Dec. 25, 1962 W. J. MAIRS 3,070,768

ROTARY POTENTIOMETERS

Filed March 18, 1960 2 Sheets-Sheet 1

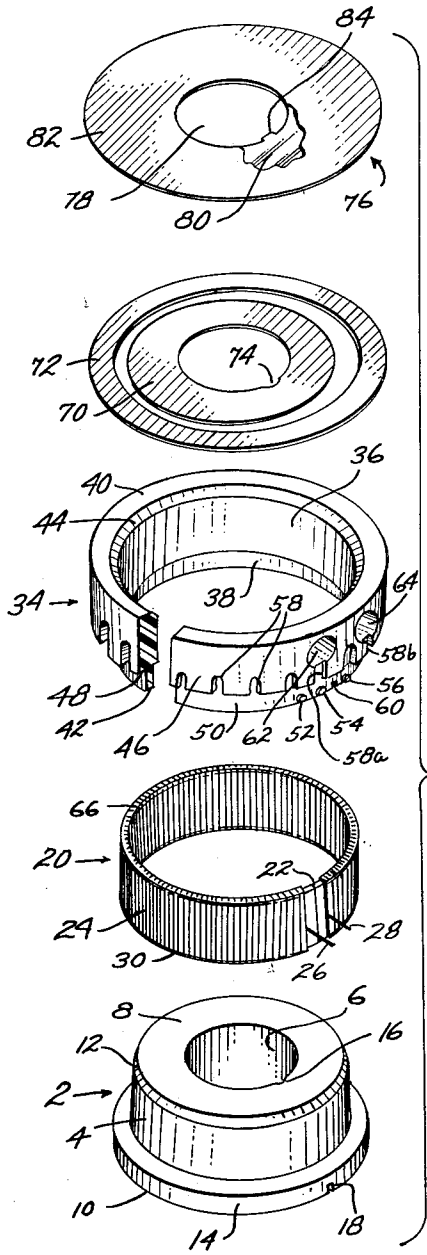


FIG. 2

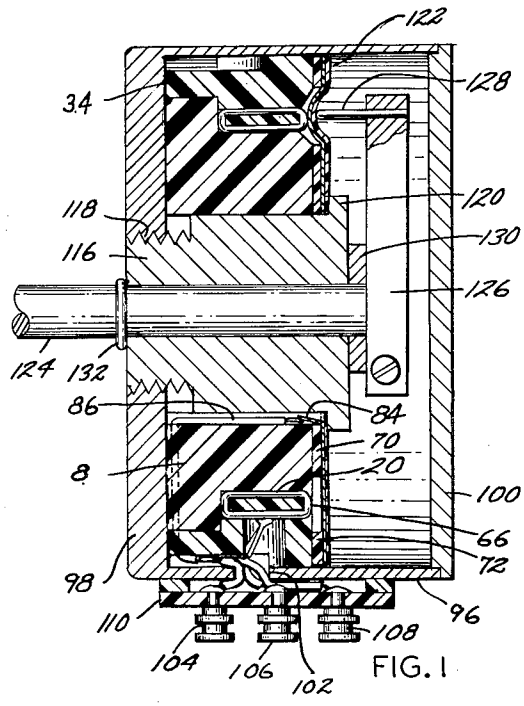


FIG. 1

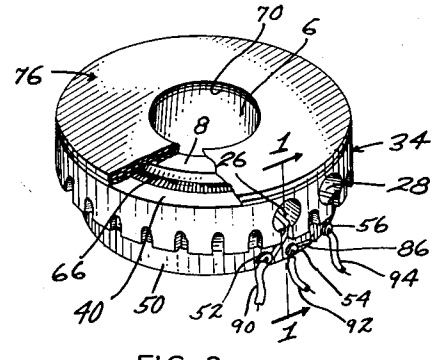


FIG. 3

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ROTARY POTENTIOMETERS

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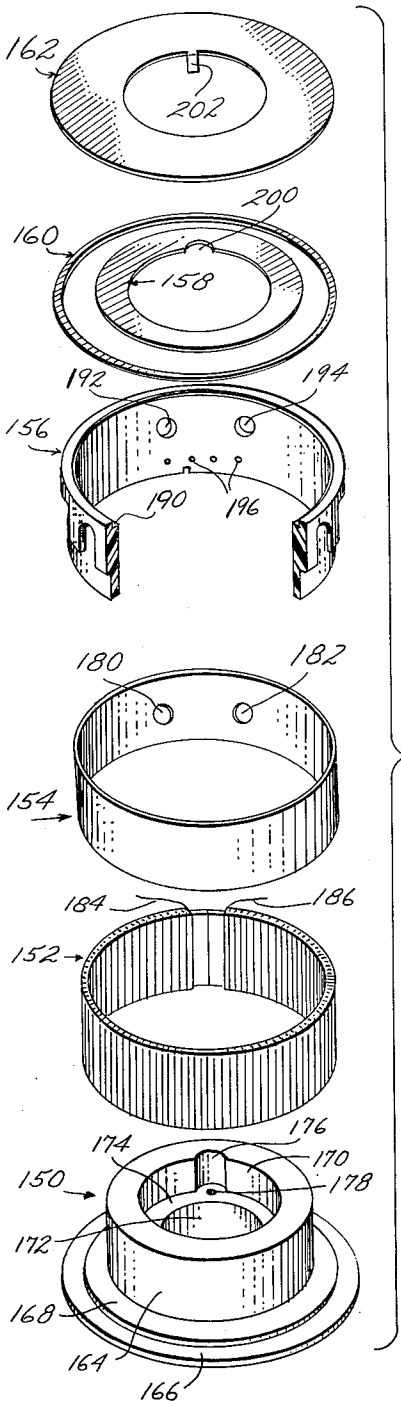


FIG. 4

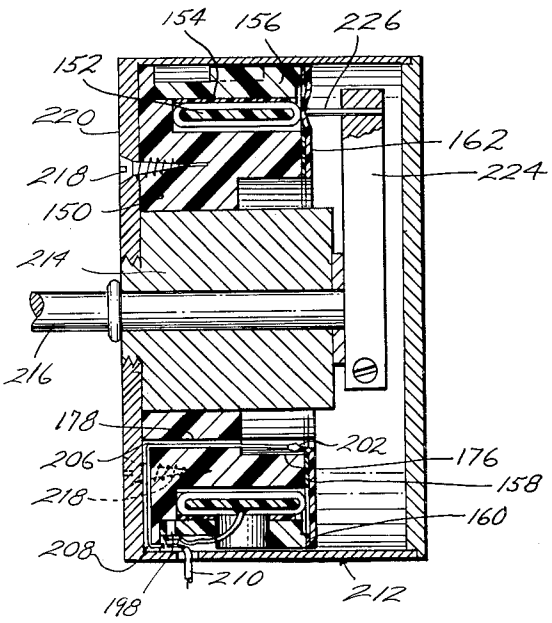


FIG. 5

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ROTARY POTENTIOMETERS

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Filed Mar. 18, 1960, Ser. No. 16,048
7 Claims. (Cl. 338—154)

This invention relates to variable resistors and more particularly to rotary potentiometers comprising a resistance wire wound about a flat card that is bent into cylindrical shape.

Heretofore I have invented a novel form of variable resistor which is disclosed and claimed in U.S. Patent No. 2,862,089, issued to me on November 25, 1958. That novel form of variable resistor utilizes a conductive resilient layer overlying but spaced from a resistance element mounted on a flat base, a nonconductive resilient layer overlying the conductive layer in close proximity thereto, and a movable pressure foot in engagement with the nonconductive layer, the pressure foot when moved acting through the nonconductive layer to press successive portions of the conductive layer down into engagement with successive portions of the resistance element. In the aforesaid construction, the conductive layer functions like the movable contact of a conventional potentiometer. While the specific constructions shown in my previous patent have many advantages, including avoidance of abrasion to the resistance element, they do not lend themselves to use of cylindrical wire-wound resistance cards which are relatively cheap and easy to manufacture and which have established over the years a reputation for precision, reliability, and ease of replaceability.

Accordingly, the primary object of the present invention is to provide an improvement on the invention claimed in my aforesaid Patent No. 2,862,089, the improvement making use of the essential principles described in that patent but involving new structural features which make possible and include the use of cylindrical wire-wound resistance cards.

In the attainment of this object I make use of two concentric cylindrical elements which define an annular space in which is positioned and secured a cylindrical wire-wound resistance card, a contact laminate secured to corresponding ends of the two cylindrical elements and spanning or bridging the annular space between the two cylindrical elements, and a rotatable pressure foot movable along the contact laminate and causing the latter to "edge wipe," i.e., contact the edge of, the resistance element.

Other objects and many of the attendant advantages of my inventive improvement will become readily apparent as reference is had to the following specification together with the accompanying drawings, wherein:

FIG. 1 is a cross-sectional view of a rotary potentiometer embodying one form of my new invention, the section through the two concentric cylindrical elements being taken at a position indicated by line 1—1 in FIG. 3;

FIG. 2 relates to the embodiment of FIG. 1 and is an exploded perspective view of the inner and outer cylindrical supports, the resistance element, the contact laminate, and the two standoff rings for the contact laminate;

FIG. 3 is a perspective view showing the components of FIG. 2 in assembled relation, with a section of the contact laminate broken away to reveal the edge of the resistance element.

FIG. 4 is an exploded perspective view of a second and preferred form of the invention; and

FIG. 5 is a cross-sectional view of a rotary potentiometer embodying said second form of the invention.

Turning first to FIG. 1, the first form of my present

invention comprises a first rigid cylindrical support element 2 having smooth exterior and interior surfaces 4 and 6 respectively, flat top and bottom end surfaces 8 and 10 respectively, a beveled surface 12 at the junction of top end surface 8 and exterior surface 4, and a peripheral flange 14 of rectangular cross-section at its bottom end. Interior surface 6 is provided with an axially extending groove 16 which joins with a radially extending groove 18 formed in the bottom end surface 10.

Sized to surround cylindrical support element 2 is a resistance element 20 comprising a flat card 22 which is bent into cylindrical shape as shown for installation between support element 2 and a second support element 34 described hereinafter. Card 22 is formed of a suitable material such as sheet plastic or plastic-impregnated paper. Wound on card 22 is a resistance wire 24. The drawings exaggerate the spacing of the turns of wire 24; in practice, the turns are wound closely together with a predetermined number of turns per unit length. The two ends of wire 24 are spaced from each other and are provided with soldered or welded wire leads 26 and 28. Resistance element 20 fits snugly on cylindrical support 2, and its bottom edge 30 seats on and is supported by flange 14. A suitable cement (not shown), such as epoxy resin cement, is applied to exterior surface 4 of cylindrical support 2 before resistance element 20 is slipped in place. The cement holds the resistance element securely in place.

This first form of my invention also comprises a second cylindrical element 34. This, like the first cylindrical element 2, is formed of rigid insulating material or of rigid conductive material protected with an overcoat of insulating material. The inner surface 36 of this second cylindrical element is sized to fit snugly about resistance element 20 when the latter is in cylindrical form as shown, and is undercut as shown at 38 to accommodate flange 14 of the inner element 2. The top and bottom end surfaces 40 and 42 respectively are flat, but a beveled surface 44 is formed at the juncture of inner surface 36 and top end surface 40. Outer surface 46 is undercut at the bottom end of cylindrical element 34 so as to form a shoulder 48 and a second outer cylindrical surface 50. Secured to this surface are three circumferentially spaced soldering terminals 52, 54, and 56. A series of uniformly spaced slots 58 are formed in outer surface 46 adjacent shoulder 48, and a radial groove 60 is cut in undersurface 42. In addition, two holes 62 and 64 are cut completely through the wall of cylindrical element 34. These holes are cut so as to intersect two slots 58*a* and 58*b* located close to terminals 52, 54, and 56.

A suitable cement (not shown) applied to the inner surfaces 36 and 38 secures outer element 34 to resistance element 20 and also to inner cylindrical support 2. The cement must be compatible with the resistance element and the inner and outer supports. An epoxy resin cement has been used satisfactorily. The outer cylindrical element 34 is oriented so that its groove 60 is in line with groove 18 of the inner element 2. The wire leads 26 and 28 project through holes 62 and 64 respectively.

The axial lengths of inner and outer elements 2 and 34 are the same; the axial lengths of flange 14 and surface 38 are also the same. Hence when the two elements are assembled one upon the other, their top surfaces 8 and 40 lie in the same plane. The two beveled surfaces 12 and 44 form a substantially V-shaped valley or groove, and the height, i.e., axial length, of resistance 20 is sufficiently great to make it protrude into the valley but preferably not great enough to project above surfaces 8 and 40. FIGS. 1 and 3 illustrate how the top edge 66 of the resistance element extends into the valley or groove formed by beveled surfaces 12 and 44.

Thereafter, standoff rings or gaskets **70** and **72** of suitable insulating material are secured by a suitable cement to the top end surfaces **8** and **40** respectively of the two cyindrical elements. Preferably, these rings have the same width as the surfaces to which they are secured so as to facilitate lining them up. The inner gasket **70** is provided with a slot **74** which is lined up with groove **16**.

On top of gaskets **70** and **72** is placed a circular contact laminate **76** having a center hole **78** coinciding substantially with the center hole or bore in inner cylindrical support **2**. Preferably, the contact laminate comprises a sheet **80** of flexible conductive material, preferably a thin metal foil such as gold, silver, or aluminum, and a sheet of flexible, resilient, relatively strong insulating material **82** such as glass fabric or nylon cloth or polyethylene sheeting, with the metal foil adhesively secured to the overlying flexible insulating material. Alternatively, the laminate may comprise a sheet of flexible, resilient fabric having a coating of conductive metal paint, e.g., silver paint, on its underside. The contact laminate is secured to the assembly by means of a suitable adhesive (not shown) which is applied to the top surfaces of the two gaskets **70** and **72**. Preferably, but not necessarily, the metal foil has a short tab **84** on its inner edge. When attaching the contact laminate to the gaskets, it is oriented so that tab **84** is in registration with groove **74**. In addition, the contact laminate is stretched out smooth and relatively taut so that it does not sag down into contact with the top edge **66** of the resistance element.

Thereafter the resistance ends **26** and **28** are bent down into the slots **58** located below holes **62** and **64** and are secured to solder terminals **52** and **56** respectively. Then a piece of conductor wire **86** is soldered to terminal **54** and bent downward and inward so as to seat in and run along slots **60** and **18** and bent upward so as to seat in groove **16** and slot **74**. The free end of this wire **86** is soldered to tab **84** of the gold foil. To terminals **52**, **54**, and **56** are then soldered insulated wires **90**, **92**, and **94** respectively.

The foregoing assembly is now ready for installation in a conventional potentiometer housing, such as housing **96** which has an integral bottom end wall **98** and a removable top end wall or cover **100**. The outer surface of the outer support element **34** bears snugly against the inner surface of housing **96** and thereby assures concentricity of the assembly. Wires **90**, **92**, and **94** are put through a hole **102** formed in its side wall and secured to terminals **106**, **104**, and **108** respectively carried by a terminal board **110** secured to the outside surface of the housing. Thereafter a bushing **116** is inserted in the housing. Its leading end is threaded and screwed into a tapped hole **118** formed at the center of end wall **98**. Bushing **116** is screwed up tight so that its flange **120** will act on the contact laminate to hold the entire resistance assembly tight against end wall **98**. Potting may be added at **122** to help keep the outer edge of the contact laminate tight against the outer standoff gasket and also to provide a secure hermetic seal. Thereafter a shaft **124** having a rotor arm **126** secured to one end is inserted in bushing **116**. Arm **126** has a pressure foot **128** adjacent its free end. A spacer bearing **130** is slipped onto the shaft before it is inserted in the bushing. As its name suggests, spacer bearing **130** spaces rotor arm **126** from the adjacent end surface of the bushing and also provides a limited bearing surface for the rotor arm. A retaining ring **132**, preferably of the C-shaped type, is slipped over the shaft and coacts with the bushing to keep rotor arm **126** in slipping engagement with spacer bearing **130**.

Pressure foot **128** and the top exposed edge **66** of the resistance element are displaced equal distances from the center axis of shaft **124**. Hence, pressure foot **128** engages the contact laminate directly above the top edge **66** of the resistance element. The length of pressure foot **128** is just sufficient to force the contact laminate into

engagement with the edge **66**. In addition, the end of the pressure foot is relatively small and round so as to press only a limited amount of the laminate into engagement with the resistance element at any one time and also so that the pressure foot will slide easily along the laminate without scratching or gouging it.

The embodiment of FIG. 1 may be used as a potentiometer or as a simple variable resistor. In the former case, an input voltage is applied across terminals **106** and **108** and a readout voltage is obtained at terminal **104**. When used as a simple variable resistor, one of the terminals **106** and **108** is not used.

The advantages of the foregoing construction are numerous. First and foremost is the fact that it provides a very practical and new way of applying the principles disclosed in my previous Patent No. 2,862,089 to conventional wire-wound cards which are far easier and cheaper to construct and use than most other forms of resistance elements useable in potentiometers; yet they are fully as precise, have a desirable low temperature coefficient, and extremely long rotational life with low noise and little, if any, change in total resistance. Another advantage is that the wire-wound card is supported on its inner and outer faces and also its bottom edge by the two cylindrical elements **2** and **34**, thereby reducing the likelihood of damage due to shock. In conventional rotary potentiometers, the inner face of wire-wound cards is left exposed for direct contact by the wiper. In addition, since the contact laminate contacts only the relatively narrow edge of the resistance card, the amount of resistance wire actually engaged by the contact laminate at any instant is quite small and, for a given pressure foot size, is even smaller than is the case with a flat resistance element having a relatively broad face. Still another advantage is obtained by slots **58**. Holes such as holes **62** and **64** may be drilled at a plurality of points about cylindrical element **34**, with slots **58** providing accessways for additional wire leads running from these holes to below shoulder **48**. Below shoulder **48** these wire leads can be extended around surface **50** to the soldering terminals **52**, **54**, and **56**, or to other extra soldering terminals, so that all connections to the terminal board can be made through a single hole in the housing wall. Because of the ease with which extra leads and extra soldering terminals can be secured to cylindrical support **34**, it is a simple matter to provide extra taps to the resistance element.

It is to be noted that the foregoing advantages are in addition to the advantages inherent in employing the principles outlined and claimed in my prior patent.

It is to be noted that the gaskets or standoff rings **70** and **74** are not absolutely necessary and may be omitted if desired. However, if the gaskets are omitted, then the top edge **66** of the resistance element must be well below the top surfaces **8** and **40** of the two concentric supports so as to prevent the contact laminate from engaging it except where forced down by the pressure foot. The gaskets simply make it easier to obtain the desired spacing between the contact laminate and the resistance element.

The second and preferred form of the invention is shown in FIG. 5. This second form comprises an inner cylindrical support **150**, a resistance element **152**, an insulating ring **154**, an outer cylindrical support **156**, inner and outer standoff rings **158** and **160**, and a contact laminate **162** which is of the same construction as contact laminate **76** illustrated in FIG. 1. Inner support **150** is a non-conductive member and comprises a cylindrical outer surface **164** whose axial length is substantially the same as the axial length of resistance element **152**, a peripheral end flange **166** which is stepped to provide an annular shoulder **168** whose outside diameter is slightly less than the inside diameter of outer support **156**, and an inner surface **170** which is stepped to provide a concentric reduced diameter surface **172**

and an annular shoulder **174**. Inner surface **170** is grooved axially as at **176** to expose a bore **178** which extends from the level of shoulder **174** to the bottom end of the support. Actually, resistance element **152** is in flat form until time for installation. Then it is bent into a cylinder with its ends in close spaced or butted relation as in FIG. 4. When bent into cylindrical form, its inner diameter is materially larger than the outer surface **164** of inner support **150**. The insulating ring **154** is made of a suitable plastic material such as a polyethylene terephthalate or a melamine resin, or paper coated with a plastic material having insulating property, and is provided with a pair of holes **180** and **182** to accommodate leads **184** and **186** which are soldered to the ends of the resistance element during the assembly operation.

The outer support **156** is a nonconductive member and is substantially identical in shape to its counterpart **34** in FIG. 1 except for certain differences noted hereinafter. One difference is that its inside surface **188** is not stepped at its bottom end. The second difference is that its top inside corner is not beveled; instead, a rectangular groove **190** is provided. The diameter of inside surface **188** is just large enough to snugly receive insulating ring **154**. The width of groove **190** may be varied substantially without affecting operation of the invention. Two relatively large holes **192** and **194** are provided to accommodate resistance leads **184** and **186**, and a plurality of small holes **196** are provided to accommodate small soldering lugs or rivets **198** (FIG. 5).

Preferably, the widths of standoff rings **158** and **160** are sufficient to cover the top end surfaces of supports **150** and **156**. However, inner ring **158** is notched as at **200** to match the cross-section of groove **176**. These two standoff rings are also formed of insulating material.

The contact laminate **162** has a tongue **202** on its inner surface. This tongue is long enough to extend down into groove **176** when the various elements are assembled in the manner now to be described.

The first step in the assembling operation is to fit the insulating ring **154** into the outer support **156** and position it so that its upper edge will be below the top or contact edge of the resistance element. In practice, this means that the top edge of the insulating ring will be slightly below the shoulder formed by groove **190**, as in FIG. 5. The insulating ring is bonded to the inner surface of outer support **156** by means of a suitable cement. Then the resistance element **152** is inserted within insulating ring **154** with the ends of its resistance wire lined up with holes **180** and **182**. The resistance element is positioned with its upper edge located at or slightly above the level of the shoulder formed by the bottom of groove **190**. The resistance element is cemented to the insulating ring by a suitable quick-drying cement compatible with the insulation ring.

Thereafter the inner support **150** is inserted within the resistance element. Although FIG. 5 shows the bottom edge of the resistance element engaging shoulder **168** of the inner support, it is not necessary for this to occur. In practice, it is preferred that the axial length of the resistance element be limited just enough to prevent it from being engaged by shoulder **168**. This helps assure against damage to the resistance element during assembly. The inner support is cemented to the outer support so as to make a solid unit. In this connection, it is to be noted that shoulder **168** fits snugly within the outer support so as to eliminate any side play while the two supports are being cemented together.

The next step is to apply the standoff rings by means of a suitable cement. Thereafter the contact laminate is laid over and cemented to the standoff rings. The contact laminate is pressed smooth so as to be free of any sag. At this point, there exists a unitary package or assembly which is ready for mounting in a suitable housing, as in FIG. 5.

Thereafter leads **184** and **186** are inserted through holes **192, 180** and **194, 182** respectively and soldered or welded to the ends of the resistance wire of resistance element **152**. The opposite ends of leads **184** and **186** are soldered to separate terminals **198**. Another lead **206** is inserted through bore **178** and secured to tongue **202** which has been bent down into groove **176** (as in FIG. 5). The other end of this lead is soldered to another one of the soldering terminals **198**. The bottom ends of the inner and outer supports are slotted to provide a groove or passageway **208** whereby lead **206** can be brought out to one of the soldering terminals **198**. External leads **210** are soldered to terminals **198** to connect the assembly into an electrical circuit.

The assembly can be accommodated by a housing **212** similar to the one shown in FIG. 1. However, it need not be clamped in place by a bushing as in FIG. 1. Although a bushing **214** is shown in FIG. 5, its function is solely to support an operating shaft **216**. The resistance assembly is secured in place by other means, namely, screws **218** which project through suitable holes in an end wall **220** of the housing and are screwed into suitable tapped holes provided in the bottom end surface of inner support **150**.

Shaft **216** carries a radial cam **224** having a contact element **226** in engagement with contact laminate **162** directly in line with the resistance element **152**. A limited area of the contact laminate is pressed into contact with the adjacent top edge of the resistance element and, as the operating shaft is rotated, different successively occurring areas of the contact laminate engage the resistance element at different points. If desired, stop means may be provided so as to limit rotation of shaft **216** to slightly less than one complete revolution. Also, if desired, potting compound may be applied over the outer edge of the contact laminate and the adjacent inner surface of the housing to completely fill in any space therebetween.

It is to be noted that the peripheral flange **166** on the inner support **150** is sized to fit snugly within housing **212** whereby to assure concentricity of the assembly, including operating shaft **216**.

It has been found that the best contact laminate is the one which uses as its insulating cover layer glass fiber cloth impregnated with tetrafluoroethylene plastic. The material is strong, resilient, and long lasting. Tests have indicated that this material has a useful life in excess of 40 million cycles.

The depth of groove **90** need not be great. In practice, the depth may be as little as .020 inch without any significant change in results. Similarly, the annular space between the resistance element and the outer surface of inner support **150** may be varied considerably. A space as wide or wider than the lateral width of the groove **190** may be used to permit proper flexure of the contact laminate.

It is to be understood that the term "wire wound card" as used herein denotes a resistance element comprising a thin-walled cylindrical support and a resistance wire wound on the support, with each turn of the wire extending generally longitudinally and running around the opposite end edge of the cylindrical support. The support may be a seamless cylinder or a flat card bent into the shape of a cylinder after the resistance wire has been wound thereon.

Obviously, many modifications and variations of my present invention are possible in the light of the foregoing teachings. It is to be understood, therefore, that the invention is not limited in its application to the details of construction and arrangement of parts specifically described or illustrated, and that within the scope of the appended claims, it may be practiced otherwise than as specifically described or illustrated.

I claim:

1. A variable resistor comprising a first cylindrical element, a second hollow cylindrical element surrounding

and secured to said first cylindrical element, said first element having a first flat end surface, said second element having a second flat end surface which is coplanar with said first end surface, a resistance element comprising a supporting cylinder and an elongated resistance wire wound on said cylinder with the turns of said wire extending generally longitudinally of the cylinder, said resistance element disposed in an annular space between said first and second cylindrical elements, said resistance element having an end edge located almost flush with said end surfaces, a resilient contact laminate in overlying spaced parallel relation to said end edge, said laminate having a first inner portion supported by said first end surface and a second outer portion supported by said second end surface, said laminate comprising a resilient conductive contact layer and a resilient backing for said conductive layer, movable means for selectively engaging different portions of said backing and pressing said backing toward said end edge just sufficient to press said conductive layer into contact with said end edge, means for connecting said resistance wire to a voltage source, and a terminal means for connecting said conductive layer to an electrical circuit.

2. A variable resistor as defined by claim 1 further including standoff rings on said end surfaces between said end surfaces and said laminate.

3. A variable resistor as defined by claim 1 wherein said two cylindrical elements are constructed of electrically nonconductive material.

4. A variable resistor comprising a cylindrical resistance unit, said resistance unit comprising a hollow cylindrical support and a resistance wire wound on said support with each turn of said wire consisting of four successive portions, a first portion located on the outside of said support, a second portion extending around one edge of said support, a third portion located on the inside of said support, and a fourth portion extending around the opposite edge of said support, first and second hollow cylinders, said cylinders having flat substantially coplanar surfaces at corresponding ends, said cylinders disposed in concentric relation and defining a narrow annular space therebetween, said resistance unit disposed in said annular space with the second portions of said wire turns located proximate to said flat surfaces, means for connecting said resistance wire to a voltage source, a flexible resilient contact laminate of annular shape secured to said coplanar end surfaces in bridging spaced relation to said resistance unit, said contact laminate having a conductive surface on one side facing said resistance unit and a nonconductive surface on the other side, means for connecting said conductive surface to an electrical circuit, and means for selectively pressing different portions of said contact laminate toward said resistor unit whereby

said conductive surface will contact different turns of said resistance unit.

5. A variable resistor comprising two concentric cylinders defining a narrow annular space therebetween, a substantially cylindrical resistance element located in said annular space and supported by said cylinders, said resistance element having a resistance wire wound about a flat cylindrical card, said resistance element positioned so that one edge of said card is substantially flush with corresponding end surfaces of said cylinders, a resilient flat annular contact laminate secured to said corresponding end surfaces in spaced bridging relation with the turns of said wire on said longitudinal edge, said laminate having a conductive layer facing said resistance element, and terminal means for connecting said resistance element and said conductive layer to an external circuit.

6. A variable resistor comprising two concentric cylinders defining a narrow annular space therebetween, a substantially cylindrical resistance element located in said annular space and physically attached to at least one of said cylinders, said resistance element comprising a flat cylindrical card and a resistance wire wound about said card, said cylindrical resistance element concealed by said cylinders with substantially only one edge thereof exposed for engagement by a contact element, said resistance element positioned so that said one edge is substantially flush with corresponding end surfaces of said cylinders, and a resilient flat contact laminate secured to and supported by said corresponding end surfaces, said laminate comprising a resilient backing and a resilient conductive contact layer attached to said backing, said flat contact laminate bridging said annular space and disposed in spaced relation with the turns of said wire on said edge.

7. A variable resistor as defined by claim 6 wherein the inner one of said two concentric cylinders is provided with a peripheral flange, and further wherein the outer of said two cylinders is provided with an annular shoulder which is engaged by said flange, said flange and shoulder cooperating to align said end surfaces in a common plane.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,070,768 December 25, 1962

William J. Mairs

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 7, line 30, beginning with "4. A variable resistor" strike out all to and including "external circuit.", in line 16, column 8, comprising claims 4 and 5; column 8, line 17, for "6" read -- 4 --; line 18, after "therebetween," insert -- the inner one of said two cylinders having a peripheral flange and the outer one of said two cylinders having an annular shoulder which is engaged by said flange, said flange and shoulder cooperating to align corresponding end surfaces of said cylinders in a common plane, --; line 27, after "with" insert -- said --; line 35, beginning with "7. A variable resistor" strike out all to and including "common plane." in line 41, comprising claim 7; in the heading to the printed specification, line 7, for "7 Claims." read -- 4 Claims. --.

Signed and sealed this 20th day of August 1963.

(SEAL)
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Commissioner of Patents

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,070,768 December 25, 1962

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Column 7, line 30, beginning with "4. A variable resistor" strike out all to and including "external circuit.", in line 16, column 8, comprising claims 4 and 5; column 8, line 17, for "6" read -- 4 --; line 18, after "therebetween," insert -- the inner one of said two cylinders having a peripheral flange and the outer one of said two cylinders having an annular shoulder which is engaged by said flange, said flange and shoulder cooperating to align corresponding end surfaces of said cylinders in a common plane, --; line 27, after "with" insert -- said --; line 35, beginning with "7. A variable resistor" strike out all to and including "common plane." in line 41, comprising claim 7; in the heading to the printed specification, line 7, for "7 Claims." read -- 4 Claims. --.

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