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[54] **SPARK-SUPPRESSING BRUSH-BRUSH HOLDER ASSEMBLY FOR ROTATING MACHINES AND SLIDING CONTACTS**

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[73] Assignee: **General Electric Company**, Schenectady, N.Y.

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[52] **U.S. Cl.** **310/220,** 310/239
[51] **Int. Cl.** **H02k 13/06**
[58] **Field of Search** 310/220, 221, 222, 310/223, 224, 248, 249, 239, 242, 240, 244, 250, 251, 252, 253, 254; 252/518; 264/61, 104

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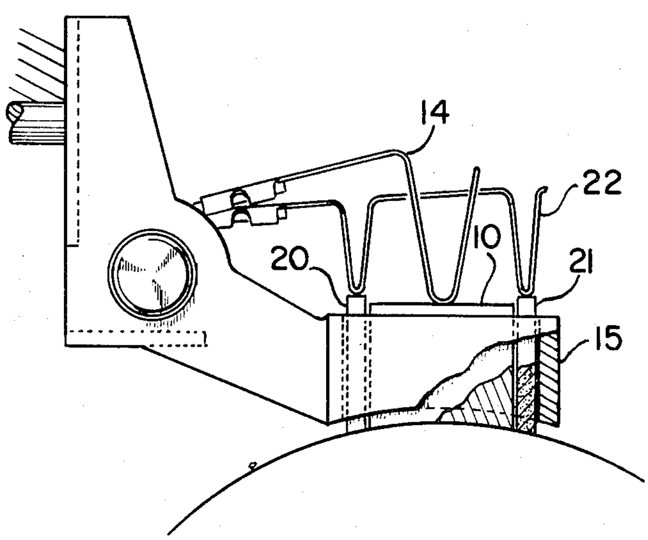
[57] **ABSTRACT**

The inclusion of a body of polycrystalline metal oxide varistor material in a brush or brush holder for the suppression of sparking between sliding contacts is disclosed. The body of metal oxide varistor material may form part of a brush contact at a leading or trailing edge thereof or may be the material comprising all, or part of a brush holder in slidable contact with the brush contact and a second contact. Accordingly, the initial electrical connection and, or the final electrical connection, between the brush contact and the other slidable contact is through the varistor material thereby reducing sparking as the sliding contacts make and break connection.

29 Claims, 6 Drawing Figures



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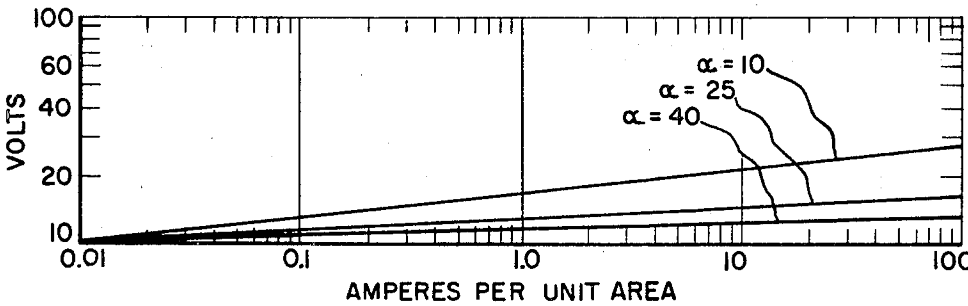

Fig.1

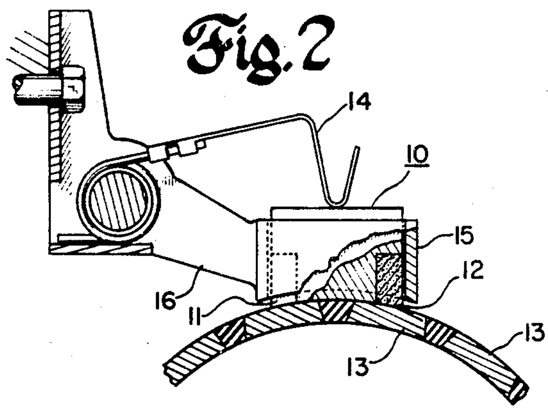

Fig.2

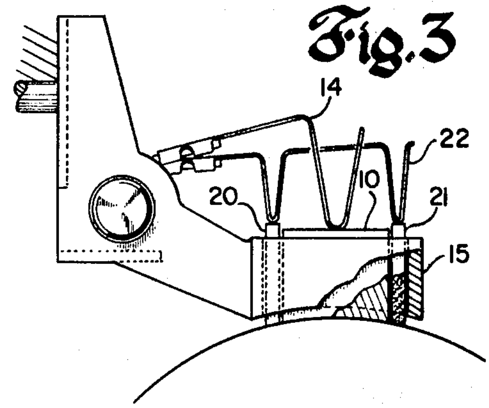

Fig.3

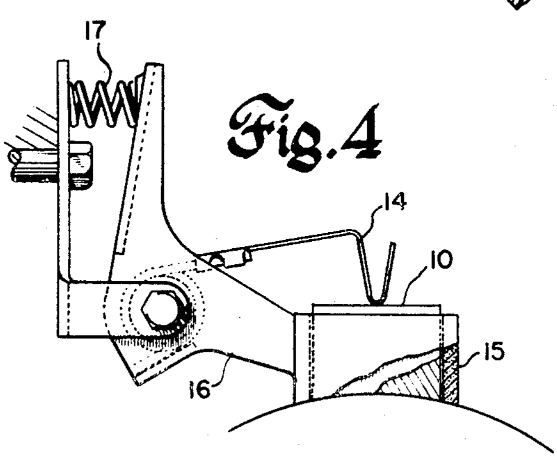

Fig.4

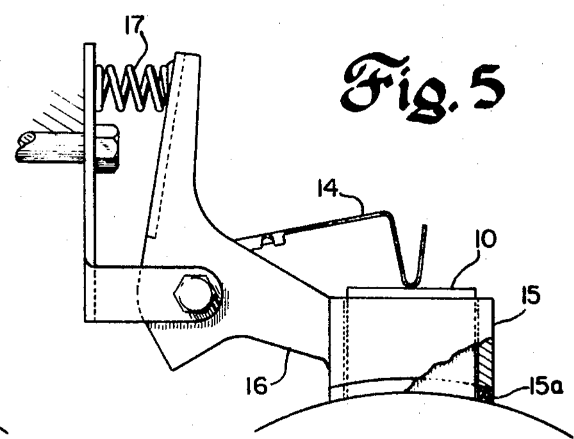

Fig.5

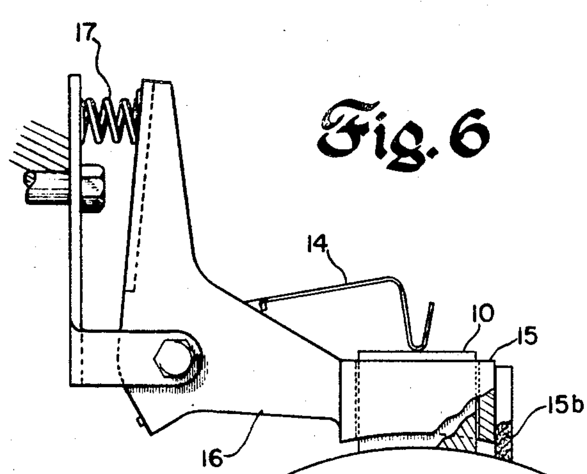

Fig.6

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SPARK-SUPPRESSING BRUSH-BRUSH HOLDER ASSEMBLY FOR ROTATING MACHINES AND SLIDING CONTACTS

Our invention relates to an improved electric current collection means utilizing a body of metal oxide varistor material, and in particular, to a brush-brush holder assembly wherein the brush or brush holder is comprised in part by such metal oxide varistor mateiral in the current path between the brush and commutator segment upon parting of the commutator segment from the brush whereby the nonlinear resistance characteristics of the metal oxide varistor material causes substantially reduced sparking.

The brushes in rotating brush-type machines and the like are generally fabricated of carbon, a relatively poor electrical conductor, reinforced by other materials. The brushes are retained in position by brush holders which generally are in the form of square or rectangular sleeves serving as a guide for any radial motion of the brush resulting from vibration or eccentricity of the armature. The brush holder may be mounted on a bracket to maintain a rigid position spaced from the commutator surface. An adjustable spring connected to the bracket bears on the top surface of the brush to maintain a desired contact pressure of the bottom surface of the brush upon the commutator segments.

The electrical current which is commutated in various rotating electrical brush-type machines such as a universal motor and direct current motor, and in apparatus such as a variable autotransformer, is inductive in nature and therefor tends to produce transient voltages between the commutator segment and brush when the two part, resulting in sparking. The sparking results in excessive brush wear, commutator bar deterioration and radio interference among other disadvantages, and can lead to flashovers to high current levels all of which limit machine performance. The prior art has been directed to various improvements in design of rotating machines in order to reduce brush-commutator sparking through different types of brushes, the use of commutating poles and electronic commutating circuits, and increased number of commutator bars or segments but the sparking is still often considered to be excessive.

Therefore, one of the principal objects of our invention is to provide an improved electric current collection means.

Another principal object of our invention is to provide a brush-brush holder assembly which provides superior spark-suppression between the brushes and commutator.

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 considertion, I is the current flowing between the two points, C is a constant and α is an exponent greater and **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 an 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 found for this new metal oxide varistor material, also referred to herein as MOV, a trademark of the General Electric Company. Although the alpha of the MOV materials in which range the alpha remains substantially constant, are identified by the current desnity 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 predeominant 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 varistor 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 varistor 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 approximately 10,000 megohms) at very low current levels in the mircoampere 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 breakdown 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 materiaal 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 severals 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, soldred, and operated at very low voltages, capabilities not possible for the larger grained silicon carbide.

Therefore, another principal object of our invention is to provide a body of metal oxide varistor material in the current path between the brush and the commutator segment of a rotating electrical machine when they part to obtain the reduced spark suppression.

A further object of our invention is to form at least one portion of the brush of the metal oxide varistor material.

A still further object of our invention is to form at least a portion of the brush holder of the metal oxide varistor material.

In accordance with our invention, we provide an improved brush-brush holder assembly wherein a body of metal oxide varistor material having an alpha exponent in excess of 10 is included in the current path between the brush and a segment of the commutator when they part. The nonlinear resistance characteristic of the metal oxide varistor material limits the voltage build-up across the parting segment and brush and thereby provides superior spark-suppression during operation of the rotating machine.

The body of metal oxide varistor material can be integrated into the brush along the leading and, or trailing edges thereof as one embodiment of our invention. Such material can also be incorporated into the brush holder as the whole or merely bottom portion thereof bearing against the commutator segments to thereby enhance the transfer of current between brush and commutator segments with reduced sparking.

The features of our invention which we 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 drawings 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 vs. amperes on a log-log scale;

FIG. 2 is an elevation view, partly in section, of a brush-brush holder assembly in accordance with our invention wherein the brush is fabricated with the MOV meterial along its leading and trailing edges;

FIG. 3 is an elevation view, partly in section, of a brush-brush holder assembly wherein bodies of MOV material are located between the brush holder and brush along both the leading and trailing edges;

FIG. 4 is an elevation view, partly in section, indicating an entire brush holder fabricated of the MOV material;

FIG. 5 is an elevation view, partly in section, indicating the bottom portion of the brush holder fabricated of the MOV material; and

FIG. 6 is an elevation view, partly in section, indicating a body of MOV material attached along the trailing edge of the brush holder.

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 α. The VOLTS abscissa is in terms of the brush-to-commutator segment voltage drop 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 to lower plots higher current levels would obviously indicate correspondingly much higher and lower resistances, respectively, and operation of the subject machines may transiently reach such levels. The "leakage" current through the MOV material is negligible compared to the rated machine current during normal operating conditions.

Referring now to FIG. 2, there is shown an improved brush-brush holder assembly constructed in accordance with our invention wherein the MOV material is incorporated in selected portions of the brush. The brush, illustrated as a whole by numeral 10 may comprise a conventional carbon brush but having leading and trailing edge portions thereof being fabricated of the hereinabove described MOV material. The MOV portions, 11, 12 may be of rectangular form as illustrated, as one example of the many shapes of such MOV portions. The MOV bodies 11 and 12 are suitably bonded to the main body of the brush 10 such that the entire brush body forms the conventional generally rectangular shape associated with brushes. The bonding may be accomplished by low temperature soldering or by pressure contact as two examples, in both cases a metallized surface being utilized on the MOV material. The metallized surface may be obtained, for example, by firing a thin layer of glass and silver particles on the MOV surface. Ohmic contact is utilized, in general, in order to take advantage of the bulk phenomenon operation of the MOV material. The bottom surfaces of the MOV bodies 11 and 12 are slightly curved and flush with the bottom surface of brush 10 which is in contact with the upper surfaces of the electrically conductive segments 13 of the commutator.

The brush 10 is in contact with the surface of the commutator (i.e., rides on the surface thereof) due to the force of a spring applied by brush spring **14** against the top surface of brush **10**. Brush **10** is maintained in its desired position relative to the commutator by means of brush holder **15** which is held in a fixed position spaced from the surface of the commutator by means of bracket **16**. Brush holder **15** is of conventional design comprising a rectangular sleeve fabricated of a high strength metal and serves as a guide for any radial motion of the brush **10** resulting from vibration or eccentricity of the armature or commutator. For purposes of simplicity, the flexible copper cable generally described as a brush shunt or pigtail which is often employed for directing the current from the brush to the brush holder is not illustrated but can be employed, as desired.

The MOV material preferably comprises 10–30 percent of the volume of the brush **10** although it should be evident that lesser and greater amounts of such MOV material may be utilized as required by particular applications without departing from the scope of our invention. The particular choice of the percentage of MOV material will depend on the optimal choice of number of commutator bars or segments which may be reduced as a result of our invention and the corresponding need for greater energy absorption in the MOV material. In the case wherein the machine rotates only in a single direction, it may be sufficient to provide the MOV material along only the trailing edge of the brush **10**. The MOV material by being located in at least the trailing edge of the brush is therefore in the current path of the brush when such brush and commutator segment first part upon rotation of the commutator. The high thermal conductivity of the MOV material also permits cooler operation of the brushes.

The principal advantage of our invention is, of course, the superior suppression of sparks and arcs which tend to develop particularly between the trailing edgs of the brushes and the commutator segments, or alternatively, to permit construction of a machine having fewer commutator segments and corresponding higher speed and lower costs. This superior suppression is obtained primarily due to the following three exceptional properties of MOV material (1) the resistance characteristics are highly nonlinear ($\alpha > 10$) over a very wide range of current and result in a high degree of voltage limiting, (2) the response time is negliglble, and (3) the high thermal conductivity permits rapid dissipation of heat developed in the commutator-brush spark generating phenomenon. In conventional commutation, upon initial parting of the commutator segment and brush, the current cannot change instantaneously and the inductive voltage $e = L\ (di/dt)$ must increase to force the same current flow to continue thereby creating the sparking and possible resulting arcing. However, the use of our body of MOV material limits the voltage build-up across the parting segment and brush and provides a relatively low resistance path for the current which thence decays at a rate determiuned primarily by the LR time constant of the machine or until a current zero is reached, the resistance of the MOV body increasing substantially as the voltage, and primarily the current, are decreasing. That is, the body of MOV material remains in the path of the current after the brush and commutator segment have first parted due to the location and geometry of such MOV body, and since the path of the current increases as the segment moves away from under the brush, the brush-to-segment voltage drop slowly increases and rapidly dissipates the stored inductive energy until, as the segment leaves the MOV body, the energy has reached zero. The amount of MOV material in the brush, and in particular, the ratio of the bottom surface of the MOV material to the bottom surface of the entire brush is chosen such that at maximum machine speed there is no current at the separation time of the body of MOV material and segment. Thus, commutator-brush sparking is substantially eliminated, or at least significantly reduced with our brush as compared to conventional brushes.

FIG. **3** illustrates an embodiment of our invention wherein two slabs of the MOV material **20** and **21** are inserted in the brush holder and retained therein between the inner end surfaces thereof and the outer leading and trailing end surfaces of a conventional carbon brush **10**. The MOV bodies **20** and **21** are spring loaded by means of spring **22** independently of the spring loading of brush **10** as provided by spring **14** bearing on the brush top surface. Bodies **20** and **21** may be each of substantially rectangular form and, as mentioned with reference to the FIG. **2** embodiment, it would be adequate to utilize only a single scuh body along the trailing edge of the brush for single direction rotating machines. The advantage of the FIG. **3** embodiment is that the separate spring loading of the MOV body and the brush provides compensation for differences in wear rate of the MOV mateirial and brush material as well as for the thermal expansion and contractions thereof.

A third embodiment of our invention is illustrated in FIG. **4** wherein the entire brush holder **15** is fabricated of the MOV material and a spring **17** forces the bottom surface of brush holder **15** to maintain a desired pressure contact with the rotating commutator. The brush **10** is of the conventional type in this particular embodiment.

FIG. **5** illustrates a fourth embodiment of our invention which is very similar to the embodiment illustrated in FIG. **4** except that the MOV material **15*a*** is located only along the bottom portion of the brush holder **15** since this is the optimum position of such material to enhance commutation. The brush holder **15** is also in contact with the rotating commutator as in the case of the FIG. **4** embodiment although it is evident that only the MOV portion **15*a*** thereof is in contact with the commutator. The MOV portion **15*a*** of the brush holder is rigidly fastened to the main body **15** of the brush holder by any convenient means such as bonding.

A fifth embodiment of our invention is illustrated in FIG. **6** wherein a conventional carbon brush **10** is utilized and a body of the MOV material is mounted along the trailing end of a conventional brush holder **15** and extends beyond the bottom surface thereof. Thus, a generally rectangular body of MOV material **15*b*** may be rigidly attached to the inner or outer surface of the trailing end of the brush holder, or alternatively, may form a trailing end thereof by being suitably connected across the adjacent two side walls of the brush holder. The body of MOV material may be located only along the lower portions of the trailing end of the brush holder and when forming the trailing end thereof may also be only along the lower portion thereof, the upper end portion remote from the commutator being fabricated of the conventional brush holder material which forms the other three sides. In the case of a reversible machine, the MOV bodies 15b are located along both the leading and trailing edges of the brush holder. Spring 17 causes the bottom surface of MOV body 15b, but not the remaining bottom surface of the brush holder, to bear against the commutator and body 15b is thus spring loaded independnetly of a brush 10. In all of the above applications, the MOV body is selected for a normal operating voltage just slightly above the expected commutator segment-to-segment (or brush) voltage drop.

Having described five embodiments of our improved brush-brush holder assembly, it should be obvious that the bodies of MOV material can assume any of a number of shapes as dictated by the particular applications and may be positioned somewhat differently from that illustrated in the drawings, the criteria being that such body or bodies of MOV material be located in the resulting path of the current between the brush and commutator segment upon parting thereof. Although only one brush is shown in each of FIGS. 2–6, it should be apparent that a conventional parallel array of separted brushes may also be retained in a brush holder, especially in the large size machines. The brush-brush holder and geometry of such assemblies can also be of other forms than that illustrated, as commonly used in smaller electric machines such as vacuum cleaners, mixers, hand tools, and the like, and the invention can also be utilized with nonrotating machines such as a tap changer or brush shifters in variable autotransformers. In this latter case, a brush having a flat bottom surface contacts flattened areas of a conductor or conductors wound on a magnetic body and the brush is moved in a circular arc. Our invention thus is broadly directed to improved electric current collection means wherein two electrically conductive members are adapted to move relative to each other and are in close proximity to each other for achieving electric current transfer therebetween. A body of the metal oxide varistor material is disposed in conjunction with the current path between the two members and results in improvement of the current transfer, and, or improved commutation of the current. The invention is also applicable in this general area of electric current collection as employed in various types of slip-rings, third-rail collectors, and trolley wire-panograph current collectors. Our invention thus introduces a new freedom of design in brush-type machines whereby the normal commutation bar-to-bar voltage restriction is alleviated thus permitting realization of machine design with higher operating speed, increased surge-current handling capability, simplified machine construction and maintenance, and greater economic freedom.

Thus, while our invention has been particularly shown and described with reference to five 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 we claim as new and desire to secure by Letters Patent of the United States is:

1. An improved spark-suppressing brush-brush holder assembly for rotating electrical brush-type machines and the like comprising

a spring-loaded brush,

a brush holder for retaining said brush in a generally fixed position relative to a rotating commutator against which said brush maintains a contact pres-

sure determined by the spring-loading thereof, and

a body of metal oxide varistor material forming a portion of said brush along the trailing edge thereof in contact with the commutator disposed in the current path between said brush and segment of the commutator when the brush and commutator segment part during rotation of the commutator, the body of metal oxide varistor material having nonlinear resistance characteristics which limit the voltage developed across the commutator segment and brush when they first part.

2. The improved brush-brush holder assembly set forth in claim 1 wherein

said body of metal oxide varistor material is a first body forming a portion of said brush along the trailing edge thereof in contact with the commutator and a second body forming a portion of said brush along the leading edge thereof in contact with the commutator.

3. The improved brush-brush holder assembly set forth in claim 1 wherein

said body of metal oxide varistor material comprises a first body spring loaded independently of the spring loading of said brush and retained between the trailing end surface of said brush and an adjacent inner end surface of said brush holder, the indepenent spring loading of said brush and said body of metal oxide varistor material providing compensation for differences in wear rate of the metal oxide varistor material and brush material due to contact with the rotating commutator.

4. The improved brush-brush holder assembly set forth in claim 3 and further comprising

a second body of metal oxide varistor mateiral spring loaded independently of the spring loading of said brush and retained between the leading end surface of said brush and an adjacent inner end surface of said brush holder.

5. The improved brush-brush holder assembly set forth in claim 3 wherein

said first body of metal oxide varistor material is of a generally rectangular shape.

6. The improved brush-brush holder assembly set forth in claim 1 wherein

said brush holder is fabricated of said body of metal oxide varistor material, and including

spring means in communication with said brush holder for maintaining a contact pressure of the bottom surface of said brush holder upon the commutator.

7. The improved brush-brush holder assembly set forth in claim 1 wherein

a bottom portion of said brush holder is fabricated of said body of metal oxide varistor material, and including

spring means in communication with said brush holder for maintaining a contact pressure of the bottom surface of said brush holder upon the commutator.

8. The improved brush-brush holder assembly set forth in claim 1 wherein

a bottom portion of said brush holder along the trailing end thereof is fabricated of said body of metal oxide varistor material and extends beyond the bottom surface of the remainder of said brush holder, and including spring means in communication with said brush holder for maintaining a contact pressure of the bottom surface of said body of metal oxide varistor material upon the commutator.

9. The improved brush-brush holder assembly set forth in claim 1 wherein

said body of metal oxide varistor material is rigidly attached to an end surface of said brush holder along the trailing edge thereof and extends beyond the bottom surface of said brush holder, and including

spring means in communication with said brush holder for maintaining a contact pressure of the bottom surface of said body of metal oxide varistor material upon the commutator.

10. The improved brush-brush holder assembly set forth in claim 1 wherein

said body of metal oxide varistor material is connected across two side walls of said brush holder to form the trailing end thereof, said body of metal oxide varistor material extending beyond the bottom surface of said brush holder, and including

spring means in communication with said brush holder for maintaining a contact pressure of the bottom surface of said body of metal oxide varistor material upon the commutator.

11. The improved brush-brush holder assembly set forth in claim 1 wherein

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

12. An improved spark-suppressing brush-brush holder assembly for brush-type electrical machines comprising

a spring-loaded brush,

a brush holder for retaining said brush in a desired position relative to one or more electrical conductors against which said brush maintains a contact pressure determined by the spring-loading thereof, and

a body of metal oxide varistor material forming a portion of said brush along the trailing edge thereof in contact with one of said conductors disposed in the current path between said brush and said conductors when the brush and said conductors part during relative motion between said conductors and brush-brush holder assembly, the body of metal oxide varistor mateiral having nonlinear resistance characteristics which limit the voltage developed across the brush and each conductor when they first part.

13. The improved brush-brush holder assembly set forth in claim 12 wherein

said body of metal oxide varistor material is a first body forming a portion of said brush along the trailing edge thereof and a second body forming a portion of said brush along the leading edge thereof.

14. The improved brush-brush holder assembly set forth in claim 12 wherein

said body of metal oxide varistor material comprises a first body spring loaded independently of the spring loading of said brush and retained between the trailing end surface of said brush and an adjacent inner end surface of said brush holder, the independent spring loading of said brush and said body of metal oxide varistor material providing compensation for differences in wear rate of the metal oxide varistor material and brush material due to the relative motion between said conductors and brush-brush holder assembly.

15. The improved brush-brush holder assembly set forth in claim 14 and further comprising

a second body of metal oxide varistor material spring loaded independently of the spring loading of said brush and retained between the leading end surface of said brush and an adjacent inner end surface of said brush holder.

16. The improved brush-brush holder assembly set forth in claim 14 wherein

said first body of metal oxide varistor material is of a generally rectangular shape.

17. The improved brush-brush assembly set forth in claim 12 wherein

said brush holder is fabricated of said body of metal oxide varistor material, and including

spring means in communication with said brush holder for maintaining a desired contact pressure of the bottom surface of said brush holder upon the conductors.

18. The improved brush-brush holder assembly set forth in claim 12 wherein

a bottom portion of said brush holder is fabricated of said body of metal oxide varistor material, and including

spring means in communication with said brush holder for maintaining a contact pressure of the bottom surface of said brush holder upon the conductors.

19. The imrpoved brush-brush holder assembly set forth in claim 12 wherein

a bottom portion of said brush holder along the trailing end thereof is fabricated of said body of metal oxide varistor material and extends beyond the bottom surface of the remainder of said brush holder, and

spring means in communication with said brush holder for maintaining a contact pressure of the bottom surface of said body of metal oxide varistor material upon the conductors.

20. The improved brush-brush holder assembly set forth in claim 12 wherein

said body of metal oxide varistor material is rigidly attached to an end surface of said brush holder along the trailing edge thereof and extends beyond the bottom surface of said brush holder, and

spring means in communication with said brush holder for maintaining a contact pressure of the bottom surface of said body of metal oxide varistor material upon the conductors.

21. The improved brush-brush holder assembly set forth in claim 12 wherein

said body of metal oxide varistor material is connected across two side walls of said brush holder to form the trailing end thereof, said body of metal oxide varistor material extending beyond the bottom surface of said brush holder, and

spring means in communication with said brush holder for maintaining a contact pressure of the bottom surface of said body of metal oxide varistor material upon the conductors.

22. The improved brush-brush holder assembly set forth in claim 12 wherein

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

23 An improved electric current collection means comprising

first and second electrically conductive members adapted for relative motion between each other and in close proximity to each other for achieving current transfer therebetween, and

a body of metal oxide varistor material forming a portion of said first member along a surface which is in close proximity to said second member disposed in conjunction with the current path between said first and second members for improving the current transfer and, or the commutation of the current.

24. The improved current collection means set forth in claim **23** wherein

said body of metal oxide varistor material comprises a first body retained along the trailing end surface of said first member.

25. The improved current collection means set forth in claim **24** and further comprising

a second body of metal oxide varistor material retained along the leading end surface of said first member.

26. The improved current collection means set forth in claim **24** wherein

said first body of metal oxide varistor material is of a generally rectangular shape.

27. The improved current collection means set forth in claim **23** and further comprising

means for retaining said first member in a desired position relative to said second member, a portion of said retaining means in closest proximity to said second member fabricated of said body of metal oxide varistor material.

28. The improved current collection means set forth in claim **23** and further comprising

means for retaining said first member in a desired position relative to said second member, said body of metal oxide varistor material rigidly attached to an end surface of said retaining means along the trailing edge thereof and extending beyond the surface thereof in closest proximity to said second member.

29. The improved current collection means set forth in claim **23** wherein

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

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