United States Patent [19]

Harnden, Jr.

[11] **3,821,686**

[45] **June 28, 1974**

[54] **PROTECTIVE CONNECTOR DEVICES**

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[22] Filed: **Oct. 21, 1971**

[21] Appl. No.: **191,217**

[52] **U.S. Cl.** **338/21**, 338/20, 339/62

[51] **Int. Cl.** **H01c 7/12**

[58] **Field of Search** 338/13, 20, 21, 322, 323, 338/331; 339/62, 63, 147, 195, 196, 222

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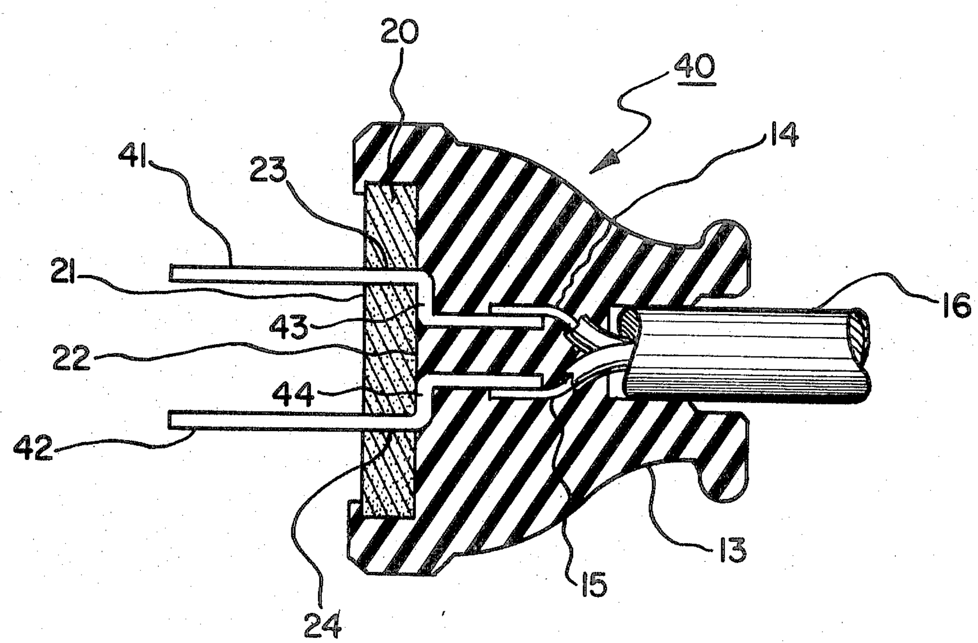
[57] **ABSTRACT**

A power connector is provided with a body of metal oxide varistor material in conductive contact with each of the electrodes thereof. The metal oxide varistor material has an alpha in excess of 10 in the current density range of 10^{-3} to 10^2 amperes per square centimeter. The portions of the body in contact with the electrodes are spaced to provide a standby current flow which is low when normal operating voltage appears across the electrodes and when voltages in excess of the normal voltage appear across the electrode, a rapidly decreasing impedance is presented by the body in accordance with the alpha of the material of the body, thereby limiting the variation in voltage between the electrodes to a value close to the normal operating voltage.

11 Claims, 10 Drawing Figures



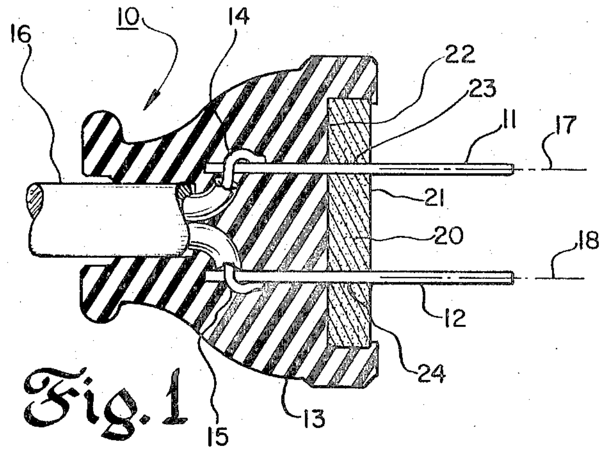


Fig. 1

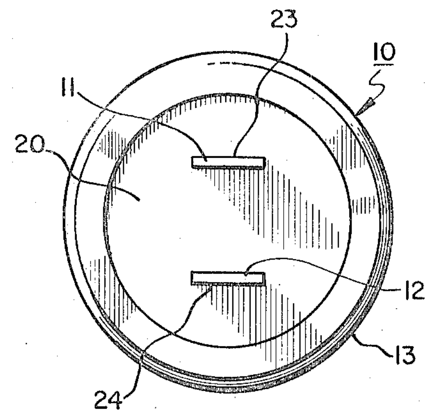


Fig. 2

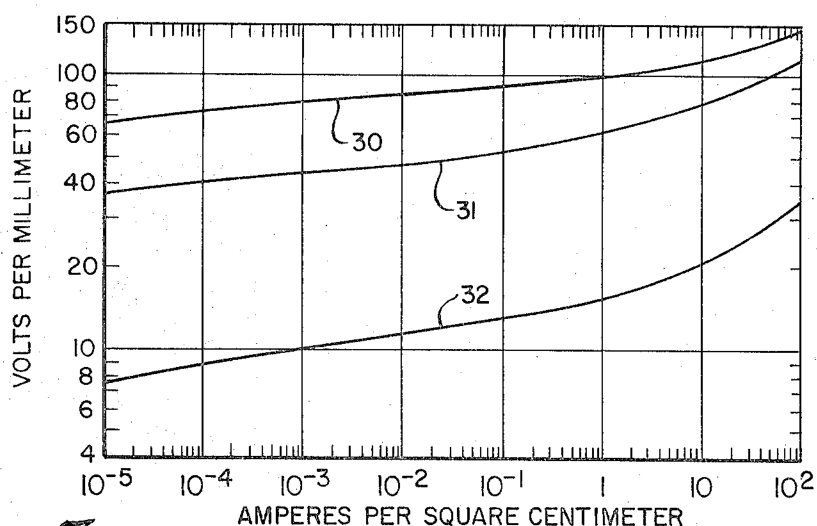


Fig. 3

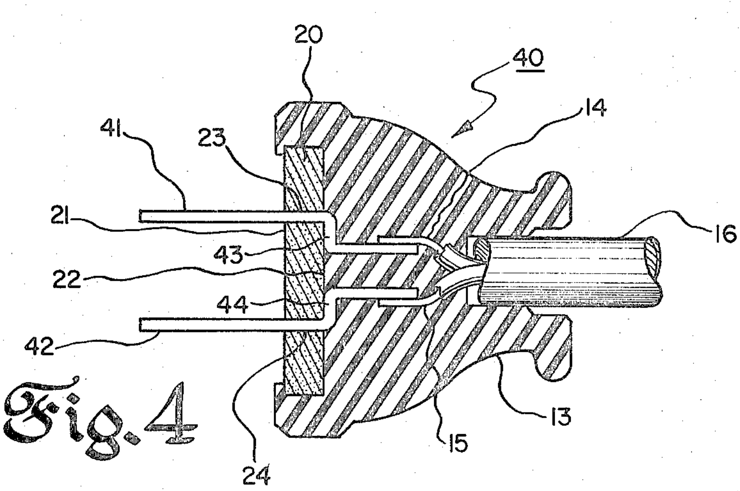


Fig. 4

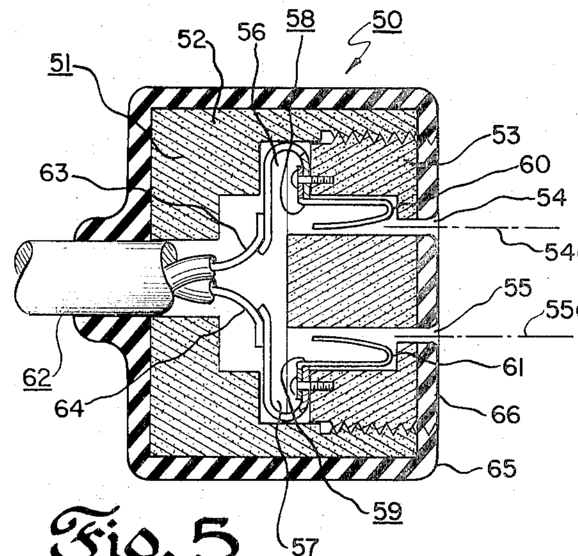


Fig. 5

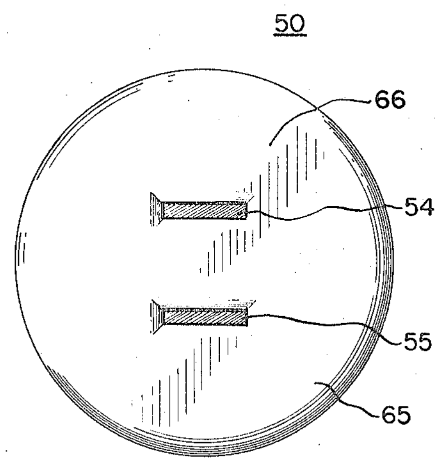


Fig. 6

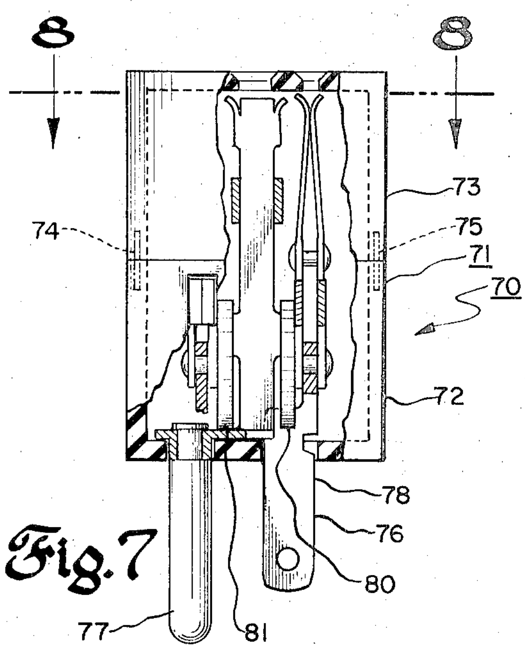


Fig. 7

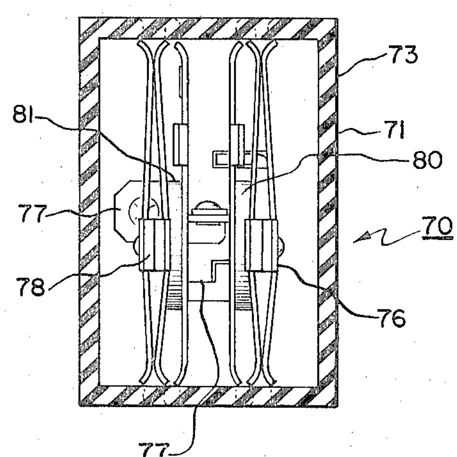


Fig. 8

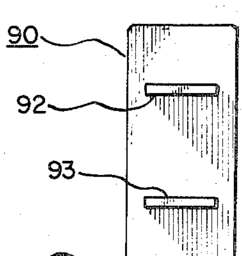


Fig. 9

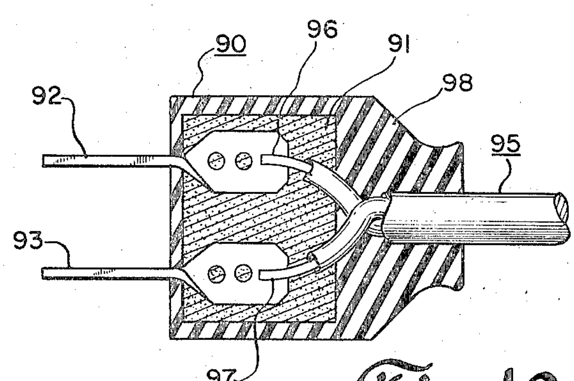


Fig. 10

PROTECTIVE CONNECTOR DEVICES

The present invention relates in general, to connector devices for connecting electrical apparatus, including appliances and the like, to sources of electrical power and in particular, relates to connector devices in which means are provided for protecting the electrical apparatus from electrical surges.

Electrical surges in the electrical utilization apparatus may arise from various sources. Lightning may cause voltage surges on power lines to which the apparatus is connected. Such surges may develop considerable voltage across the power lines and contain considerable power resulting in destruction of the utilization apparatus connected to the lines, if not suitably protected. Also, disconnecting an appliance having reactive elements from a power line, while the appliance is in operation, may produce high induced voltages in the circuits of the appliance and arcing at the electrodes may occur as well. Accordingly, a need exists for providing protection of electrical apparatus and the like against voltage surges arising from natural and from man-made causes.

Accordingly, an object of the present invention is to provide a connector which, in addition to the providing of the connection function, also provides electrical surge protection.

Another object of the present invention is to provide a surge protector connector which is simple and compact, and which also is economical in construction and in operation.

Another object of the present invention is to provide a surge protection connector which has substantially negligible time delay in the operation thereof in suppression of the surges.

Another object of the present invention is to provide a connector which is constructed of a minimum number of elements.

Another object of the present invention is to provide a connector which is flexible as to the physical form thereof as well as the range of electrical operation thereof.

Another object of the present invention is to provide a surge protection connector which is utilizable over a wide range of frequencies, as well as utilizable in both alternating current and direct current systems.

Another object of the present invention is to provide a simple surge protection connector with capabilities of absorbing power surges of considerable energy.

In carrying out the invention, in one illustrative form, there is provided a pair of electrodes, each including an elongated element. The longitudinal axes of the elongated elements of the electrodes are substantially parallel and adapt to engage a respective conductor of a pair of mating power conductors. Each of the electrodes is provided with means for connecting them in circuit, for example, to a utilization apparatus or to a power circuit. A body of metal oxide varistor material which has an alpha in excess of 10 in the current density range of 10^{-3} to 10^{2} amperes per square centimeter is provided in conductive contact with each of the electrodes. The portions of the body in contact with the electrodes are spaced to provide a standby current flow which is low when normal operating voltage appears across the electrodes and when voltages in excess of the normal voltage progressively appear across the electrode, a rapidly decreasing impedance is presented by the body in accordance with the alpha of the body, thereby limiting the variation in voltage between the electrodes to a value close to the operating voltage.

The features of the present invention which are believed to be novel are set forth 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 drawings in which,

FIG. 1 is a sectional view of a connector in accordance with the present invention.

FIG. 2 is a side view of the embodiment of FIG. 1.

FIG. 3 shows graphs of the electrical characteristics of three materials of differing voltage gradients and alphas suitable for use in the connector devices of the present invention.

FIG. 4 is a sectional view of another embodiment of the present invention similar to the embodiment of FIG. 1 in which the elongated electrodes extend for a partial distance along the surface of the body of metal oxide varistor material.

FIG. 5 is a sectional view of another embodiment of the present invention showing a power connector formed in a block of metal oxide varistor material.

FIG. 6 is a side view of the embodiment of FIG. 5.

FIG. 7 is a front view partially in section of one embodiment of the present invention as applied in connection with a three-way power connector adapter having a ground terminal in addition to power terminals.

FIG. 8 is a top view partially in section of the embodiment of FIG. 7.

FIG. 9 is another embodiment of the present invention in which the electrodes of the connector are secured to a surface of a wafer of metal oxide varistor material.

FIG. 10 is a side view of the embodiment of FIG. 9.

Referring now to FIGS. 1 and 2, there is shown an embodiment of my invention as applied to a conventional power connector for connecting electrical apparatus such as an appliance to a source of power. The connector **10** includes a pair of elongated electrodes **11** and **12** having respective longitudinal axes **17** and **18** which are generally parallel in orientation. Each of the electrodes **11** and **12** has a pair of parallel opposed surfaces in accordance with standard commercial practice. One end of each of the electrodes is embedded in a plastic insulating block or casing **13**. Each of the adjacent ends within the casing of the elongated conductors **11** and **12** within the casing is connected, for example, by soldering to a respective conductor of a pair of conductors **14** and **15** of cable **16**. The adjacent other ends of the elongated electrodes are spaced with their flat opposed surfaces generally parallel for insertion in a standard power outlet in a power distribution system.

A wafer **20** of metal oxide varistor material is provided, having a pair of opposed major faces or surfaces **21** and **22**. A pair of apertures **23** and **24** are provide, each extending from one opposed major face to the other major face thereof. The holes are dimensioned to provide good conductive contact between electrodes and wafer.

The wafer **20** is constituted of a metal oxide varistor material such as described in Canadian Pat. No. 831,691, which has a nonlinear voltage versus current characteristic. The metal oxide varistor material described in the aforementioned patent is constituted of fine particles of zinc oxide with certain additives which have been pressed and sintered at high temperatures to provide a composite body or wafer of material. The current versus voltage characteristics of the composite body is expressed by the following equation:

$$I = (V/C)^{\alpha} , \quad (1)$$

where

V is voltage applied across a pair of opposed surfaces or planes,

I is the current which flows between the surfaces.

C is a constant which is a function of the physical dimensions of the body as well as its composition and the process used in making it,

α is a constant for a given range of current and is a measure of the nonlinearity of the current versus voltage characteristic of the body.

In equation (1), when V is used to denote voltage between opposed planes of a unit volume of material, or voltage gradient, current flow through the unit volume of material in response to the voltage gradient becomes current density. For the metal oxide varistor material for current densities which are very low, for example, in the vicinity of a microampere per square centimeter, the alpha (α) is relatively low, i.e., less than 10. In the current density range of from 10^{-3} to 10^2 amperes per square centimeter, the alpha is high, i.e., substantially greater than **10** and relatively constant. In the current density ranges progressively in excess of 10^2 amperes per square centimeter, the alpha progressively decreases. When the current versus voltage characteristic is plotted on log-log coordinates, the alpha is represented by the reciprocal of the slope of the graph in which current density is represented by the abscissa and voltage gradient is represented by the ordinate of the graph. For a central range of current densities of from 10^{-3} to 10^2 amperes per square centimeter, the reciprocal of the slope is relatively constant. For current densities below this range, the reciprocal of the slope of the graph progressively decreases. Also for current densities above this range, the reciprocal of the slope of the graph progressively decreases.

The voltage gradient versus current density characteristics of three types of material in log-log coordinates are set forth in FIG. **3.** Graphs **30** and **31** are materials of high voltage gradient material and graph **32** is a graph of low voltage gradient material. For all of the graphs in the current density range from 10^{-3} to 10^2 amperes per square centimeter, the alpha is high and is substantially greater than 10 and relatively constant. For current densities progressively greater than 10^2 amperes per square centimeter, the alpha progressively decreases. For current densities progressively less than 10^{-3} amperes per square centimeter, the alpha also progressively decreases.

As the metal oxide varistor material is a ceramic material, the surfaces thereof may be metallized for facilitating electrical connections thereto in a manner similar to the manner in which other ceramic materials are metallized. For example, Silver Glass Frit, Du Pont No. 7713, made by the Du Pont Chemical Company of Wilmington, Delaware, may be used. Such material is applied as a slurry in a silk screening operation and fired at about 550°C to provide a conductive coating on the surface. Other methods such as electroplating or metal spraying could be used as well.

The nonlinear characteristics of the material results from bulk phenomenon and is bi-directional. The response of the material to steep voltage wave fronts is very rapid. Accordingly, the voltage limiting effect of the material is practically instantaneous. Heat generation occurs throughout the body of material and does not occur in specific regions thereof as in semiconductor junction devices, for example. Accordingly, the material has good heat absorption capability as the conversion of electrical to thermal energy occurs throughout the material. The specific heat of the material is 0.12 calories per degree Centigrade per gram. Accordingly, on this account, as well, heat absorption capability of the material is advantageous as a surge absorption material.

The material, in addition to the desired electrical and thermal characteristics described above, has highly desirable mechanical properties. The material has a fine grain structure, may be readily machined to a smooth surface and formed into any desired shape having excellent compressive strength. The material is readily molded in the process of making it. Accordingly, any size or shape of material may be readily formed for the purposes desired.

For the connector of FIGS. **1** and **2,** the spacing of the electrodes **11** and **12,** and hence the spacing of the apertures **23** and **24,** is fixed by standard commercial practice. Accordingly, to provide an appropriate low current drain through the wafer **20** under normal operating voltages for plug, the metal oxide varistor material with the appropriate voltage gradient versus current density characteristics is selected. The normal operating voltage rating of the connector of FIGS. **1** and **2** may be altered without use of a different material by the provision of electrodes which extend along one of the opposed surfaces of the wafer toward one another, thereby applying a higher voltage gradient to the wafer for a given applied voltage between the electrodes. FIG. 4 shows such a connector **40** in which the electrodes **41** and **42** are provided, each having two ninety degree bends to provide respective central sections **43** and **44,** each of which extend along the surface toward one another. In other respects, the connector of FIG. **4** is identical to the connector of FIG. **1** and identical elements are identically designated.

Reference is now made to FIGS. **5** and **6** which show another connector **50** including a composite block **51** or body of material having a base member **52** and a cylindrical insert member **53** threaded to engage matching threads in a cylindrical opening in the base member and inserted therein. The composite block **51** is provided with a pair of elongated recesses **54** and **55** extending from an outer surface inward into the body **51.** The elongated recesses **54** and **55** have respective longitudinal axes **54***a* and **55***a* which are substantially parallel. Another pair of recesses **56** and **57** is also provided, each laterally disposed and opening into recesses **54** and **55,** respectively. A pair of electrode assemblies **58** and **59** are provided, each supported in a respective one of the second pair of recesses **56** and **57.** Each of the elongated elements **60** and **61** of the electrodes **58** and **59** are aligned in a respective one of the first pair of elongated recesses **54** and **55.** Through an opening in the rear of the block **51** opposite the elongated recesses **54** and **55** is provided a cable with a pair of conductors 63 and 64 which are connected to respective elongated electrodes 58 and 59. The base member 51 and the insert member 52 are made of metal oxide varistor material having the characteristics such as set forth in the graphs of FIG. 3 selected to provide the desired voltage versus current characteristic for the connector. The composite metal varistor oxide body 51 may be enclosed in suitable insulating plastic coatings 65 and 66.

Reference is now made to FIGS. 7 and 8 which show another embodiment of the invention as applied to a power connector adapter 70 for connection to a power outlet to provide three power outlets. The adapter is usable with a standard power outlet which has a pair of power electrodes and a ground electrode. The adapter 70 includes a housing 71 which is in the form of a parallel piped shell separable into an upper portion 72 and a lower portion 73 held together by a pair of pins 74 and 75 in the upper portion which are insertable in corresponding holes in the lower portion. The adapter 70 is provided with three assemblies of electrodes 76, 77, and 78, each having a plug end and a receptacle end. The plug ends of the assemblies extend outside the housing 71 and the receptacle ends are contained entirely within the housing. The housing 71 is provided with three sets of three openings, each located on a respective side of the housing and each opening in a side registering with a respective receptacle end of the assemblies of electrodes. The first plug end of electrode assembly 76 is inserted in an aperture in the base of the lower housing. Three pairs of conductive fingers are provided in the assembly 76 with each of the three pairs extending in directions to register with the apertures in the sides and the top of the housing 71. The second electrode assembly 77 has a circular plug end which fits into a corresponding aperture in the base of the housing 71. Other portions of the assembly 77 are provided with three pairs of finger contacts which register with respective holes in the sides and top of the housing. The third electrode assembly 78 is provided with a plug end which fits into a hole behind the hole for the plug assembly 76 in the base of housing 71 and forms with it a pair of electrodes pluggable into a corresponding power outlet ends. The assembly 78 is provided with three pairs of conductive fingers which register with corresponding openings in the sides and top of the housing 71. The portion of each of the conductor assemblies 76, 77, and 78 connecting the plug portions with the three receptor portions thereof are formed so as to be supported in slots and shoulders in the housing 71 to maintain the three electrode assemblies in insulated spaced relationship with respect to one another and also to provide proper registry with each of three-way outlets in the top and two sides of the housing 71. The construction described above is conventional.

In accordance with the present invention, to maintain insulating relationship between the first electrode assembly 76 and the second electrode assembly 77, that is the ground assembly, a disc 80 of metal oxide varistor material is provided and maintained by a pressure fit between the electrode assembly 76 and the electrode assembly 77. The disc 81 includes a pair of opposed surfaces, one which is in pressure contact with the first electrode assembly 76 and the other of which is in pressure contact with the second electrode assembly 77. Similarly, another disc 81 of metal oxide varistor material is provided. The disc 81 also includes a pair of opposed surfaces, one of which is in pressure contact with the third electrode assembly 78 and the other of which is in pressure contact with the second electrode assembly 77. For discs of particular metal oxide varistor material having a particular voltage gradient versus current density characteristic, the thickness or distance between the opposing surfaces of the discs is set so as to provide the desired low operating or standby current flow in the range of voltages for which the connector is designed and to provide low impedance when voltage surges appear across the electrode assemblies. The discs provide structural support for the electrode assemblies and maintain the electrode assemblies in insulative relationship as well as provide surge protection for apparatus powered therethrough.

Reference is now made to FIGS. 9 and 10 which show a connector wafer 91 of metal oxide varistor material having a pair of opposed surfaces. A pair of substantially flat elongated electrodes 92 and 93 are provided, each having a pair of major opposed surfaces. Each of the electrodes 92 and 93 are twisted intermediate the ends thereof to provide a substantially 90° twist therein whereby a continuous major surface at one end thereof is perpendicular to the same major surface at the other end thereof. One end of electrode 92 is secured, for example, by soldering or riveting, to a major face of wafer 91 and similarly, one end of the other electrode 93 is secured to the same major face of the wafer and in spaced relationship thereto to orient the other ends of said electrodes in a manner such that the major surfaces of electrodes 92 and 93 or the longitudinal axes thereof are substantially parallel. The adjacent ends of the electrodes 92 and 93 are spaced with respect to one another along the surface of the metal oxide varistor body 71 to provide the desired voltage versus current characteristic of the connector for the particular metal oxide varistor material used. A cable 95 is provided with a pair of conductors 96 and 97, connected to respective electrodes 92 and 93 by means suitable such as soldering. The metal oxide varistor body portions of the electrodes, and a portion of the cable may be suitably housed by enclosing them in an insulating plastic casing 98.

Although in the embodiment of FIGS. 1 and 2, the opposed major surfaces of the elongated electrodes are all substantially parallel, it is apparent that the invention is equally applicable to connectors in which the opposed major surfaces of the electrodes are at different orientations, for example one electrode with major surfaces at right angles to the orientation of the major faces of another electrode. Also, although electrodes are shown in FIGS. 1 and 2 which are rectangular or oblong in cross section, it is apparent that the invention is applicable to electrodes of other cross sections, such as circular, for example. While two electrodes are shown in the exemplary embodiment of FIGS. 1 and 2, the invention is applicable as well to connectors having more than two and can include many electrodes.

While the invention has been described in specific embodiments, it will be appreciated that modifications may be made by those skilled in the art and I intend by the appended claims, to cover all such modifications as fall within the true spirit and scope of the invention.

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

1. An electrical connector comprising:

a pair of electrodes each including an elongated element, the longitudinal axes of the elongated elements of said electrodes being substantially parallel, the elongated elements of said electrodes adapted to engage a respective conductor of a pair of mating conductors,

each of said electrodes provided with means for connecting said electrodes in circuit,

a body of metal oxide varistor material in conductive contact with said electrodes; and

a body of electrically insulating material surrounding said means for connecting and at least a portion of said electrodes and said body of metal oxide varistor material.

2. The combination of claim **1** in which said material has an alpha in excess of 10 in the current density range of 10^{-3} to 10^{2} amperes per square centimeter.

3. The combination of claim **1** in which the portions of said body in contact with said electrodes are spaced to provide a standby current flow between said electrodes which is low when normal operating voltage appears across said electrodes and when voltages in excess of normal voltage progressively appear thereacross rapidly decreasing impedance is presented by said body in accordance with the alpha of the body of material thereby limiting the variation in voltage between said electrodes.

4. The combination of claim **1** in which said body is a disc having a pair of opposed major faces, each of said electrodes conductively contacting a respective major face of said disc.

5. The combination of claim **1** in which a third electrode is provided having an elongated element having a longitudinal axis generally parallel to the longitudinal axis of each of the elongated elements of said other electrodes and adapted to engage a third mating conductor,

another body of metal oxide varistor material in conductive contact with said third electrode and one of said other electrodes,

said third electrode being provided with means for connecting said third electrode in circuit.

6. The combination of claim **1** in which one of said pair of electrodes is a ground electrode.

7. The combination of claim **3** in which said body is a disc having a pair of opposed major faces, a pair of spaced apertures, each extending from one major face to the opposite major face thereof, each of said electrodes extending through a respective one of said apertures and in conductive contact with said body.

8. The combination of claim **7** in which each of said electrodes include a portion which extends along one surface of said disc, said portions extending toward one another and at their nearest points spaced a distance less than the distance between said apertures, whereby the standby operating voltage may be set independently of the spacing of the elongated portions of said electrodes for a body of material of predetermined voltage gradient versus current density characteristics.

9. The combination of claim **1** in which said body is a block having a pair of elongated recesses extending from an outer surface inward into said body, the longitudinal axes of said elongated recesses being substantially parallel, another pair of recesses, each opening into a respective one of said first pair of recesses, each of said electrodes supported in a respective one of said second pair of recesses, each of the elongated elements of said electrodes aligned in a respective one of said first pair of elongated recesses.

10. The combination of claim **1** in which said body is a wafer having a pair of major opposed surfaces and in which each of said electrodes is conductively secured to a respective region of one of said opposed major faces, the parallel elongated elements of said electrode extending outward from said body.

11. The combination of claim **10** in which each of said electrodes is substantially flat rod with a pair of major opposed surfaces, each of said electrodes having a substantially ninety degree twist intermediate the ends thereof whereby the major surfaces of said elongated elements of said rods are perpendicular to the major faces of said rods making conductive contact with said wafer.

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