the range of 700°–1000° F to provide hermetic seals, a glazed alumina ceramic being brazed to the ends of the heater.

FIG. 4 illustrates a third embodiment of my improved electrical resistance heater which is distinguished from the FIG. 1 embodiment in that the ends of the heater are confined in a common body to provide single-end connection to an electrical power source. Thus, a unitary cylindrical body comprising an MOV material portion 21 and an electrically insulating portion 22 enclosed in an electrically conductive hollow cylindrical metallic member 24, forms a common terminal end of my heater in which are located the connections of the heating coil 10 to the lead-in sections 11. The MOV material portion 21 is shown located at the ends of sheath 13, the sheath being soldered, brazed, or otherwise connected, as indicated by fillets 23, to enclosing hollow cylindrical member 24 which functions as an extension of sheath 13. Hollow cylindrical member 24 encloses all of body portion 21 and extends at least to the edge of body portion 22 spaced from body portion 21 and may extend along the outer end surface 25, as desired, or required by the particular application. The electrically insulating portion 22 may be a ceramic or phenolic material and is shown located at the end of MOV portion 21 spaced from sheath 13. Alternatively, the positions of portions 21 and 22 may be interchanged. The joined ends of heating coil 10 and ends of lead-in sections 11 are thus imbedded in the body comprising portions 21 and 22. The connection of coil 10 and lead-in sections 11 may be in either of portions 21 or 22. The orientation of the lead-in sections relative to hollow cylindrical member 24 is such that the spacing between lead-in sections 11 is approximately equal to the spacing between the lead-in sections and member 24 in order to provide relatively equal voltage clamping between the lead-ins and a lead-in and the sheath. The material 12 compacted between sheath 13 and coil 10 may be of the type described with reference to FIGS. 2 or 3. It is thus seen that the body of MOV material 21 provides the same transient voltage suppression function as in FIGS. 2 and 3 and also forms part of a rigid support member for containing both ends of the heating coil 10.

Having described three embodiments of my improved electrical resistance heater, it would be obvious that the bodies 16 of MOV material can assume any of a number of shapes as determined by the cross-sectional shape of outer sheath 13. Thus, the illustratively implied hollow cylindrical shapes of MOV bodies 16 and sheath 13 may assume a more square cross-sectional shape in some applications. Thus, while my invention has been particularly shown and described with reference to three illustrated embodiments thereof, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the scope of the invention as defined by the following claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In an improved electrical resistance heater comprising

an electrically conductive heating coil embedded in a heat resistant, electrically insulating material,

a pair of electrically conductive lead-in sections connected to the ends of said heating coil, and

a metallic sheath enclosing the embedded heating coil and adjacent portions of said lead-in sections,

the improvement comprising

at least one body of metal oxide varistor material electrically connected to said lead-in sections and the metallic sheath and filling the spaces therebetween, the metal oxide varistor body exhibiting high electrical resistance at normal operating voltage applied to said lead-in sections and exhibiting nonlinear resistance characteristics which limit the voltage between the lead-in sections and sheath in response to transient voltages on a power line supplying electric power to the heater thereby preventing incipient breakdown through repeated stressing and subsequent arcing between said heating coil and sheath.

2. In the improved electrical resistance heater set forth in claim 1 wherein

said at least one body of metal oxide varistor material are two dense bodies thereof confined in the spaces defined by inner surfaces of end portions of said sheath and outer surface of the lead-in sections whereby said bodies of metal oxide varistor material provide low resistance paths for shunting the transient voltage to the sheath.

3. In an improved electrical resistance heater set forth in claim 2 and further comprising

a pair of bodies of heat resistant, electrically insulating material confined in the spaces surrounding the junctures of said heating coil and said lead-in sections and defined by the inner surfaces of said sheath and adjacent end surfaces formed by the heating coil embedding insulating material and adjacent end surfaces of said two bodies of metal oxide varistor material.

4. In the improved electrical resistance heater set forth in claim 2 wherein

said embedding heat resistant, electrically insulating material includes a percentage by volume of metal oxide varistor material.

5. In the improved electrical resistance heater set forth in claim 4 wherein

the percentage of metal oxide varistor material is in the range of 1 to 100 percent.

6. In the improved electrical resistance heater set forth in claim 2 wherein

said embedding heat resistant, electrically insulating material is metal oxide varistor material confined in the space defined by the inner surface of a central portion of said sheath and adjacent end surfaces of said two bodies of metal oxide varistor material for also providing improved thermal conductivity.

7. In the improved electrical resistance heater set forth in claim 3 wherein

said pair of bodies of heat resistant, electrically insulating material are bodies of metal oxide varistor material.

8. In the improved electrical resistance heater set forth in claim 2 and further comprising

electrical insulating means disposed along the most widely spaced outer surfaces of said bodies of metal oxide varistor material and in contact with said sheath for electrically insulating said bodies of metal oxide varistor material from the environment external of the heater.

9. In the improved electrical resistance heater set forth in claim 2 and further comprising

terminal means connected to the outer ends of said lead-in sections for providing connection to the power line.

10. In the improved electrical resistance heater set forth in claim 1 wherein

said metallic sheath has two end portions formed into a common end portion,

said at least one body of metal oxide varistor material is one dense body thereof confined in the space defined by the inner surface of the common end portion of said sheath and outer surfaces of the lead-in sections whereby said body of metal oxide varistor material provides a low resistance path for shunting the transient voltage to the sheath and also forms at least part of a single-ended terminating member for said heater.

11. In the improved electrical resistance heater set forth in claim 10 wherein

the spacing between said lead-in sections is approximately equal to the spacing between said sheath and a lead-in section.

12. An improved electrical resistance heater comprising

an inner electrical conductor consisting of a pair of lead-in sections and a heating coil connected therebetween,

an outer metallic sheath surrounding said heating coil and at least an adjacent portion of each of said pair of lead-in section and adapted to be connected to a known potential which may include ground,

heat resistant, electrically insulating material confined and moderately compacted in the space between said outer metallic sheath and said heating coil, and

metal oxide varistor material confined and sufficiently compacted to form two dense bodies thereof in the spaces between said metallic sheath and correspondingly surrounded portions of said lead-in sections, said varistor material sealings said spaces, the metal oxide varistor material bodies exhibiting high electrical resistance at normal operating voltage applied to said lead-in sections and exhibiting nonlinear resistance characteristics which limit the voltage between the lead-in sections and sheath in response to transient voltages and provide low resistance paths for shunting the transient to the sheath and thereby dissipating it and preventing arcing between said heating coil and sheath.

13. The improved electrical heater set forth in claim 12 wherein

said lead-in sections of the inner electrical conductor are concentric with the outer metallic sheath and the metal oxide varistor material is in the form of two hollow cylinders.

14. The improved electrical resistance heater set forth in claim 12 wherein

said heating coil is a helical coil of wire having a predetermined resistance and positioned concentric with the outer metallic sheath.

15. The improved electrical resistance heater set forth in claim 12 wherein

said metal oxide varistor material has an alpha exponent in excess of 10.

16. The improved electrical resistance heater set forth in claim 12 wherein

the structure comprising said heating element, sheath and heat resistant, electrically insulating material is U-shaped.

17. The improved electrical resistance heater set forth in claim 12 wherein

said heat resistant, electrically insulating material includes at least a percentage by volume of metal oxide varistor material whereby the latter metal oxide varistor material provides further protection against arcing between the heating coil and sheath.

18. The improved electrical resistance heater set forth in claim 12 wherein

said heat resistant, electrically insulating material is powdered fused magnesium oxide.

19. The improved electrical resistance heater set forth in claim 17 wherein the percentage of metal oxide varistor material is in the range between 1 and 100 percent.

20. The improved electrical resistance heater set forth in claim 12 wherein

the heat resistant, electrically insulating material in the space surrounding the junctures of said lead-in sections and said heating coil is a metal oxide varistor material in compacted, sintered form.

21. The improved electrical resistance heater set forth in claim **12** wherein

said lead-in sections are parallel to each other and spaced apart in close relationship,

said metallic sheath has a common end portion surrounding the end portions of said heating coil and adjacent portions of said lead-in sections, and

said two dense bodies of metal oxide varistor material form a common body thereof in the space between the common end portion of said metallic sheath and said lead-in sections.

22. The improved electrical resistance heater set forth in claim **21** wherein

the spacing between said lead-in sections is in the order of the spacing between said sheath and a lead-in section.

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