Sept. 19, 1967 W. L. GREENWOOD 3,343,115

ELECTRICAL RESISTANCE ELEMENT

Filed Dec. 2, 1964 3 Sheets-Sheet 1

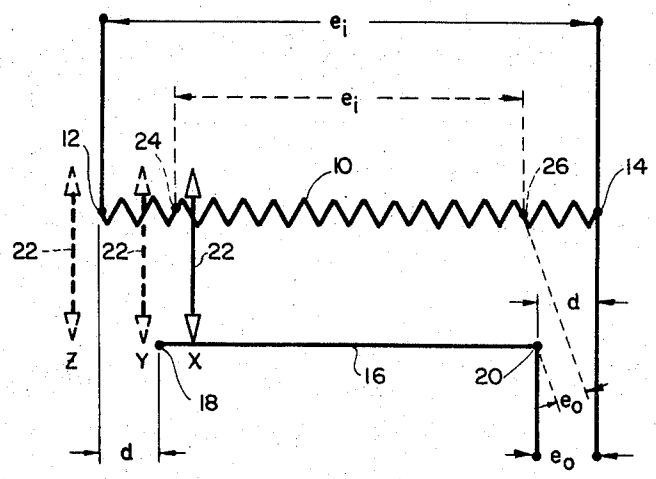


FIG. 1

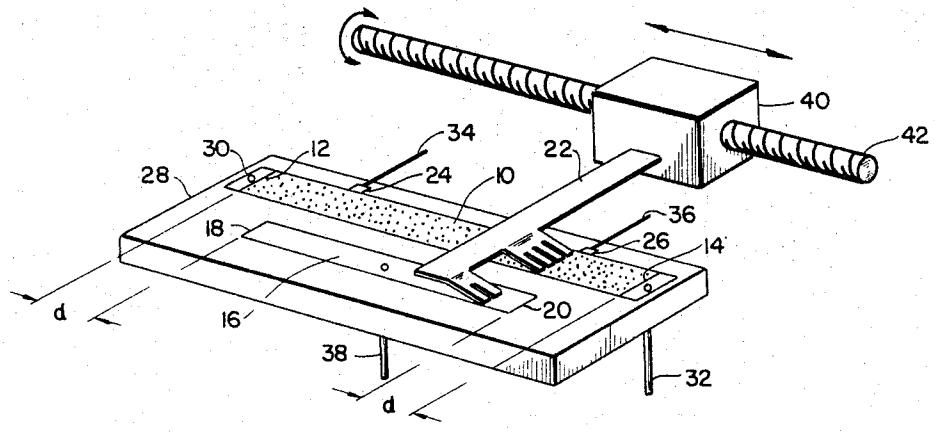


FIG. 2

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ELECTRICAL RESISTANCE ELEMENT

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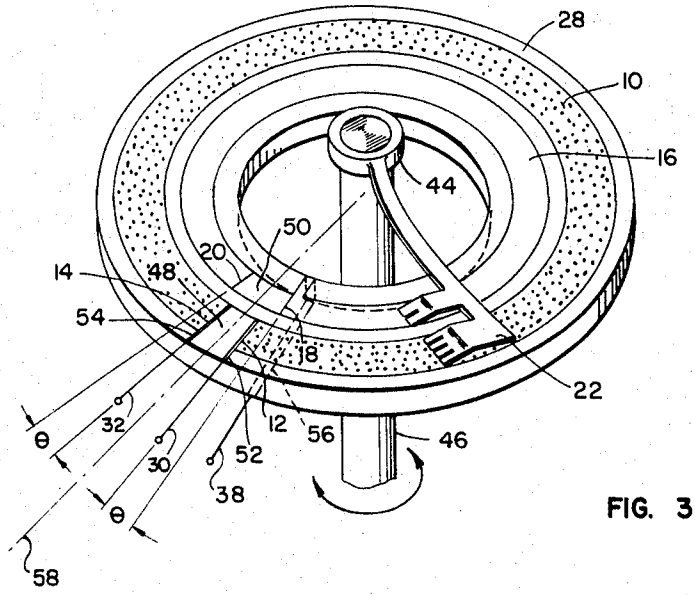


FIG. 3

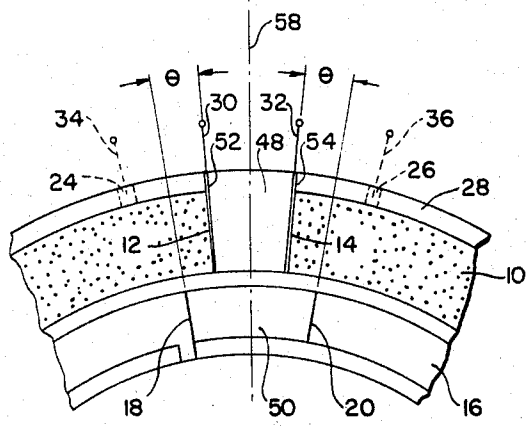


FIG. 4

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ELECTRICAL RESISTANCE ELEMENT

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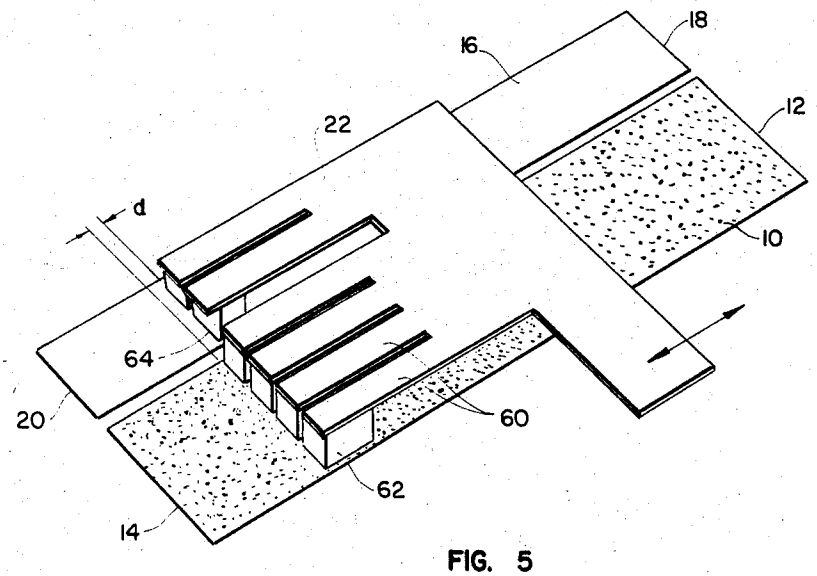


FIG. 5

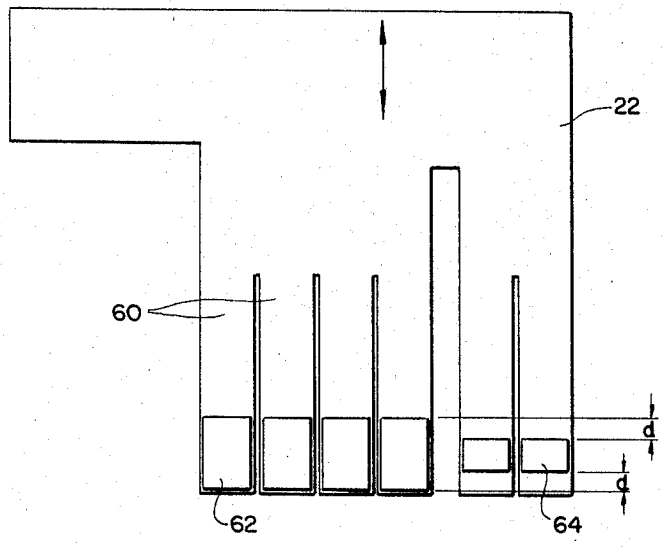


FIG. 6

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United States Patent Office 3,343,115 Patented Sept. 19, 1967

3,343,115

ELECTRICAL RESISTANCE ELEMENT

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Filed Dec. 2, 1964, Ser. No. 415,351
7 Claims. (Cl. 338—174)

ABSTRACT OF THE DISCLOSURE

A variable resistance device including a resistance element having ends thereof terminating adjacent a nonconductive region, a collector element having ends spaced from but associated with the respective ends of the resistance element and a conductive wiper adapted to simultaneously traverse the resistance and collector elements, the ends of the collector element being so arranged with respect to the respective ends of the resistance element and the contacts of the wiper as to electrically disconnect the wiper from external electrical circuitry at a point in wiper travel prior to the instant the wiper traverses from the resistance element to the nonconductive region.

The present invention relates generally to an electrical impedance or resistance element and, more particularly, to an electrical resistance element of the type used in a variable resistance device having a movable contact or wiper adapted to traverse the resistance element.

The electrical resistance element employed in variable resistance device, such as a potentiometer, rheostat, and the like, may be arranged in a variety of ways. For example, the element may be disposed rectilinearly, in which case the wiper moves generally in a straight line along the element, or it may be disposed in a circular fashion, in which case the wiper rotates about a centrally located axis. Irrespective of the physical form or disposition of the resistance element, the wiper may be required to leave the electrically active portion of the resistance element and traverse an insulated bridge or "dead space." When the resistance element is formed in a circular shape, for example, an insulated bridge or dead space must of necessity be provided between the end points of the element to prevent a short-circuit of the potential difference existing between the two end points during operation of the device. In certain applications it may be required that the wiper of a variable resistor employing a circular resistance element be continuously rotated, in which case the wiper traverses the dead space each revolution.

In formed-base variable resistance devices, which employ resistance elements made of a resistance material which is applied as a thin layer or film on a nonconductive support or base, certain deleterious effects are produced when, during sustained operation of the device, the movable wiper is caused to continually leave an end point of the resistance element. For example, burning of the end points of the resistance element has been observed. This may change the electrical resistivity of the element at those points and may also change the wiper "break-off" point, that is, the point at which the wiper breaks contact with the electrically active portion of the resistance element. Burning of the element at its end points adversely affects the service life of the device and appears to result from the structural characteristics of the film or layer type resistance elements. To aid in the understanding of the cause of these problems, some discussion regarding the apparent structural nature of the subject resistance materials may be helpful.

One such material, commonly called "cermet" is formed of a ceramic-type binder, such as glass, having dispersed therein finely divided particles of metal. See for

example U.S. Patent No. 2,950,995, issued Aug. 30, 1960, to T. M. Place, Sr., et al. and assigned to Beckman Instruments, Inc. Cermet is deposited as a viscous mixture upon a refractory base, dried and then fired at elevated temperatures to form a hard, smooth film. The resulting element exhibits conductive electrical properties and relatively high resistivity.

Contrary to previous speculations, recent investigations appear to indicate that the dispersion of the metal particles in the ceramic binder may not be uniform throughout all portions of the resistive layer. As a result, at the end points of the resistance element, there may be concentrations of only a few metal particles separated laterally (that is, across the width of the element), by relatively large interspaces of nonconducting binder. Since all the current flowing between the wiper and resistance element must pass through the few metal particles at the end of the resistance element, the current concentrations may be of such magnitude as to cause melting and oxidation of the metal particles. It further appears that the temperatures generated may be sufficient to momentarily melt the glass binder in the immediate vicinity of the metal particles. Upon solidification, isolated "islands" of fused metal particles may be formed with a resultant loss in continuity coupled with a shift in the wiper "break-off" point. Additionally, the electrical resistivity at the burned end point of the resistance element may also be altered.

If the current drawn by the wiper is large enough at the moment the wiper leaves the resistance element end point, another problem which may arise is arcing between the wiper and end point. Arcing causes localized high temperatures which may result in further deterioration of the element end points due to burning and erosion.

The problems delineated above, and which the present invention seeks to overcome, arise in a similar fashion in other types of resistance elements such as those fabricated of conductive plastic in which particles of graphite or other conductive material are dispersed in an organic (nonconducting) binder. Thus, it is intended that the invention described below and shown in the drawings be equally applicable to all resistance devices employing resistance elements of the class exemplified by cermet and conductive plastic.

It is therefore an object of this invention to provide a variable resistance device in which the end points of the resistance element are not subjected to burning, arcing or other detrimental phenomena.

It is a further object of this invention to provide a variable resistance device with a switching means to protect the end points of the resistance element from burning, arcing and other detrimental phenomena.

It is a more specific object of this invention to provide means for interrupting the flow of current through the wiper before the wiper leaves the resistance element and for reestablishing current flow through the wiper after the wiper has traversed the insulated bridge or dead space and is again in contact with the resistance element.

According to a first, specific, exemplary embodiment of the invention, there is provided a variable resistance device comprising a nonconductive support or base having a surface upon which a film or layer of resistance material such as cermet or conductive plastic has been applied or otherwise affixed in the form of a first track of a given length adapted to be traversed by a movable wiper. If the track is formed in a circle, an insulated bridge or dead space comprising a small segment of the circle is provided between the end points of the track. A second film track made of a highly conductive material such as gold or silver and extending parallel to or concentric with the first track is applied to the conductive base and serves as a commutator or collector for electrically connecting the wiper member with an exter-

nal circuit. The end points of the resistance element comprising the first track are displaced with respect to the end points of the collector element comprising the second track in such a manner that the wiper breaks contact with the collector element (and hence the external circuit) before it breaks contact with the resistance element. As a result, the wiper is no longer drawing current by the time it leaves the resistance element and begins traversing the insulated bridge space separating the resistance element ends. Burning due to current concentrations at the resistance element end points is therefore eliminated and any arcing which may occur will take place between the wiper and the collector element which, because of its high conductivity, is capable of dissipating large quantities of heat.

According to another, specific, exemplary embodiment of the invention, there is provided a variable resistance device in which the corresponding end points of both the resistance element and the collector element are in alignment. However, the wiper contacts which slidably traverse the collector element are made smaller than the wiper contacts which slidably traverse the resistance element. As a result, the connection with the external circuit is broken first at one or the other end point of the collector element since the collector wiper contacts leave the end point of the collector element before the larger resistance element wiper contacts leave the corresponding end point of the resistance element. As in the first exemplary embodiment described, the detrimental effects of high current concentration and arcing at the resistance element end points are eliminated.

The invention, together with further objects and advantages thereof, can best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 represents, diagrammatically, the circuit of a variable resistance device incorporating a first embodiment of the present invention;

FIG. 2 is a perspective view of a rectilinear motion variable resistance device incorporating the first embodiment of the present invention;

FIG. 3 is a perspective view of a rotary motion variable resistance device incorporating the first embodiment of this invention;

FIG. 4 is a plan view of a portion of the rotary motion variable resistance device depicted in FIG. 3;

FIG. 5 is a perspective view of a portion of a rectilinear motion variable resistance device incorporating a second embodiment of the invention; and

FIG. 6 is a bottom view of the wiper assembly of the variable resistance device of FIG. 5.

Referring now to the drawings in which like reference numerals designate like elements, FIG. 1 illustrates a schematic representation of a variable resistance device connected, for exemplary purposes, as a voltage divider. The device comprises a resistance element **10** having end points **12** and **14** across which may be connected a voltage source or input, e_i. Placed immediately adjacent element **10** and running generally parallel therewith, is a commutator or collector element **16** having end points **18** and **20**. Collector **16** connects the resistance element **10** with an external output circuit through wiper **22**. Wiper **22** is adapted to move horizontally in the device of FIG. 1 and thereby traverses both the resistance element **10** and the collector element **16**. The wiper is in slidable, electrical contact with both of these elements throughout the portion of its travel between end points **18** and **20** of the collector **16**. The output voltage e_o of the voltage divider appears across end points **14** and **20** of elements **10** and **16**, respectively. The output voltage e_o is a function of the input voltage e_i, the position of the wiper **22** along the resistance element **10** between end points **18** and **20** of the collector **16** and the output circuit load (not shown).

As shown in FIG. 1, the left-hand end point **12** of resistance element **10** is horizontally displaced a distance *d* from left-hand end point **18** of the collector **16**. Right-hand end points **14** and **20** of the resistance element and collector element, respectively, are likewise displaced. It is thus aparent that if the wiper **22** is moved toward either the left or the right, electrical contact between the wiper **22** and the collector element **16** will be broken first. For example, if the wiper is moved to the left from initial position *x* to position *y* and then to position *z*, the latter two positions being shown by the dotted representations in FIG. 1, it may be seen that the wiper initially breaks contact with the collector **16** at end point **18** and later with the resistance element **10** at end point **12**. Hence, the wiper breaks the electrical connection between the resistance element and the external circuit at point **18** thereby protecting the resistance element at point **12** from burning. Further, assuming sufficient current is being drawn by the wiper at the instant of separation, arcing only occurs between the wiper and end point **18** of the collector.

As is evident from FIG. 1, if the input voltage e_i is applied across the whole length of the resistance element **10** at points **12** and **14**, only that portion of the resistance element lying between end points **18** and **20** of the collector will be active. For example, if the end portions of the resistance element designated by the distance *d* each represent 5% of the total resistance, then the usable resistance range will be 5% to 95%. The output voltage e_o will be similarly limited with respect to the input voltage e_i. If a resistance range of essentially 0% to 100% is desired, the input voltage e_i may be connected across intermediate points **24** and **26** instead of end points **12** and **14**. It is desirable to have intermediate connection points **24** and **26** lie opposite end points **18** and **20**, respectively, of the collector. However, since that configuration may result in discontinuities in the output voltage when the wiper simultaneously traverses an intermediate connection point and the corresponding end point of the collector element, the intermediate connection points **24** and **26** may be located a short distance inside the corresponding collector element end points. This configuration is shown in FIG. 1 and assures a smooth 0%–100% output curve, although the active or effective length of the resistance element is somewhat shortened. The effective length of the resistance element, lying between points **24** and **26**, may represent, for example, 86% of the total length of the element between the end points **12** and **14**. The output voltage e_o in this case is obtained across points **26** and **20** of the resistance element and collector, respectively, as shown by the dotted lines.

FIG. 2 of the drawings shows a rectilinear motion variable resistance device constructed in accordance with the inventive concept described above with the aid of FIG. 1. Resistance element **10** with end points **12** and **14** and collector element **16** with end points **18** and **20** are affixed to an insulating base **28**. Resistance element **10** may be a deposited cermet film, a molded conductive plastic, or other suitable resistive material. Collector element **16** typically may be a deposited film of gold or silver or other highly conductive substance. Terminals **30** and **32** are shown connected to the resistance element **10** at its end points **12** and **14**. Alternatively, terminals **34** and **36** may be connected to intermediate points **24** and **26** on the resistance element to obtain substantially a 0%–100% range. Points **24** and **26** lie short distances inside points **18** and **20**, respectively. Terminal **38**, connected to the collector **16**, is provided for connection to the external circuit. Wiper assembly **22**, made of a suitable conducting material, is shown in sliding contact with both elements **10** and **16**. The wiper assembly **22** is affixed to a traveling nut **40** which is internally threaded for engagement with a threaded shaft **42**. Rotation of the threaded shaft **42** in either direction by en external force applying means (not shown), causes the traveling nut **40** to move

longitudinally in one direction or the other along the threaded shaft **42**. The wiper **22** may thereby traverse the entire length of the insulating base **28**.

The application of this invention to a rotary variable resistance device is shown in FIGS. 3 and 4. In this embodiment, an insulating base **28** is shaped in the form of a circular disc with resistance element **10** and collector element **16** applied in ringlike fashion to the surface of the disc and generally concentric therewith. Although the drawings depict the resistance element **10** as being placed exteriorly of the collector element **16**, the positions of these elements, if desired, may be reversed. The wiper **22**, in slidable contact with elements **10** and **16**, is attached to insulated collar **44** which in turn is fixed to a rotary drive shaft **46**. Rotary drive shaft **46** is generally coaxial with the resistance element **10** and collector **16**. Rotation of shaft **46** thus causes the wiper **22** to rotatably traverse the elements **10** and **16**. End points **12** and **14**, which lie on radii extending from the drive shaft axis, are separated by an insulating bridge **48** made of a nonconductive material such as glass or plastic or other material dependent upon the type of resistance element employed. The surface of the bridge **48** should be flush with the surface of the resistance element on either side of the bridge so that the wiper will make a smooth transition from the resistance element to the bridge and back to the resistance element. Similarly, a circular arc segment comprising bridge **50** is provided between end points **18** and **20** of the collector element **16**. End points **18** and **20** also lie on radii extending from the drive shaft axis. Bridge **50** may be fabricated of appropriate insulating material such as fused glass or a thermosetting plastic, the surface of the bridge **50** being flush with the adjacent surfaces of the collector element **16** to insure unhindered travel of the wiper **22**. Terminal strips **52** and **54**, which may consist of conductive silver paint fused on the resistance element or metal strips embedded in the resistance element or the like, serve to connect the resistance element **10** with external circuitry. Likewise, a metallic conductor bar or an underlaid strip **56** of conductive silver paint is provided as a circuit connection for the collector element **16**.

As in the rectilinear embodiment of the variable resistance device depicted in FIG. 2, the resistance element terminals may alternatively be connected at intermediate points **24** and **26** to provide essentially a 0%–100% resistance range. Such alternate connection for the rotary variable resistor is illustrated in FIG. 4.

Bridges **48** and **50** may be placed symmetrically of a radial line **58**. Collector bridge **50** includes an angle slightly larger than resistance element bridge **48** in order to achieve the objectives of the invention. By way of example, bridge **48** may extend 5° on each side of the line of symmetry **58** while bridge **50** may be 6° on each side. Accordingly, the difference angle, designated in FIGS. 3 and 4 as θ, is then 1°.

Referring to FIGS. 3 and 4, it can be seen that in operation of the rotary variable resistor, the wiper, whose contact fingers lie along a radial line, breaks contact first with the collector element **16** (and hence, the external circuit) irrespective of the direction of rotation of the wiper.

FIGS. 5 and 6 show an alternative embodiment of the invention as applied to a rectilinear motion variable resistance device. Referring to FIG. 5, a wiper **22**, with resilient contact fingers **60** and block-like wiper contact elements **62** and **64**, is caused to longitudinally traverse, in either direction, the length of the resistance and collector elements **10** and **16**, respectively, by an actuating mechanism such as that depicted in FIG. 2.

In this embodiment of the invention, the corresponding end points **12**, **18** and **14**, **20** of the resistance element **10** and the collector element **16** are in alignment. Thus, in the case of the rectilinear motion device illustrated in FIG. 5, the elements **10** and **16** are of the same length.

As may be better seen in FIG. 6, collector wiper contacts **64** are shorter in length than resistance element contacts **62**. Contacts **62** "overhang" contacts **64** by a distance d on either side. As a result, if the wiper element is moved toward either extremity of the resistance device, past the end points of the resistance element **10** and collector element **16**, electrical connection with the external circuit will first be broken between the contacts **64** and the collector element **16**. The ends of the resistance element are thereby protected from burning, arcing and other adverse effects.

It will be obvious that this alternative embodiment of the invention is equally applicable to variable resistance devices having forms other than the rectilinear device of FIGS. 5 and 6. For example, a rotary variable resistance device, constructed in accordance with the alternative embodiment of the invention, would comprise resistance and collector elements whose corresponding end points lie substantially on the same radius. The collector element contacts of the wiper would include a smaller angle than the resistance element contacts, the latter contacts "overhanging" the former by substantially equal angular distances θ on either side so that the benefits of the invention may be realized irrespective of the direction of rotation.

It will be equally obvious that a 0%–100% resistance range may be achieved in the alternative embodiment if the resistance element terminals are attached to the resistance element a distance somewhat greater than d (or angular distance θ, in the case of the rotary variable resistance device) from the end points.

While there has been shown and described particular embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departure from the invention and therefore, it is intended to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A resistance device comprising
a nonconducting base member;
a resistance element supported by said base member;
a collector element supported by said base member;
said resistance element being longer than said collector element, each of said elements having end points so arranged that said end points of said resistance element extend beyond said end points of said collector element;
electrical terminals connected to said resistance element at points lying intermediate the end points of said collector element; and
a movable wiper traversing in slidable contact both said resistance element and said collector element during part of its travel but only said resistance element during another part of its travel.

2. The resistance device of claim **1** wherein
said resistance element is in the form of a first film track supported by said base member; and
said collector element is in the form of a second film track supported by said base member.

3. The resistance device of claim **2** in which said first track is spaced equidistant from said second track.

4. In a resistance device having a nonconducting base member, a resistance element with end points, a collector element with end points, said resistance and collector elements being supported by said base member, and a wiper element adapted to traverse, in slidable contact, both said resistance and collector elements, the improvement comprising
the end points of the resistance element being located beyond the end points of the collector element in the direction of wiper travel a sufficient distance to allow the wiper element to leave an end point of the collector element before it leaves the corresponding

end point of the resistance element electrical terminals connected to said resistance element at points lying intermediate the end points of the collector element.

5. A resistance device comprising
a nonconducting base member;
a resistance element in the form of a first track of a first given length supported by said base member;
a collector element in the form of a second track of a second given length supported by said base member;
said first track being spaced substantially equidistant from said second track;
at least one end of said first track extending beyond the corresponding end of said second track;
electrical terminals connected to said first track at points lying intermediate the end points of said second track; and
a movable wiper traversing in slidable contact both first and second tracks during part of its travel but only said first track during another part of its travel.

6. A variable resistance device comprising
a nonconducting base member;
a resistance element in the form of a first linear track, having a first length, supported by said base member;
a collector element in the form of a second linear track, having a second length, supported by said base member in spaced-apart, parallel relation with said first element;
the end points of said collector element lying intermediate the end points of said resistance element;
electrical terminals connected to said resistance element at points lying intermediate the end points of said collector element; and
a movable, conductive wiper element traversing the entire length of said resistance device and which is in sliding contact with both said resistance element and said collector element over the length of said collector element.

7. A variable resistance device comprising
a non-conducting base member;
a resistance element supported by said base member in the form of a first circular arc segment of a first included angle;
the end points of said circular resistance element being separated by a first insulated bridge element comprising a circular arc segment lying between the end points of said circular resistance element;
said resistance element and said first bridge element together forming a first circular track;
a collector element supported by said base member in the form of a second circular arc segment of a second included angle;
the end points of said circular collector element being separated by a second insulated bridge element comprising a circular arc segment lying between the end points of said circular collector element;
said collector element and said second bridge element forming a second circular track;
said second circular track being concentric with said first circular track, and said second included angle of said collector element being smaller than, and lying within, said first included angle of said resistance element;
electrical terminals connected to said resistance element at a point lying intermediate the end points of said collector element; and
a rotatable, conductive wiper element in sliding contact with both said resistance and collector element tracks during part of its travel but only with said resistance element track during another part of its travel.

References Cited

UNITED STATES PATENTS

2,873,336	2/1959	Tassara	338—174 X
2,959,729	11/1960	Karg	338—130 X
3,174,000	3/1965	Goldbeck	200—16
3,206,702	9/1965	Greenwood	338—162

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