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C. A. HULT ET AL  
ADJUSTABLE RESISTOR

3,188,595

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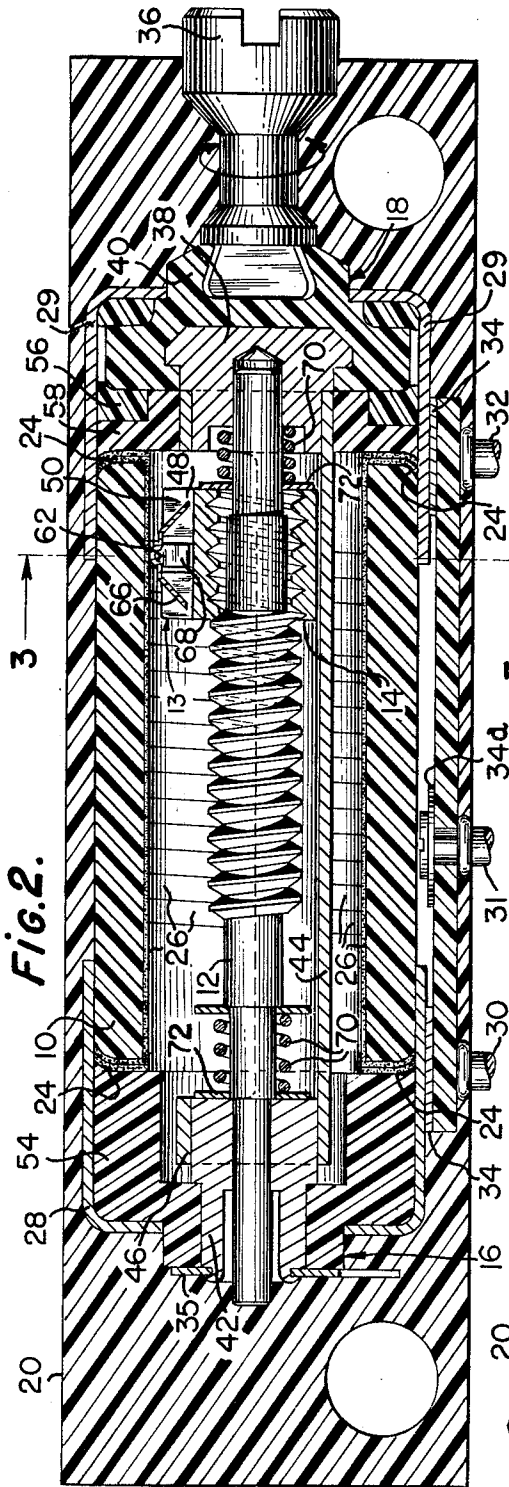


Fig. 2.

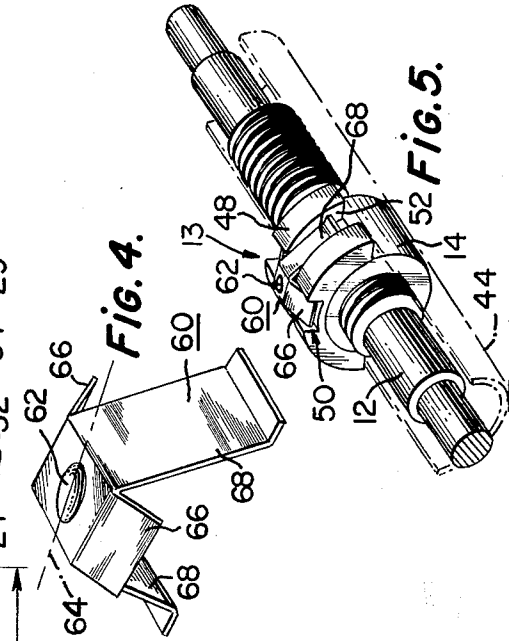


Fig. 4.

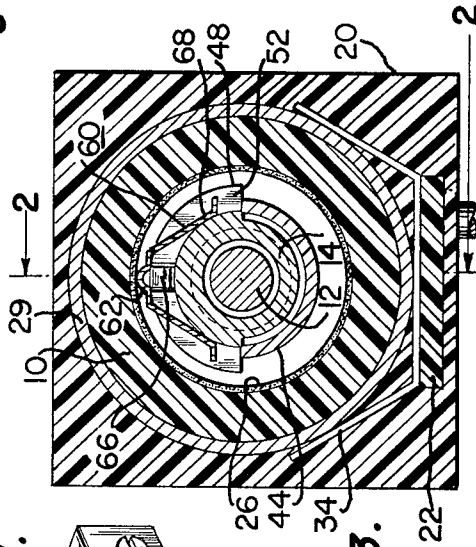


Fig. 3.

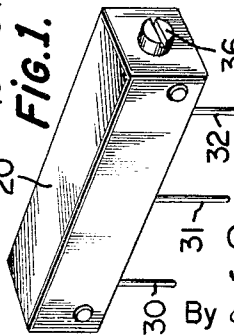


Fig. 1.

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3,188,595

**ADJUSTABLE RESISTOR**

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This invention relates to an adjustable electrical resistor wherein the resistance element is in the form of electrically conductive film and, more particularly, to a multi-turn film potentiometer having a high degree of resolution. In a preferred embodiment of the invention a potentiometer is formed having an extended helical resistive film path and a wiper adapted to continuously track the film path.

It is known to form adjustable electrical resistors in which the electrically resistive element comprises a carbon or metal film deposited by evaporation or other known techniques upon the inner surface or wall of a tubular substrate or base member. In such resistors the inner surface of the substrate usually is glazed prior to metal deposition. Terminations of an electrically conductive material are provided on the tube ends and a portion of the outer surface at each end of the tube. These terminations provide the necessary electrical path from the resistive element to the end caps which are force fitted on the outer tube surface.

The resistive element is adjusted to a desired resistance value by a method known as spiralling. Spiralling is accomplished through the use of an electric probe or an abrasive wheel to form a helical cut in the resistive element on the inside of the tubular substrate such that the resistive path is in the form of a helix or spiral. The resistance between the ends of the tubular substrate may be varied by changing the pitch of the spiral. The pitch of the lead screw which drives the contactor or wiper along the helical film path is selected to be the same as the pitch of spiral cut. A typical spiral lead screw and follower arrangement for causing a contactor to follow a helical path is described in a U.S. patent, 1,606,153, issued November 9, 1926, to Harry A. Douglas. As described in Douglas' patent, a helix or spiral follower designed to carry a contactor is threaded on a lead screw having the same pitch as the spiral resistance element so that the contactor will follow the spiral path of such element.

The advantage of such a multi-turn film-type adjustable resistor is that due to the relatively long length of the spiral path, as compared to the length of the tubular substrate, a high degree of resolution in the variation of the resistance of the adjustable resistor can be readily obtained.

Unfortunately, however, such adjustable resistors have many disadvantages. Many of these disadvantages have arisen due to the type of contactors employed. For example, a simple leaf spring employed as a contactor, wherein one end of the leaf spring is fixed and the other end contacts the film, has been found to be direction sensitive. This sensitivity is due to the pressure differentials arising during rotation as the contactor is either pushed or pulled along the film path. Pulling the leaf spring contactor along the film path lightens its pressure against the film and greatly increases noise or contact resistance. If the contactor is pushed, the converse is true, i.e., contact pressure increases which greatly decreases contact resistance. To overcome this directional sensitivity, the contactor length would have to be greatly reduced to produce rotational forces that are tangential (not normal) to the film surface. Shortening greatly increases contact pressure and hence film wear.

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Also some difficulty has been encountered in designing a contactor that is capable of maintaining constant film contact pressure with variations in the smoothness of the substrate surface on which the film is deposited.

It is, therefore, an object of this invention to obviate many of the disadvantages of the prior art adjustable resistors.

Another object of this invention is to facilitate the positioning of an electrical contactor on an electrically conductive film.

Still another object of this invention is to provide an improved contactor for film type adjustable resistors.

In a preferred embodiment of this invention the adjustable resistor consists of an electrically non-conductive tubular base member which has a helix of a thin film of an electrically resistive material deposited on its inside wall. Terminals are placed at either end of the tubular base member so as to contact at least a portion of the thin film. End caps, having openings, are placed over either end of the tubular base member. The openings in the end caps are such as to receive a slider, comprising a contactor mounted on a contactor support, threaded on a lead screw. A slotted tube, placed over the lead screw is adapted to rotate the contactor and contactor support about the lead screw. By selecting the pitch of the spiral film path and the pitch of the lead screw threads to be the same, the contactor traverses the entire length of the spiral film resistor path.

In accordance with this invention the contactor is mounted in the contactor support or follower such as to permit it to have one direction of freedom with respect to the contactor support which is normal to the surface of the resistive film. This is accomplished by forming a contactor from a sheet of resilient material into the form of a cross. In the junction area of the cross there is formed an elongated protuberance having a major axis that is in substantial alignment with the film path to facilitate the protuberance's following the film path. The arms of the cross are inclined away from the protuberance. Two of the opposite arms of the cross are short and are inclined at a shallow angle to locate the contactor in the follower and maintain its position in the follower during rotation. The end edge surfaces of the short arms do not contact the follower and, therefore, do not provide a spring action.

The remaining two arms of the cross are longer than the shorter arms and are inclined to rest upon circumferential grooves in the follower. Depression of the contactor at the protuberance forces these arms to a shallower tangential angle on the periphery of the circumferential grooves. This provides the necessary spring action and maintains the protuberance in contact with the film.

Further advantages and features of this invention will become apparent upon consideration of the following description read in conjunction with the drawings wherein:

FIGURE 1 is an isometric view of an exemplary embodiment of an adjustable resistor formed in accordance with this invention;

FIGURE 2 is a longitudinal section view of the adjustable resistor illustrated in FIGURE 1;

FIGURE 3 is an end section view of the adjustable resistor illustrated in FIGURE 1 taken along the section line 3-3 of FIGURE 2;

FIGURE 4 is a pictorial view of the contactor of this invention; and

FIGURE 5 is a pictorial view of the adjusting mechanism of this invention.

The adjustable resistor or potentiometer shown in FIGURES 1 through 5 comprises a tube 10 which may be formed of an electrically nonconductive material such as

a ceramic. The adjustable resistor includes a lead screw 12 on which is mounted a follower 14 and a carriage 44 in the shape of a slotted tube or sleeve which comprises the adjusting mechanism of the adjustable resistor. The adjusting mechanism is mounted by suitable end and header assemblies 16 and 18. This entire unit, including the base member 10, the adjusting mechanism and the end and header assemblies 16 and 18 respectively, is encapsulated within an encapsulant 20 such as an epoxy resin. A terminal board 22 is placed adjacent the outside of the base member 10 prior to encapsulation to provide for an external electrical connection to both ends and to the follower of the adjustable resistor through pins 30, 31 and 32 in the terminal board.

Having thus described the overall configuration of the adjustable resistor, the specific details of its construction in accordance with this invention will now be described with particular reference to FIGURES 2, 3, 4 and 5.

The tubular base member 10 consists of an electrically non-conductive tube on the smooth, cylindrical inside surface of which is deposited a thin film 26 of an electrically conductive material, i.e., a resistance film. The resistance film 26 may be any of the known films such as a carbon film or a nickel composition deposited by sublimation or other known methods upon the inner surface of the tubular base member 10. Typically the inner surface of the tubular base member 10 is glazed prior to metal deposition. Terminations 24 of an electrically conductive material such as a metallic frit or gold plating are provided on the ends and on a portion of the outer surface of each end of the tubular base member 10. These terminations 24 provide the necessary electrical path from the ends of film 26 to end caps 28 and 29. An external electrical connection to the end caps 28 and 29 is made through the respective pins 30 and 32 of a terminal board 22 to terminals 34 which are soldered to the respective end caps 28 and 29.

The film 26 is adjusted to the desired resistance value by that method known as "spiralling." Spiralling is accomplished preferably through the use of an electric probe although an abrasive wheel may be used also. The use of the electric probe rather than an abrasive wheel is preferred to prevent contamination of the resistive path with particles of the glaze or base member. Such particles, if not thoroughly removed, may be trapped and carried by the contactor 60. Because of their hardness these particles would cause the film to wear rapidly away. Using an electric probe, the film 26 is vaporized leaving a smooth surface relatively free of particles. In a typical case the spiralling is such as to create a film helix having 15 turns, each turn of which has a path width typically of .030 inch.

The end caps 28 and 29 are generally in the shape of cups having central openings therein to receive and mount the adjusting mechanism of the adjustable resistor. The adjusting mechanism includes a header assembly 18, the lead screw 12, a sleeve 44 and the end assembly 16. The header assembly 18 is made up of a slotted adjustment head 36 and a bushing 38 which are assembled into an integral unit by the use of a cylindrical molding 40, the header assembly being mounted for rotation within the encapsulant 20 as indicated by the directional arrows in FIGURE 2. The adjustment head 36 and bushing 38 are of a suitable metallic material whereas the molding 40 may be of a plastic such as Teflon which provides a good seal, has a low coefficient of friction, is somewhat flexible, and provides electrical insulation between the adjustment head 36, the bushing 38 and the end cap 29.

The lead screw 12, whose center portion is threaded, is gold plated for improved conductivity and corrosion resistance, and is supported at one end by the rotatable bushing 38. The other end of the lead screw 12 is fixedly supported by the end assembly 16 which includes the fixed bushing 42 coaxially mounted with an insulating bushing 54. A terminal 35 is soldered to the fixed bushing 42 which in turn is soldered to the lead screw 12. The ter-

terminal 35 is electrically connected to the center pin 31 on the terminal board 22. The sleeve or carriage 44 is metallic and in the shape of a half cylinder axially cut, but with a portion 46 at either end extending more than 180° around. The right hand end (in the drawing) of sleeve 44 is force fitted onto the bushing 38 so that it is driven by rotation of the adjustment head 36. The left hand (in the drawing) end portion 46 of sleeve 44 is loosely fit over the fixed bushing 42 to permit its free rotation about that bushing.

A slider 13 includes a contactor support or follower 14 which is threaded over the lead screw 12 and is generally cylindrical in shape having an axial portion 48 of enlarged diameter into which are formed an axial groove 50 and a circumferential groove 52. The pitch angles of the lead screw 12 and the helical film path 26 are selected to be substantially identical. Upon rotation of the header assembly 18 by the slotted adjustment head 36, the sleeve 44 engages the axial portion 48 of the follower 14 and causes it to rotate about the lead screw 12. The follower 14 is driven laterally with respect to the axis of the tubular base member 10 at the pitch angle of the lead screw 12 such that it traverses the film helix 26 substantially from one end to the other.

The follower 14 is normally made of any suitable material such as brass and preferably is rhodium plated for improved electrical conductivity, wear resistance, and corrosion resistance. It is threaded to allow mating with the thread of the lead screw 12. The insulating bushing 54 may be any suitable material such as a plastic known commercially as Teflon. This bushing acts as a seal and also an electrical insulator between the fixed bushing 42 and the left hand end cap 28.

The header end of the resistor is sealed by the use of Silastic washers 56 and an additional Teflon bushing 58. This additional Teflon bushing 58 reduces wear on the molding 40 and aids in centrally locating the header assembly 18 by locating the end of sleeve 44.

In accordance with the invention, a cross shaped contactor 60 formed of a resilient, electrically conductive sheet material, such as 0.002 inch Ney Oro G metal. It is cross shaped so as to rest in the axial and circumferential grooves 50 and 52, respectively. The contactor 60 is made into a single point type by forming an elongated protuberance 62, whose major axis 64 is canted to be in substantial alignment with the helical film path 26. The protuberance 62 is of sufficient height such that only it contacts the film 26. The contactor 60 has a pair of short arms 66 and a pair of long arms 68. The short arms 66 are inclined away from the protuberance 62 at a shallow angle and function to locate the contactor in the axial groove 50 of the follower 14 during its rotation. The ends of these arms do not contact the bottom but only the sides of the axial groove 50, hence do not provide any spring action. The longer arms 68 of the contactor 60 also are inclined away from the protuberance 62 but rest upon the bottom of the circumferential groove 52 of the follower 14. Upon depression of the contactor 60 at the protuberance 62, these longer arms 68 are forced against the bottom of radial groove 52 causing the arms to spread somewhat and maintain contact between the protuberance 62 and the film path 26.

The contactor protuberance 62 is elongated in accordance with this invention for several reasons. With the typical 0.002 inch material, the formation of the simple protuberance of spherical shape of a sufficient height would tend to rupture the material. The elongated protuberance has less tendency to rupture the material. Any increase in material thickness, to permit the formation of such protuberance or dimple without rupture, would greatly increase contact pressure and hence increase wear. Also the elongated protuberance 62 reduces the pressure per unit area on the film due to increased contact area and hence causes less wear of the film. Finally, the elongated protuberance 62 presents a shallower meet

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angle with the surface of the film 26. Hence frictional forces due to irregularities in the film surface are reduced.

Also in accordance with the invention, the major axis of the protuberance 62 is slightly canted such that it is in alignment with the pitch angle of the helical film path 26. This particular contactor arrangement is such that the only force acting on the contactor 60 is that normal to the film surface. The contactor 60 is relatively insensitive to the direction of its movement with respect to the film surface.

A spring 70 and a pair of washers 72 placed on either side of the spring 70 are placed on either end of the lead screw 12 to provide a clutch action. The washers may be gold-plated brass and the spring beryllium copper. The spring is placed into compression by the washers 72 which are located upon shoulders formed at either end of the lead screw 12. These spring and washer combinations act as free running clutches for the follower 14. The lead screw 12 is not threaded at either end to permit the clutch action and the ends are of reduced diameter so that the follower 14 may disengage from the threads as it reaches either end of the film 26. As the follower 14 disengages, it compresses either of the springs 70 such that upon reversal of rotation of the adjustment head 36, the compressed spring 70 forces engagement of the follower 14 with the threads of the lead screw 12. The clutch action prevents damage to the unit through excessive rotation of the adjustment head 36.

The use of the spiral film element has several advantages over the conventional straight strip element of the type described in U.S. Patent 2,926,324, issued February 24, 1960, to Barden et al., for example. The increased length of the helical spiral path provides improved resolution of resistance values. As the pitch of the protuberance 62, lead screw 12, and film path 26 are substantially identical, tracking of the film by the follower 14 is continuous. The larger film area thus permitted, i.e., the entire inside of the base member rather than a mere strip, permit a greater dissipation of heat. Also the relatively narrow film path 26 tends to reduce errors in non-linearity of the resistance between the contactor and either end terminal due to "field effects."

There has thus been described an improved adjustable resistor unit which has a high degree of resolution of resistance. The contactor is formed such that it is relatively insensitive to the direction of its rotation. Also an elongated protuberance is formed on the contactor and is canted so as to be in substantial alignment with the helical film path to facilitate tracking of the film path.

Since many changes could be made in the above construction and many apparently widely different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

We claim:

1. An adjustable resistor comprising:  
 an electrically non-conductive tubular base member having a smooth, cylindrical inside wall,  
 a helix of a thin film of an electrically resistive material on said inside wall of said tubular base member,  
 an electrically conductive terminal on at least one end of said tubular base member contacting at least a portion of said thin film,  
 a slider adapted to move along said helix, said slider including  
 an electrically conductive contactor, said contactor having a protuberance adapted to engage said thin film,  
 said protuberance being elongated in the direction of its travel over said resistive film,  
 means for adjusting said resistor by moving said slider along said helix substantially from one end of said film to the other thereby to obtain improved resolu-

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tion of the resistance change between said contactor and said terminal as said slider is moved,  
 and means for connecting said terminal and said contactor into an electrical circuit.

2. An adjustable resistor comprising:  
 an electrically non-conductive tubular base member, a helix of a thin film of an electrically resistive material on the inside wall of said tubular base member, an electrically conductive terminal on at least one end of said tubular base member contacting at least a portion of said thin film,  
 an electrically conductive slider adapted to move along said helix,  
 means for adjusting said resistor by moving said slider along said helix substantially from one end of said film to the other thereby to obtain improved resolution of resistance change between said slider and said terminal as said slider is moved,  
 and means for connecting said terminal and said slider into an electrical circuit,  
 said slider including a contactor and a contactor support,  
 said contactor support being generally cylindrical in shape and having axial and circumferential grooves therein,  
 said contactor being formed from resilient sheet material into the form of a cross,  
 the junction area of said cross having a protuberance adapted to engage said film,  
 the arms of said cross being inclined away from said protuberance and positioned in said grooves whereby the pressure per unit area of said protuberance on said film is substantially independent of the direction of movement of said slider.

3. The combination set forth in claim 2 wherein said protuberance is elongated in the direction of its motion relative to said film thereby further to reduce the pressure per unit area on said film.

4. The combination set forth in claim 2 wherein said protuberance is elongated to have a major axis that is in substantial alignment with the spiral pitch angle of said helix.

5. The combination set forth in claim 2 wherein two of the oppositely disposed arms of said cross have a length greater than the remaining arms and are disposed in said circumferential grooves to abut the bottom of said circumferential grooves thereby to maintain contact between said protuberance and said film despite irregularities in its surface smoothness.

6. The combination set forth in claim 5 wherein said remaining arms are of insufficient length to contact the bottom of said axial grooves of said contactor support.

7. The combination set forth in claim 2 wherein two of the oppositely disposed arms of said cross have a length greater than the remaining arms and are disposed in said circumferential grooves to abut the bottom of said circumferential grooves thereby to maintain contact between said contactor and said film despite irregularities in its surface smoothness, and

said protuberance is elongated to have a major axis that is substantially in alignment with the spiral pitch angle of said helix whereby each turn of said helix may be tracked by said protuberance without overlapping the adjacent turns of said helix.

8. An adjustable resistor comprising:  
 an electrically resistive film element, slider means that is movable along the length of said resistive element, said slider means including a contactor and a contactor support,

said contactor formed from electrically conductive resilient sheet material in the shape of a cross, the junction area of said cross having a protuberance adapted to contact said resistive film element,  
 said contactor support having substantially mutually perpendicular grooves formed therein, the arms of

said cross being inclined away from said protuberance and positioned in said grooves to permit movement of said contactor relative to said contactor support only in a direction normal to the surface of said resistive film element whereby the pressure per unit area of said protuberance on said film is substantially independent of the direction of movement of said slider means.

9. The combination set forth in claim 8 wherein said protuberance is elongated to have a major axis that is in substantial alignment with the direction of motion of said slider means.

10. The combination set forth in claim 8 wherein two of the oppositely disposed arms of said cross have a length greater than the remaining arms thereby to rest upon the bottom of their corresponding grooves in said contactor support to thereby maintain continuous contact between said protuberance and said film.

11. The combination set forth in claim 10 wherein said remaining arms are of insufficient length to contact the bottoms of their corresponding grooves in said contactor support.

12. An adjustable resistor comprising:

an electrically non-conductive tubular base member, a helix of a thin film of an electrically resistive material on the inside wall of said tubular base member,

an electrically conductive terminal on at least one end of said tubular base member contacting at least a portion of said thin film,

an electrically conductive slider adapted to move along said helix,

means for adjusting said resistor by moving said slider along said helix substantially from one end of said film to the other thereby to obtain improved resolution of resistance change between said slider and said terminal as said slider is moved,

said adjusting means including a threaded lead screw fixedly mounted coaxially within said tubular base member,

a cylindrically shaped sleeve member coaxially and rotatably mounted over said lead screw,

a spring member coaxially positioned over at least one end of said lead screw, said slider threadingly engaging said lead screw and adapted to be rotated by said sleeve member, said end of said lead screw being unthreaded thereby to permit the disengagement of said slider from the threads of said lead screw when it has reached the corresponding end of said helix by compressing said spring member, thereby to facilitate the reengagement of said slider on the threads of said lead screw upon a reversal of the rotation of said sleeve member,

and means for connecting said terminal and said slider into an electrical circuit,

said slider including a contactor and a contactor support,

said contactor support being generally cylindrical in shape and having axial and circumferential grooves therein,

said contactor being formed from resilient sheet material into the form of a cross,

the junction area of said cross having a protuberance, the arms of said cross being inclined away from said protuberance and positioned in said grooves to per-

mit movement of said contactor relative to said contactor support only in a direction normal to the surface of said thin film whereby the pressure per unit area of said protuberance on said film is substantially independent of the direction of movement of said slider.

13. An adjustable resistor comprising:

an electrically non-conductive tubular base member having a smooth, cylindrical, inside wall,

a helix of a thin film of an electrically resistive material on said inside wall of said tubular base member,

an electrically conductive terminal on at least one end of said tubular base member contacting at least a portion of said thin film,

electrically conductive slider means adapted to move along said helix,

said slider means including a contactor, said contactor having a protuberance adapted to engage said thin film,

said protuberance being elongated in one dimension thereby to reduce the pressure per unit area of said contactor on said film,

means for adjusting said resistor by moving said slider means along said helix substantially from one end of said film to the other thereby to obtain improved resolution of the resistance change between said slider means and said terminal as said slider means is moved,

said adjusting means including a threaded lead screw fixedly mounted coaxially within said tubular base member,

a cylindrically shaped sleeve member coaxially and rotatably mounted over said lead screw,

a contactor support member for carrying said contactor threaded on said lead screw and adapted to be rotated by said sleeve member,

a spring member coaxially positioned over at least one end of said lead screw, said end of said lead screw being unthreaded and of reduced diameter thereby to permit the disengagement of said slider means from the threads of said lead screw when it has reached said end of said film helix by compressing said spring member thereby to facilitate the reengagement of said slider means on the threads of said lead screw upon a reversal of the rotation of said sleeve member,

and means for connecting said terminal and said slider means into an electrical circuit.

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