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Digirolamo et al.

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[54] ABRADED VARIABLE RESISTANCE CONTROL AND METHOD OF MANUFACTURE

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[52] **U.S. Cl.** **338/174,** 338/195, 29/620

[51] **Int. Cl.** **H01c 9/02**

[58] **Field of Search** 338/195, 174, 162; 29/620, 29/610

[56] **References Cited**

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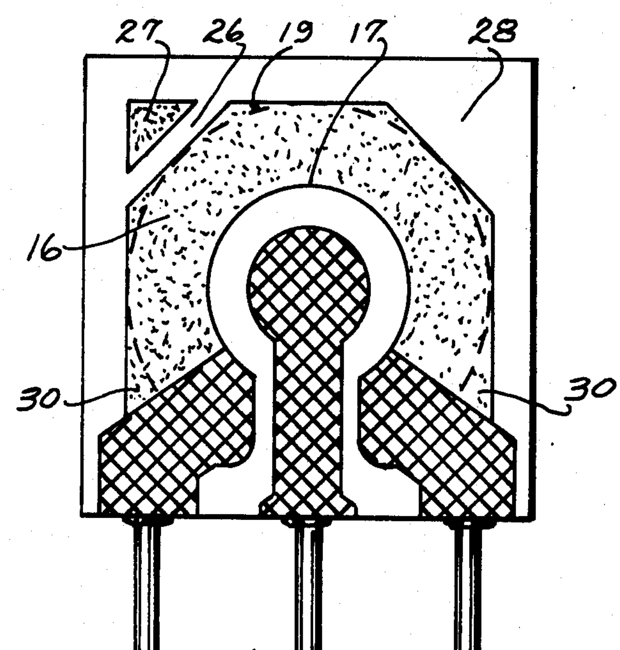
[57] **ABSTRACT**

A variable resistance control is provided wherein a resistance path having an inner edge defined by a circular arc and an outer edge defined by straight lines tangent to an imaginary circular arc concentric with the circular arc defining the inner edge is supported on a nonconductive base. The straight lines intersect to define corners at the outer periphery of the resistance path. In order to bring the resistance within specified tolerances without materially affecting the linearity of the resistant path, the corners are abraded by removing a portion of the resistance material between the imaginary circular arc and the outer edge at the corners.

11 Claims, 5 Drawing Figures



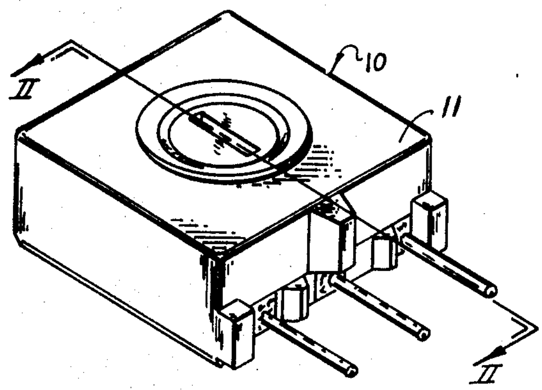


FIGURE-1

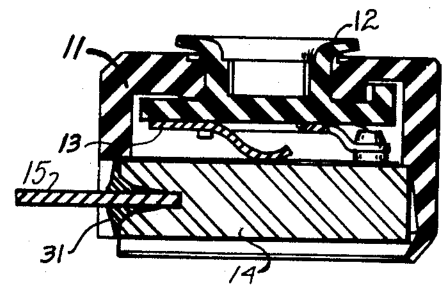


FIGURE-2

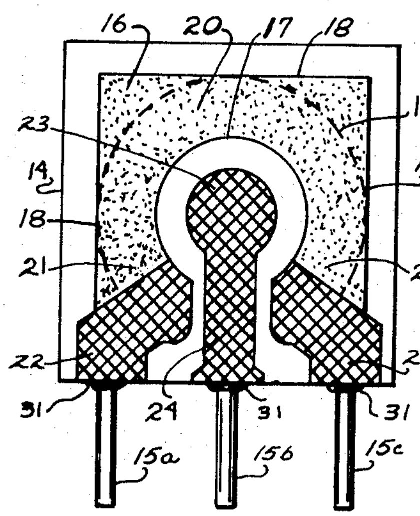


FIGURE-3

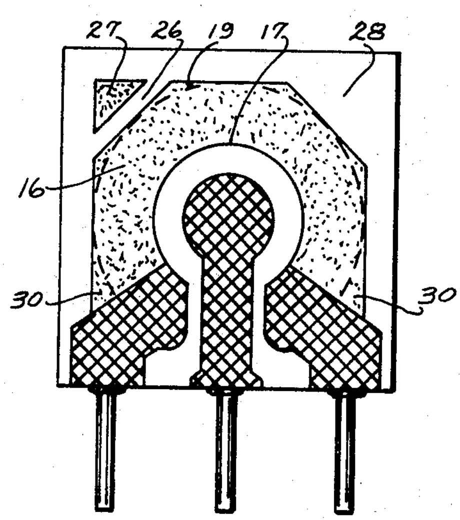


FIGURE-4

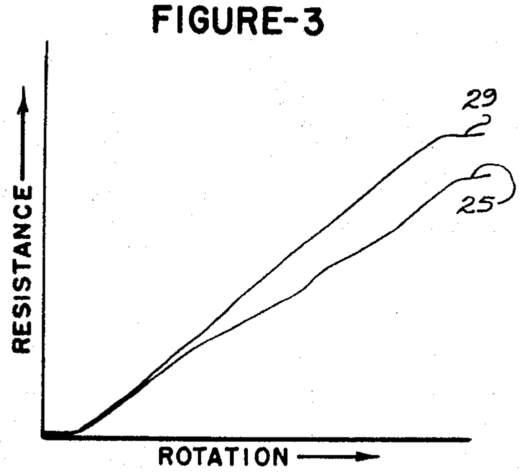


FIGURE-5

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ABRADED VARIABLE RESISTANCE CONTROL AND METHOD OF MANUFACTURE

The present invention relates to variable resistance controls and, more particularly, to an abraded resistance element for a variable resistance control and a method of making such an element.

Resistance elements are commonly made by applying a resistance material as a thin layer or film on a nonconductive support or base. Cermet resistance materials formed of a mixture of finely divided glass and a conductive fraction are deposited in a viscous mixture on a nonconductive base and fired at high temperatures to form a resistance element or film that is hard and smooth. The resistance of such a film is a function of the length, width and thickness of the deposited film. In processing these elements it is difficult to obtain the exact value desired since slight changes in the length, width and thickness of the fired film bring about variations between the desired end resistance and the actual resistance. It is important that the resistance gradients of these elements conform within exceedingly close tolerances to the specification of any circuit in which they are to be used. Accordingly it would be desirable to manufacture these elements having uniformity within specified tolerances.

In the past resistance elements have been brought within the desired tolerances by abrading a portion of the resistance film such as shown in Schellanger U.S. Pat. No. 2,082,980. In order to achieve predictability and fall within the desired tolerances required by the specification of the circuit, any abrupt changes in the linearity of the resistance element must be eliminated. Since the current takes the shortest possible path through a resistance element, the current density of an arcuate resistance element is highest at the inner edge. Since the current density is highest around the inner edge, it is difficult to abrade the inner edge without bringing about abrupt changes in the linearity of the resistance element. Accordingly it would be desirable to provide a method of abrading a resistance element without bringing about undesirable abrupt changes in the resistance.

Another problem associated with abrading the resistance element relates to the requirement that the surface to be traveled by the movable contactor must be smooth and uncut. In the preparation of a resistance element any deviation from the smooth uncut surface in the area wherein the movable contactor wipes the surface will result in corresponding undesirable electrical noise as the contactor moves about its path. Since the width of the film is usually quite small, the amount of correction that may be accomplished by abrading without affecting the path of the movable contactor has been limited. Accordingly it would be desirable to provide an abraded resistance element wherein the resistance path can be abraded to bring about a substantial increase in resistance without affecting the surface to be traversed by the contactor.

In the past when the inner edge has been abraded it has been found that it is preferable to merely remove a small portion around the complete inner edge thus raising the resistance without bringing about an abrupt change. With the present day desire for the miniaturization of such controls this brings about a serious limitation. Since the inner edge of the arcuate path must be spaced from the collector a distance sufficient to provide for electrical clearance, an increase of material on the inner edge to provide for abrading would result in a wider control as the spacing of the inner edge from the collector would have to be calculated for those elements which would not require abrading. Accordingly it would be desirable to provide a resistance element wherein the resistance can be increased without requiring additional material along the inside edge and corresponding increased width of the overall element.

Accordingly it is a general object of the present invention to provide a variable resistance element which can be abraded to bring the element within specified tolerances. Another object of the present invention is to provide a variable resistance element having a smooth uncut path surface for traversal by a movable contactor. An additional object of the present invention is to provide a variable resistance element wherein the resistance value of the element can be varied without substantially changing the linearity of the element. Yet another object of the present invention is to provide a variable resistance element wherein the resistance value of the element can be varied without increasing the width of the element. A further object of the present invention is to provide a variable resistance element having a square pattern with abradable corners for bringing the resistance element within specified tolerances. Further objects and advantages of the present invention will become apparent as the following description proceeds and the features of novelty characterizing the invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

Briefly, the present invention is concerned with a variable resistance element wherein a resistance material forming a resistance path is deposited on a nonconductive support. The resistance path has an inner edge partially defined by a circular arc equidistant from a center point and an outer edge lying outside an imaginary circular arc concentric with the circular arc defining the inner edge. A conductive material forming a conductive path is deposited on the nonconductive support and spaced from the inner edge of a resistance path a sufficient distance to provide for electrical clearance. Terminals are inserted in the nonconductive support and electrically connected to the resistance path and the conductive path. In a preferred embodiment the outer edge is defined by straight lines tangent to the imaginary circular arc. The straight lines intersect to define corners at the outer periphery of the resistance path. To bring the resistance element within specified tolerances without materially affecting the linearity of the resistance element, the corners are abraded by removing a portion of the resistance material between the imaginary circular arc and the outer edge of the corner.

For a better understanding of the present invention reference may be had to the accompanying drawings wherein the same reference numerals have been applied to like parts and wherein:

FIG. 1 is an isometric view of a variable resistance control built in accord with the present invention;

FIG. 2 is a cross section of a variable resistance control embodying the present invention taken along lines II—II of FIG. 1;

FIG. 3 is a top plan view of a variable resistance element built in accord with the present invention;

FIG. 4 is a top plan view of the variable resistance element shown in FIG. 3 with portions abraded in accord with the present invention; and

FIG. 5 is a graph showing resistance of the element before and after abrading.

Referring now to the drawings, the variable resistance control is generally indicated at **10** in FIG. **1**. FIGS. **1** and **2** are substantially as shown and described in application Ser. No. 704,843 filed Feb. 12, 1968, and assigned to the assignee of the present invention. That application discloses a variable resistance control the structure of which can be used with the variable resistance element disclosed in this application and is incorporated herein by reference. As best shown in FIG. **2**, the control **10** comprises a dust excluding housing **11**, a rotatably supported control operating means in the form of a driver **12**, a movable contactor **13**, and a nonconductive base **14**. Terminal pins **15** extend from the base **14** for connection to an electrical circuit.

A resistance material defining a resistance path **16** is applied to the base **14** by any suitable operation such as brushing, spraying of silk screening. The resistance material can be formed of a cermet resistance material comprising a nonconductive glass binder material having minute particles of a conductive fraction dispersed throughout such as disclosed in Faber, Sr. et al. U.S. Pat. No. 3,304,199 assigned to the same assignee as the present invention. After the resistance material is deposited onto the base **14** it is cured to bond the resistance material to the surface of the base **14** such as by firing at a suitable temperature to fuse the glass particles into a glass matrix as well known in the art. As shown in FIG. **3** the resistance path **16** has an inner edge partially defined by a circular arc **17** and an outer edge defined by intersecting straight lines **18**. The straight lines **18** are tangent to an imaginary circular arc **19** that is concentric with the circular arc **17** defining the inner edge of the resistance path **16**. Preferably, the outer edge of the resistance path **16**, as defined by the straight lines **18**, is spaced from the outer edge of the base **14**. This is especially desirable where a metal housing is utilized so as to provide electrical clearance between the outer edge of the resistance path **16** and the metal housing. Intersection of the straight lines **18** forms corners and defines an overall U-shaped resistance path with a bottom **20** and a pair of legs **21**. Conductive material in the form of conductive pads **22** is deposited on the base **14** at the end of the legs **21** to electrically connect the resistance path **16** to terminals **15***a* and **15***c* through a solder **31** surrounding the terminals **15***a*, **15***c*. Conductive material in the form of a center collector **23** is deposited on the base **14** and electrically connected to terminal **15***b* by means of deposited conductive material forming a conductive path **24** and solder **31** surrounding the terminal **15***b*.

It is obvious that the configuration of the resistance path **16** as shown in FIG. **3** provides for the optimum amount of resistance material that can be deposited on the base **14** and maintain the desired electrical clearance between the inner edge and the collector and between the outer edge and the housing. Previously a resistance path would have an inner edge corresponding to the circular arc **17** shown in FIG. **3** and an outer edge corresponding to the imaginary circular arc **19**. When using mechanized assembly and printing procedures it is desirable to have a square base for ease of handling. Accordingly the outer edge of the base would have to be spaced a sufficient distance from the imaginary circular arc **19** to provide the desired electrical clearances. Since the straight lines **18** are tangent to the imaginary circular arc **19** and parallel to the outer edge of the base **14**, the addition of the material outside of the imaginary circular arc **19** does not result in the need to widen the base **14**. When it was desired to abrade the prior art resistance elements around the inside edge of the resistance path, a corresponding increase in the width of the base was required to provide the necessary electrical clearances. The collector **23** must be spaced from the circular arc **17** a distance sufficient to provide for electrical clearance, such distance being dependent upon the particular parameters of the circuit for which the resistor is to be used. If the resistance path **16** were printed with additional material along the inside edge the distance between the inner edge as defined by circular arc **17** and the collector **23** must be determined for the element as originally printed since some and hopefully many of the elements will fall within the desired tolerances and not require abrading. Therefore if the width of the resistance path between the circular arc **17** and the imaginary circular arc **19** were untouched so as to provide for a smooth and uncut surface for the contactor **13** to travel, then the outer edge defined by the imaginary circular arc **19** as shown in FIG. **3** would have to be spaced outwardly from the present position shown in FIG. **3**. Accordingly the width of the base **14** would have to be enlarged to provide for the necessary electrical clearance between the housing and the outer edge of the resistance path **16**.

Ordinarily the resistance change for each incremental movement of an electrical contactor in contact with the resistance path is constant where the resistance path is formed of a homogenous resistance material and the thickness and width of the path are uniform. This constant incremental change produces a linear resistance element. Accordingly one would not expect a linear resistance element from the path shown in FIG. **3** since the width of the path varies from one point to another. One would expect a large departure in linearity at the corners of the resistance path **16** due to the large amount of resistance material lying between the straight lines **18** and the imaginary circular arc **19**. Surprisingly, this is not the case. In FIG. **5**, the curve **25** corresponds to the resistance versus rotation curve of a resistance element such as shown in FIG. **3**. While there are two slight depressions in the curve **25** corresponding to the corners of the resistance path **16**, the curve **25** does not have any abrupt changes in the resistance value and will conform within specified tolerances for the majority of applications. Thus it would not be necessary to abrade those elements that met the desired end resistance since the curve **25** is substantially linear and without undesirable abrupt changes. The substantial linearity of the resistance path **16** shown in FIG. **3** can be best explained by the fact that there is a low current density at the corners and accordingly the additional resistance material in the corners is thought to have little effect on the overall resistance value of the element. This is because more electrical current will flow along the inside edge defined by circular arc **17** resulting in a higher current density at the inside edge and a lower current density at the outside edge.

Referring now to FIG. **4** the resistance path **16** is shown having its upper right and left-hand corners abraded in two separate embodiments. In the upper left-hand corner a denuded area **26** separates the resistance path **16** from a corner portion **27**. It is not necessary to have a very large denuded area **26** since the current will flow along the resistance path **16** which is of much lower resistance than the infinite resistance across the denuded portion **26**. The upper right-hand corner of the resistance path **16** has been abraded leaving the denuded area **28**. The resistance material may be abraded by any suitable method, the choice of which will determine the ultimate configuration. The denuded areas **26** and **28** are bounded on the side of the resistance path **16** by a straight line tangent to the imaginary circular arc **19**. The area could extend to the imaginary circular arc **19**, however, it is obviously much simpler to abrade a straight portion than to attempt to follow the circular contour of the imaginary circular arc **19**. This is another advantage of the instant application since the care and precision required in abrading around the inside edge are eliminated by the much simpler method of abrading a straight path through the resistance material at the corner of the resistance path **16**. In view of the fact that the U-shaped resistance path as shown in FIG. **3** results in a substantially linear curve as shown by curve **25** in FIG. **5**, one would make two presumptions relating to abrading the corners of such a pattern. One being that if the corners were abraded they would not result in a substantial increase in resistance; the other being that if there were an increase there would be abrupt changes due to the substantial reduction in the amount of material at those portions. Surprisingly, neither of these presumptions are accurate. Curve **29**, shown in FIG. **5**, discloses the resistance versus rotation curve of a resistance element after abrading the corner portions. Curve **29** clearly results in a substantial increase in the end resistance over the unabraded curve **25** and also results in a more linear curve. It is easy to explain why curve **29** is more linear than curve **25** since by abrading the corners we have removed the portions of the resistance path **16** that resulted in curve **25** having the slight depressions. It is not fully understood why the substantial increase is achieved over an unabraded resistance element in view of the unabraded element's linearity being explained by the low current density at the corners, however, tests have shown that as much as a 35 percent increase can be obtained without affecting linearity appreciably. For an even greater percentage increase in the overall resistances, the portions **30** lying outside of the imaginary circular arc **19** can be removed.

From the above description it will be apparent that a very simple method has been provided for abrading a variable resistance element to bring the same into tolerance. While there has been illustrated what is at present considered to be a preferred embodiment of the present invention and modification thereof it will be appreciated that numerous changes or modifications are likely to occur to those skilled in the art and it is intended in the appended claims to cover all those changes and modifications which fall within the true spirit and scope of the present invention.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. The method of making a resistance element for a variable resistance control comprising the steps of:

a. depositing a resistance material on a nonconductive base, said material defining a resistance path being generally U-shaped with a bottom and a pair of legs, an inner edge of said resistance path being partially defined by a circular arc and an outer edge of said resistance path being defined by straight lines tangent to an imaginary circular arc with said circular arc partially defining said inner edge, said straight lines being parallel to edges of said base,

b. providing a center collector on the nonconductive base, and center collector being spaced from the inner edge of said path to provide electrical clearance between said path and said collector,

c. providing terminals in electrical connection with said resistance path, and

d. removing a portion of the resistance path lying between said imaginary circular arc and said outer edge.

2. The method of making a resistance element for a variable resistance control comprising the steps of:

a. depositing a resistance material on a surface of a nonconductive base, said material defining a resistance path being generally U-shaped with a bottom and a pair of legs, an inner edge of said resistance path being partially defined by a circular arc and an outer edge of said resistance path being partially defined by intersecting straight lines forming at least one corner at the bottom of the U-shaped path,

b. depositing conductive material in the form of a center collector on said surface of the nonconductive base, said center collector being spaced from the inner edge of said path to provide electrical clearance between said path and said collector,

c. inserting terminals in said base in electrical connection with said resistance path and said collector, and

d. abrading a portion of the outer edge of the resistance path at said corner.

3. The method of making a resistance element for a variable resistance control comprising the steps of:

a. depositing a resistance material on a nonconductive base, said material defining a resistance path being generally U-shaped with a bottom and a pair of legs, an inner edge of said path being partially defined by a circular arc and an outer edge of said resistance path being partially defined by straight lines tangent to an imaginary circular arc concentric to the circular arc defining said inner edge, said straight lines intersecting to form at least one corner at the bottom of the resistance path,

b. depositing conductive material in the form of a center collector on the nonconductive base, said center collector being spaced from the inner edge of said path to provide electrical clearance between said path and said collector,

c. inserting terminals in said base in electrical connection with said resistance path and said collector, and

d. abrading a portion of the outer edge of the resistance path at said corner.

4. A variable resistance control comprising a base, a plurality of terminals extending from said base for connection to an electrical circuit, a driver supported for rotation relative to the base, a resistance path supported on a surface of said base, said resistance path being generally U-shaped with a bottom and two legs, an inner edge of said path being partially defined by a circular arc and an outer edge of said path being partially defined by straight lines, said outer edge having contiguous denuded areas at the bottom of the generally U-shaped path, a collector supported on said surface and spaced from the inner edge of said path, one of said straight lines being tangent to an imaginary circular arc concentric to the circular arc partially defining said inner edge at the bottom of said path, two of said straight lines spaced on opposite sides of said collector being perpendicular to said one and tangent to said imaginary circular arc, conductive material deposited on said base electrically connecting said resistance path and said collector with said terminals, and a contactor constrained to rotate upon rotation of said driver for wipingly engaging said collector and said resistance path.

5. The variable resistance control of claim 4, wherein said contiguous denuded areas have a boundary tangent to said imaginary circular arc.

6. A variable resistance control comprising a base, a driver supported for rotation relative to the base, a resistance path supported on a surface of said base, said resistance path being generally U-shaped with a bottom and two legs, an inner edge of said path being partially defined by a circular arc, an outer edge of said path being partially defined by straight lines and having contiguous denuded areas at the bottom of the generally U-shaped path, a collector supported on said surface and spaced from the inner edge of said path, one of said straight lines being tangent to an imaginary circular arc concentric to the circular arc partially defining said inner edge at the bottom of said path, two of said straight lines spaced on opposite sides of said collector being perpendicular to said one and tangent to said imaginary circular arc, said one and said two being parallel to edges of said base, terminals electrically connected to said resistance path for connection to an electrical circuit, and a contactor constrained to rotate upon rotation of said driver for wipingly engaging said collector and said resistance path.

7. The variable resistance control of claim 6, wherein said contiguous denuded areas have a boundary tangent to said imaginary circular arc.

8. A method of making a resistance element for an electrical control comprising the steps of:

a. depositing a thin film of resistance material on a surface of a dielectric base, said thin film being defined by a generally U-shaped configuration with a bottom and a pair of legs, the inner edge of said thin film being partially defined by a circular arc and an outer edge of said thin film being defined by straight lines tangent to an imaginary circular arc concentric with said circular arc partially defining said inner edge, said straight lines being parallel to edges of said base,

b. curing the thin film deposited on the surface of the dielectric base and produce a resistance path,

c. connecting terminals to the legs of the resistance path,

d. measuring the resistance between the pair of terminals, and

e. removing a portion of the resistance path lying between the imaginary circular arc and the outer edge of the dielectric base to increase the resistance of the resistance path.

9. The method of claim 8, wherein the step of depositing the thin film of resistance material comprises the step of screening the thin film of resistance material onto the surface of the dielectric base.

10. The method of claim 8, wherein portions of the outer edge of the thin film at the junctions between the bottom and each of the legs are defined by a pair of square corners and the step of removing comprises the removing of a narrow strip of resistance path diagonally of the corners to increase the resistance value of the resistance path connected to the terminals.

11. The method of claim 8, wherein the resistance material is cermet and the step of curing comprises firing the thin film deposited on the base at a temperature sufficient to bond the thin film of cermet to the surface of the base.

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