

[54] PROTECTIVE CONNECTOR DEVICES

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[58] Field of Search 338/220, 221, 20, 338/21; 337/353, 354; 339/150 R, 150 C, 150 F, 151 R, 151 C, 151 M, 154 R, 153, 176 P, 222, 195 R, 195 A, 195 S, 191 R, 191 A, 191 M, 191 S

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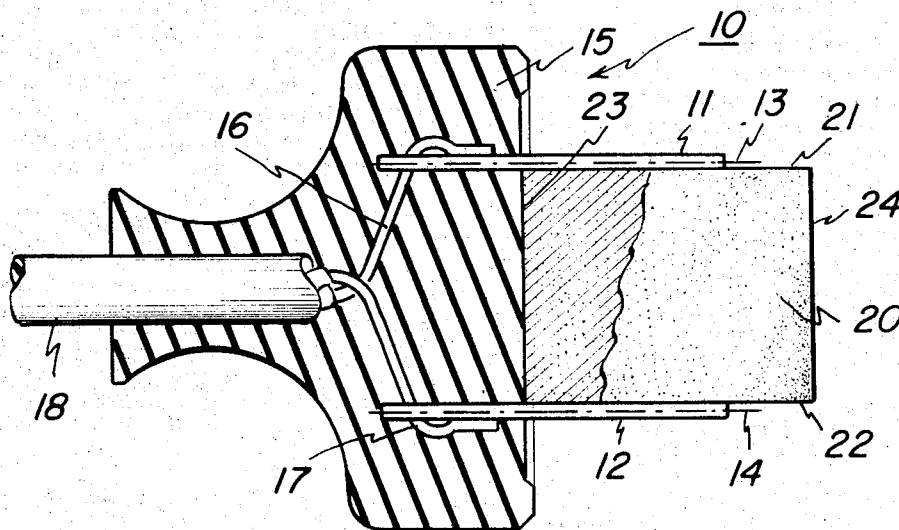
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ABSTRACT

At least one of the elongated electrodes of a protective connector are provided with elongated extensions of metal oxide varistor material. 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. Accordingly, when the electrodes are disengaged from the electrodes of a mating connector, the metal oxide varistor extension of the protective connector is the last to be disengaged from the electrodes of the mating connector, thereby placing such an extension in series with any discharge currents and thus limiting the magnitude of any voltage developed by the disengagement of the connectors.

7 Claims, 9 Drawing Figures



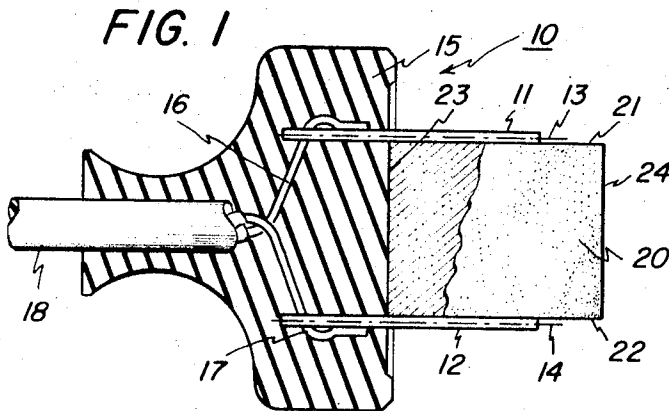
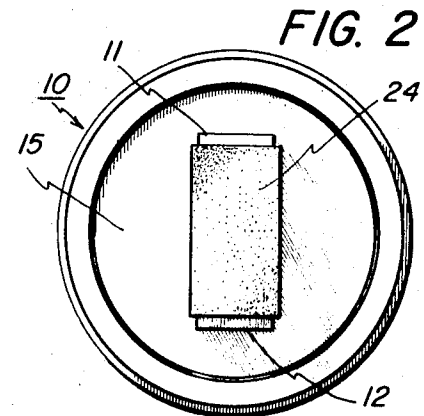
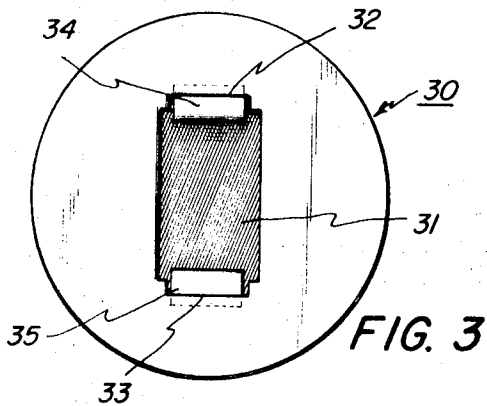
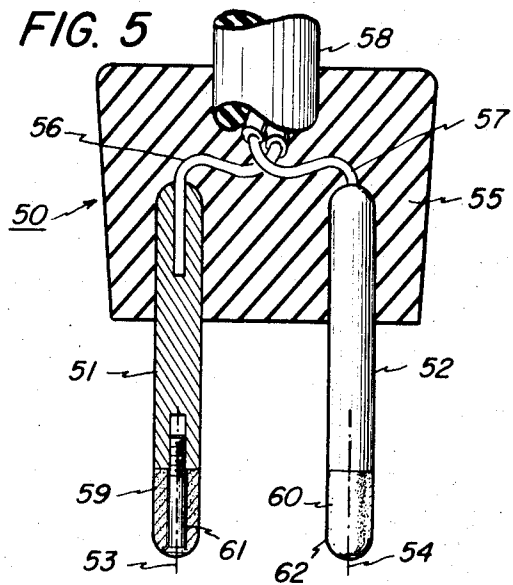
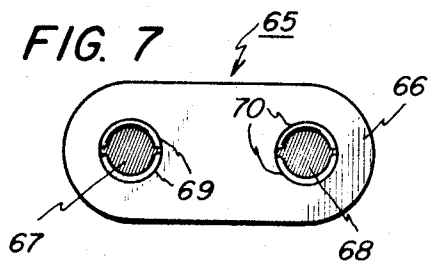
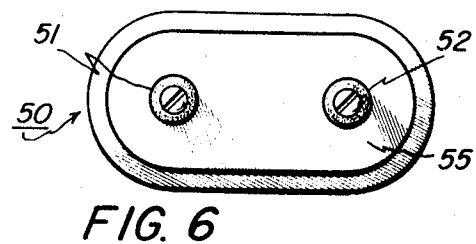


FIG. 8

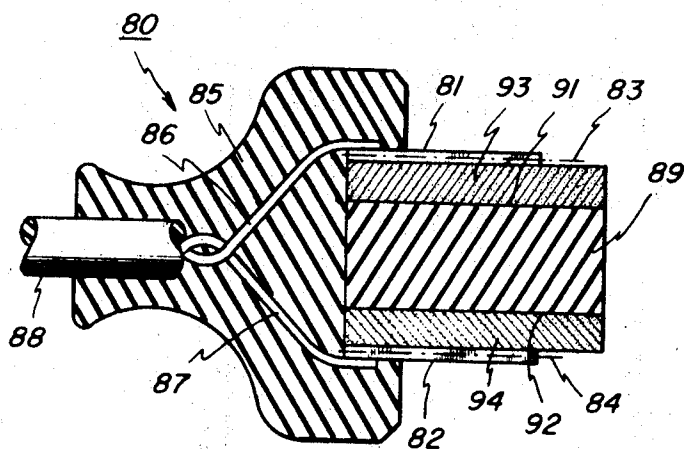


FIG. 9

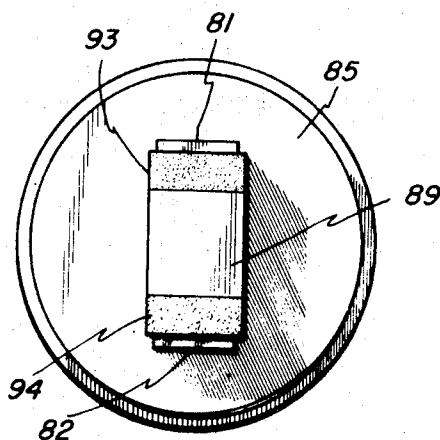
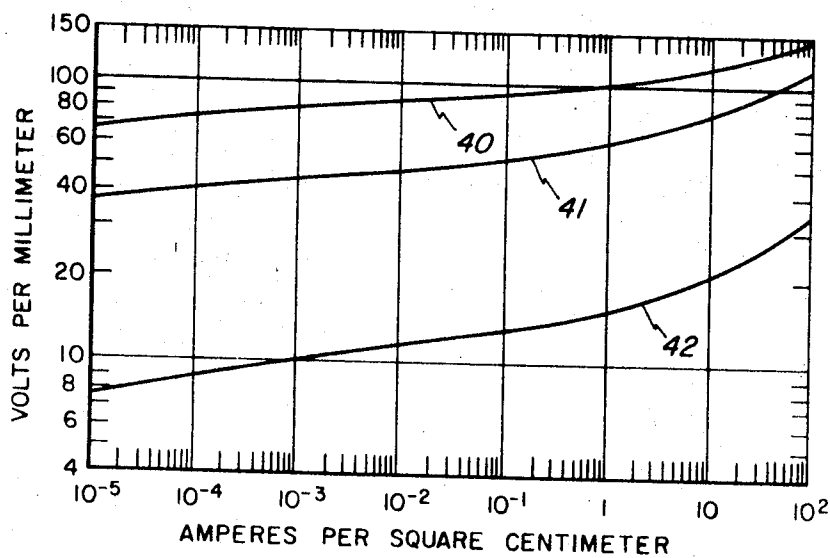


FIG. 4



PROTECTIVE CONNECTOR DEVICES

The present invention relates in general to connector devices for connecting electrical apparatus to sources of electrical signal and power and particularly relates to connector devices in which means are provided for protecting the electrical apparatus from electrical surges due to the disconnection of such devices and apparatus from the power source.

Electrical apparatus such as motors have reactive elements included therein and when such apparatus is disconnected from the power line, high voltages are induced in the circuits of the apparatus producing stress in the insulation thereof and producing arcing in the electrodes as well. Accordingly, a need exists for providing protection of electrical apparatus against voltage surges arising from such disconnecting operations.

An object of the present invention is to provide a connector which in addition to providing the connecting function also provides electrical surge protection.

Another object of the present invention is to provide a surge protector connector which is simple, reliable and effective 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 the suppression of surges.

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 the electrical operation thereof.

Another object of the present invention is to provide surge protection connector which is utilizable over a wide range of frequencies and with signal sources as well as power sources.

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 thereof, there is provided a pair of elongated electrodes. The longitudinal axes of the elongated elements are substantially in parallel. One of the ends of each of the electrodes is adapted to engage a respective conductor of a pair of adjacent mating conductors. The other of the ends of each of the electrodes is provided with means for connecting the electrodes in circuit. A pair of members of metal oxide varistor material is also provided, each of the members being in contact with a respective one of said elongated electrodes and extending beyond said one end thereof. Accordingly, when one of the electrodes is caused to engage a respective mating conductor, the respective mating conductor makes contact first with the member of metal oxide varistor material in contact with the one electrode. When an electrode is withdrawn from its mating conductor, the metal oxide varistor member limits the voltage between the electrode and its mating electrode to a low value determined by the separation of the electrode from the mating electrode and by the voltage gradient versus current density characteristic of the metal oxide varistor material.

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 an end view of the embodiment of FIG. 1,

FIG. 3 is an end view of a receptacle for receiving the connector of FIGS. 1 and 2,

FIG. 4 shows graphs of the electrical characteristics of three materials of differing voltage gradients and phases suitable for use in the connector devices of the present invention,

FIG. 5 is a sectional view of another embodiment of the present invention,

FIG. 6 is an end view of the embodiment of FIG. 5,

FIG. 7 is an end view of a receptacle for use with the connector of FIGS. 5 and 6,

FIG. 8 is a sectional view of a further embodiment of the present invention,

FIG. 9 is an end view of the embodiment of FIG. 7.

Referring now to FIGS. 1 and 2, there is shown an embodiment of my invention as applied to a power connector for connecting electrical apparatus to a source of power. The connector 10 includes a pair of elongated electrodes 11 and 12 having respective longitudinal axes 13 and 14 which are generally parallel in orientation. Each of the electrodes 11 and 12 has a pair of parallel opposed surfaces. One end of each of the electrodes is embedded in a plastic insulated block 15 or casing. Each of the adjacent ends 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 16 and 17 of cable 18. The other adjacent ends of the elongated electrodes 11 and 12 are spaced with their flat opposed surfaces, generally parallel for insertion in a power outlet or receptacle 30 such as shown, for example, in FIG. 3. A block or body 20 of metal oxide varistor material is provided having a pair of opposed surfaces 21 and 22, in conductive contact with respective inwardly directed surfaces of the respective electrodes 11 and 12. One end 23 of the block is bonded or embedded in insulating block 15. The other end 24 of the block extends beyond the ends of the electrodes 11 and 12.

FIG. 3 shows a receptacle 30 for use in connection with the connector 10 of FIG. 1. The receptacle has an enlarged opening 31 which extends inward. Supported on opposed surfaces 32 and 33 of the generally rectangular opening are respective resilient spring conductive members 34 and 35 of elongated configuration forming mating conductors for the respective conductive electrodes 11 and 12 of FIGS. 1 and 2. Accordingly, when the connector 10 is inserted into the opening of the receptacle, the mating conductors 34 and 35 make contact initially with surface portions 21 and 22 of the block 20 metal oxide varistor material and upon further insertion, the conductors 34 and 35 make conductive contact with conductive members 11 and 12. Conversely, on removal of the connector 10 from the receptacle, the contact between each of the electrodes 11 and 12 and respective ones of the corresponding mating conductors 34 and 35 is initially broken leaving a portion of the surfaces 21 and 22 of the body 20 in conductive contact with respective electrodes. Accordingly, in the event of high transient current flow through the conductors 11 and 12 due to interruption of an inductive circuit, voltage surges in the circuit are limited by the portions of body 20 in series circuit as

will be explained below. The body also has the capability of absorbing considerable energy in the process as will be also explained below. In addition to providing a series impedance of particular characteristics, the body of metal oxide varistor material also provides a shunting impedance which maintains the voltage between the electrodes to a value determined by the voltage versus current density characteristics of the material as will be apparent in connection with FIG. 4.

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. 4. Graphs 40 and 41 are materials of high voltage gradient material and graph 42 is a graph of low voltage gradient material. For all of the graphs in the current density range 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, duPont No. 7713, made by the duPont 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 surfaces 21 and 22 of body 20 is fixed by power connector design practice. Accordingly, to provide an appropriate low current drain through the wafer 20 under normal operating voltages for the plug, the metal oxide varistor material with the appropriate voltage gradient versus current density characteristics is selected. The surfaces 21 and 22 extend beyond the end of the electrodes 11 and 12 for a distance to allow adequate absorption of transient surges which are produced by the disengagement of the connector 10 from its mating connector 30 of FIG. 3.

Reference is now made to FIGS. 5 and 6 which show another embodiment of the present invention. The connector 50 includes a pair of elongated 51 and 52 electrodes having respective longitudinal axes 53 and 54 which are generally parallel in orientation. One end of each of the electrodes 51 and 52 is embedded in a plastic insulating block 55 of casing. Each of the adjacent ends of the elongated conductors 51 and 52 within the casing is connected, for example, by soldering, to a respective conductor of a pair of conductors 56 and 57 of a cable 58. The adjacent other ends of the elongated electrodes 51 and 52 are spaced with their axes generally parallel. A pair of cylindrical elongated members 59 and 60 of metal oxide varistor material is provided, at the ends of each of the electrodes respectively. Each

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of the elongated members 51 and 52 of metal oxide varistor material is secured to the respective electrode by means of insulating screws 61 and 62, for example, of nylon which extends through holes along the axis of the body member into threaded portions of the electrodes 51 and 52.

The connector of FIGS. 5 and 6 is suitable for use with a receptacle 65 such as is shown in FIG. 6. The receptacle 65 includes a generally insulating support body 66 which has a parallel pair of cylindrical holes 67 and 68. A pair of resilient semi-cylindrical conductive fingers are secured in each of the holes to the body 66 to provide a pair of resilient mating electrodes 69 and 70 for engagement with respective electrodes 51 and 52 of the connector 50. On insertion of the connector 50 into the receptacle 65 of FIG. 6, the elongated members 59 and 60 of metal oxide varistor material make initial contact with the mating conductors 69 and 70, respectively, and similarly, on removal of the connector 50 from the receptacle 65, contact is initially broken between the elongated electrodes 51 and 52 and the respective mating conductors 69 and 70 and subsequently, between the elongated members 59 and 60 of metal oxide varistor material and the respective mating conductors 69 and 70. Accordingly, when circuit connections in which inductive currents are flowing are broken, the inductive voltage surges are absorbed by the metal oxide varistor material and limited to safe or desired values.

Reference is now made to FIGS. 8 and 9 which show another embodiment of the present invention. The connector 80 includes a pair of elongated electrodes 81 and 82 having respective longitudinal axes 83 and 84 which are generally parallel in orientation. Each of the conductors 81 and 82 has a pair of parallel major opposed surfaces. One end of each of the electrodes 81 and 82 is embedded in a plastic insulating block 85 or casing. Each of the adjacent ends of the elongated conductors 81 and 82 within the casing is connected for example, by soldering, to a respective conductor of a pair of conductors 86 and 87 of cable 88. The adjacent other ends of the elongated electrodes 81 and 82 are spaced with their flat opposed surfaces generally parallel for insertion in a power outlet such as shown in FIG. 3. Also provided is a block of insulating material 89 having a pair of opposed surfaces 91 and 92 to which are secured respective slabs 93 and 94 of metal oxide varistor material. Each of the slabs 93 and 94 have a pair of opposed surfaces, one of which is secured to an adjacent opposed surface of the insulating member 89 and the other opposed surface of which is connected to a respective inwardly directed opposed surface of an adjacent elongated electrode. The slabs 93 and 94 are co-extensive with the insulating member in direction of the longitudinal axes of the electrodes 81 and 82 and extend beyond the end of the electrodes at one end. The other end of the block 89 and attached slabs 93 and 94 is bonded or embedded to the insulating block 85 or casing. The operation of the connector of FIGS.

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7 and 8 is similar to the operation of the connectors of FIGS. 1 and 5.

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,

one of said electrodes being an elongated electrode, one end of said elongated electrode adapted to engage a mating conductor, the other end of said elongated electrode being provided with means for connecting the electrode in circuit,

a member of metal oxide varistor material in contact with said elongated electrode and extending beyond said one end whereby when said elongated electrode is caused to engage said mating conductor said mating conductor makes contact first with said member of metal oxide varistor material.

2. The combination of claim 1 in which said 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.

3. The combination of claim 1 in which said member of metal oxide varistor material limits the voltage between said elongated electrode and said mating conductor to a low value when they are initially disengaged determined by the separation of said elongated electrode from said mating conductor and by the voltage gradient versus current density characteristic of said material.

4. The combination of claim 1 in which the other of said electrodes is an elongated electrode, one end of said other elongated electrode adapted to engage another mating conductor, the other end of said other electrode being provided with means for connecting said other electrode in circuit, another member of metal oxide varistor material in contact with said other elongated electrode and extending said one end thereof, the longitudinal axes of said elongated electrodes being substantially parallel.

5. The combination of claim 4 in which said members of metal oxide varistor material are elongated slabs in which the longitudinal axes thereof are parallel to the longitudinal axis of said elongated electrodes.

6. The combination of claim 4 in which said members of metal oxide varistor material are surface adjacent portion of a block of metal oxide varistor material in contact with adjacent opposed surfaces of the conductive electrodes, said block extending beyond said one end of said conductive electrodes.

7. The combination of claim 4 in which said members of metal oxide varistor material are elongated members secured to the ends of said elongated electrodes.

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