

April 1, 1969

R. W. NAYLOR
VARIABLE RESISTANCE CONTROL HAVING A RESISTANCE
WIRE SUPPORTING CYLINDRICAL SUBSTRATE

3,436,714

Filed Dec. 29, 1966

Sheet 1 of 2

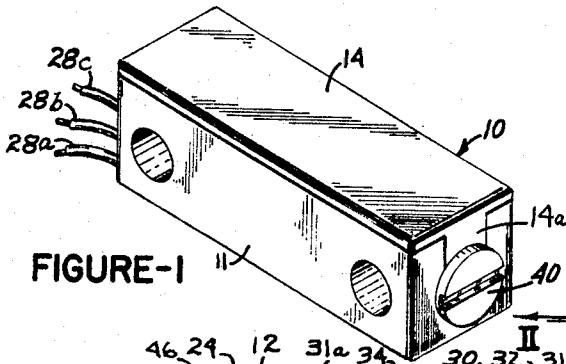


FIGURE-1

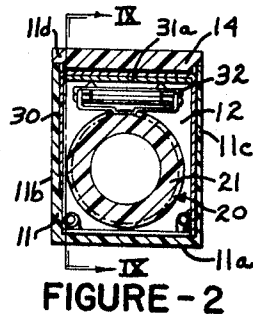


FIGURE-2

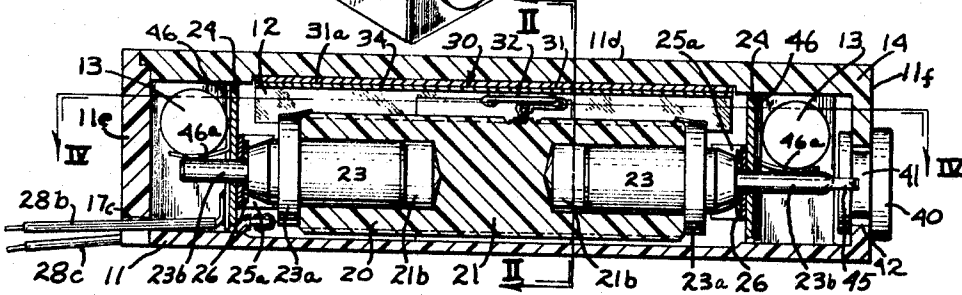


FIGURE-3

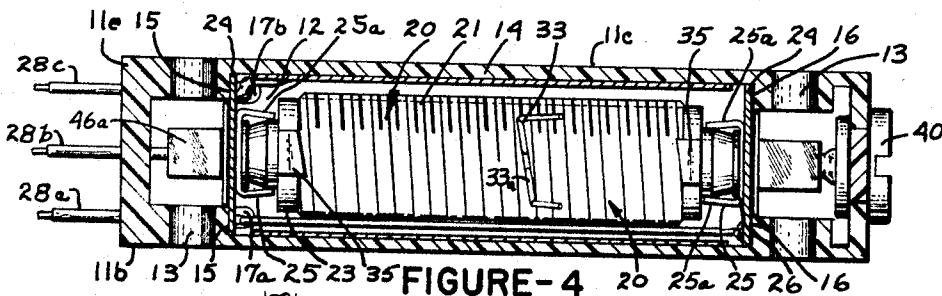


FIGURE-4

FIGURE-5

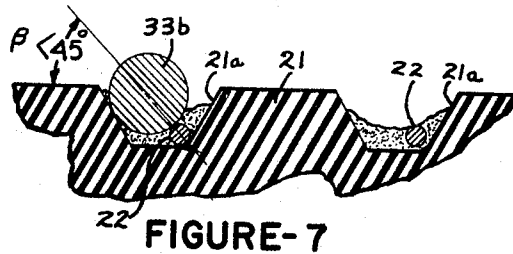
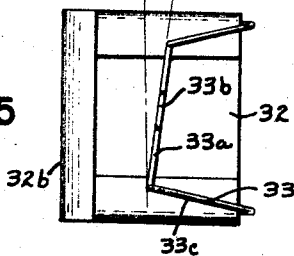
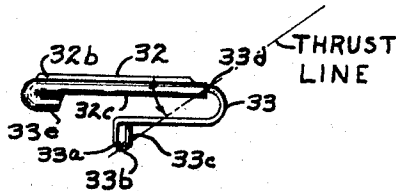


FIGURE-7

FIGURE-6



INVENTOR

ROBERT W. NAYLOR

BY John J. Haydos
ATTORNEY

April 1, 1969

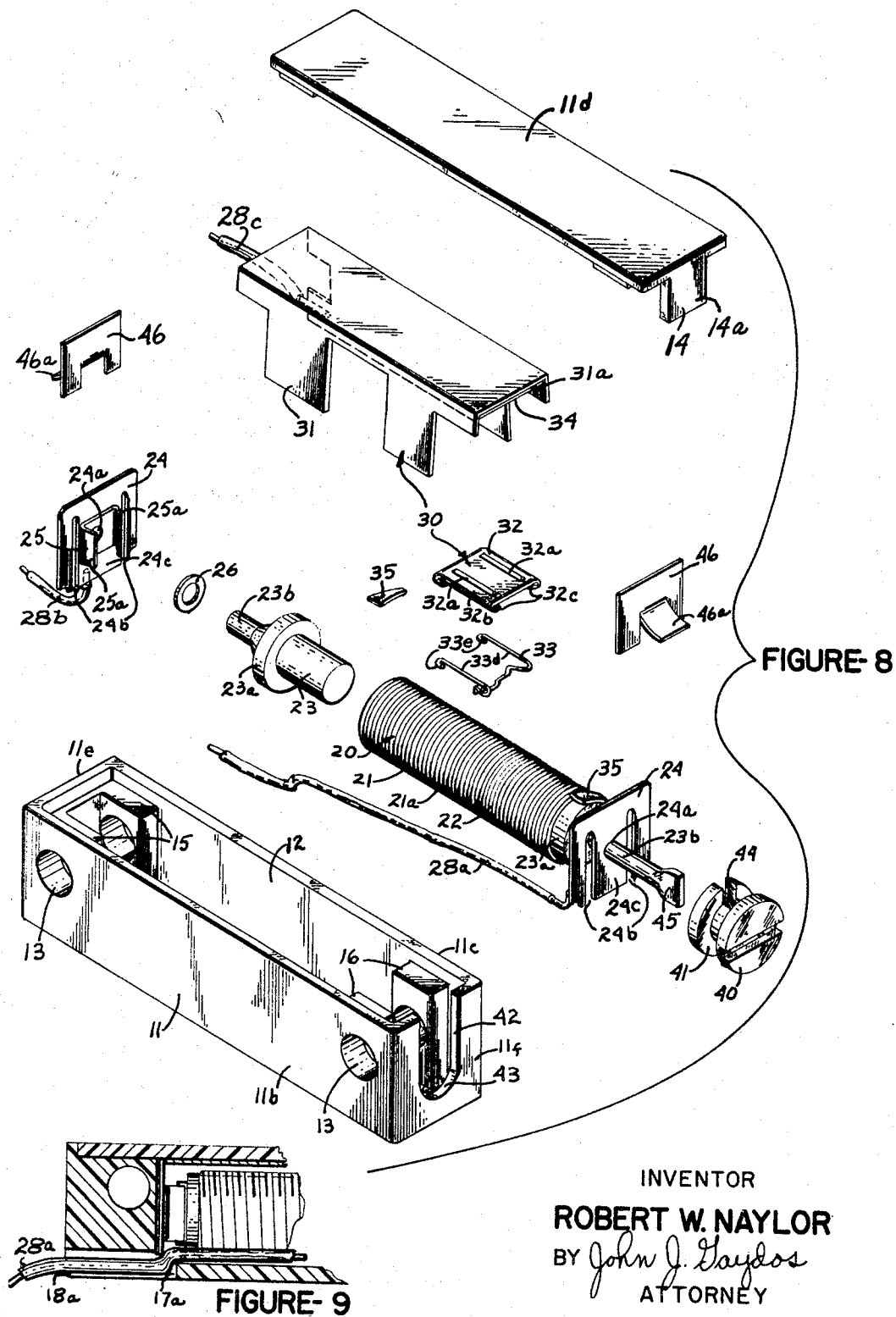
R. W. NAYLOR

3,436,714

VARIABLE RESISTANCE CONTROL HAVING A RESISTANCE
WIRE SUPPORTING CYLINDRICAL SUBSTRATE

Filed Dec. 29, 1966

Sheet 2 of 2



INVENTOR

ROBERT W. NAYLOR

BY *John J. Gaydos*
ATTORNEY

1

2

3,436,714

VARIABLE RESISTANCE CONTROL HAVING A RESISTANCE WIRE SUPPORTING CYLINDRICAL SUBSTRATE

Robert W. Naylor, Weston, Ontario, Canada, assignor to CTS Corporation, Elkhart, Ind., a corporation of Indiana

Filed Dec. 29, 1966, Ser. No. 605,798

Claims priority, application Canada, Dec. 24, 1966, 978,898

Int. Cl. H01h 61/01

U.S. Cl. 338—145

24 Claims

ABSTRACT OF THE DISCLOSURE

Control includes a resistance wire wound on a cylindrical substrate. Movable contactor comprises a contact wire disposed in a groove in the substrate and wiping engaging the resistance wire as the cylindrical substrate is rotated. Rotation of the cylindrical substrate effects rectilinear movement of the contactor along a stationary collector electrically connected to and mechanically guiding the contactor. Tension members frictionally coupled with shafts supporting the substrate maintain a desired value of rotational torque of the control. Apertured end springs rotatably support the shafts supporting the rotatable substrate and complete the electrical circuit between terminal leads and the ends of the resistance wire. A knob rotatably supported by the housing is provided with a radially disposed slot in which a deformed end of one of the shafts is received.

The present invention relates to variable resistance controls, and more particularly, to a wirewound variable resistance control of the rectilinear type.

In an infinite resolution variable resistance wirewound control, a movable contactor generally is in continuous engagement with an incremental section of a small diameter resistance wire as the contactor is wiped intermediate the ends of the wire. The prior art is replete with such controls; however, such controls are limited to a resistance of less than 200 ohms. Efforts to increase the resistance in excess of 200 ohms have been successful solely by helically winding the wire into a coil and then spirally supporting the helically wound wire on a bobbin, the small helical coils giving rigidity to the small diameter wire and increasing the length and resistance of the resistance wire between the ends thereof. Although such construction enables more resistance wire to be employed in a control, true infinite resolution is unobtainable since the movable contactor moves from one convolution to the adjacent convolution as the contactor is wiped along the resistance wire. Other attempts of obtaining an infinite resolution rectilinear wirewound control having a resistance in excess of 200 ohms have been unsuccessful because of the extreme difficulty of maintaining a resistance wire of less than .005 inch in diameter properly wound on a bobbin. The inability of minimizing wear and maintaining minimum contact resistance between the movable contactor and the resistance wire also has limited the maximum resistance available with such control. It would, therefore, be desirable to provide an infinite resolution variable resistance wirewound control having a maximum resistance at least many times greater than 200 ohms.

Accordingly, it is an object of the present invention to provide an improved infinite resolution variable resistance control. Another object of the present invention is to provide a variable resistance control with a movable contactor having a wire segment of a contact wire engaging

the resistance wire with the major axis of the wire segment parallel to a line tangential to the bobbin supporting the resistance wire. An additional object of the present invention is to provide improved means for operably connecting the bobbin of a variable resistance control to an externally disposed knob. A further object of the present invention is to provide a variable resistance control with a rotatable helically grooved bobbin having a resistance wire wound in the helical groove. Still another object of the present invention is to provide a variable resistance control with a laterally shiftable movable collector. Still an additional object of the present invention is to provide a variable resistance control with improved current transfer means between the ends of the resistance wire and the lead wires. A still further object of the present invention is to provide a variable resistance control with an improved torque tension member. Yet another object of the present invention is to provide a variable resistance control with an improved lubricant for reducing friction and minimizing wear between the movable contact and the resistance wire. Yet an additional object of the present invention is to provide a variable resistance control with improved clutch means for limiting rectilinear motion of the movable contactor. Yet a further object of the present invention is to provide a variable resistance control with means providing high contact pressure between the stationary collector and the movable contactor. 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 control comprising a grooved cylindrical substrate having a resistance wire wound in the groove of the substrate. A pair of shafts extending outwardly from the ends of the substrate rotatably support the substrate in a housing. A movable contactor having a contact wire disposed in the groove wipingly engages the resistance wire as the cylindrical substrate is rotated. A stationary collector mounted in the housing in spaced relationship to the axis of the cylindrical substrate is in engagement with and guides the movable contactor as the contactor is driven rectilinearly by the substrate. For increasing rotational torque of the substrate, a pair of tension members frictionally engage the shafts. The ends of the resistance wire are secured to the shafts and shoulders formed on the shafts are in electrical contact with a pair of apertured end springs rotatably supporting the shafts. Terminal leads secured to the end springs and to the stationary collector extend outwardly of the housing. The end portion of one of the shafts is constrained to rotate with a knob rotatably supported by the housing.

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: FIGURE 1 is an isometric view of a variable resistance control made in accord with the present invention; FIGURE 2 is a sectional view taken along line II—II of FIGURE 3, assuming that FIGURE 3 is shown in full; FIGURE 3 is a longitudinal sectional view of the control shown in FIGURE 1; FIGURE 4 is a sectional view taken along line IV—IV of FIGURE 3, assuming that FIGURE 3 is shown in full; FIGURE 5 is a bottom plan view of the movable contactor of the control of FIGURE 1; FIGURE 6 is a side view of the movable contactor shown in FIGURE 5; FIGURE 7 is a grossly enlarged fragmentary section showing the contact wire of the movable contactor engaging a segment of the resistance wire disposed in the helical groove of the

cylindrical substrate; FIGURE 8 is an exploded view of the control of FIGURE 1; and FIGURE 9 is a fragmentary section taken along line IX—IX of FIGURE 2 showing improved means for securing lead wires to the housing.

Referring now to the drawings, there is illustrated a variable resistance control generally indicated at 10 comprising a housing 11, having a bottom wall 11a, side walls 11b and 11c, a top wall 11d and end walls 11e and 11f defining a hollow interior or cavity 12 containing a resistance element assembly 20. The housing 11 is provided with a pair of transverse apertures 13 to facilitate mounting of the control 10. A cover 14 closes the cavity 12 of the housing 11, the top portion of the cover 14 defining the top wall 11d of the housing. The cover 14 and the housing 11 are preferably molded from a suitable molding resin such as a phenol condensation composition or a methacrylate resin. As best seen in FIGURE 8 of the drawings, the portions of the side walls surrounding the transverse apertures 13 are reinforced by increasing the thickness of the walls around the apertures 13.

Considering now the resistance element assembly 20, it comprises a cylindrical substrate or bobbin 21 of dielectric material such as alumina or steatite. A helical groove 21a (see FIGURE 7) is formed on the outer surface of the bobbin 21 and a resistance wire 22 is wound in the groove 21a. For the purpose of rotatably supporting the bobbin 21 in the housing 11, the ends of the bobbin 21 are provided with a pair of inwardly extending cylindrical bores 21b (see FIGURE 3) and a pair of bobbin end members 23 are pressed into the bores. Preferably the bores 21b and the end members 23 are tapered to improve the fit therebetween. Each of the end members is provided with an annular member 23a having a diameter substantially equal to the outer diameter of the bobbin for limiting insertion of the end members into the bores 21b. The annular members 23a abut against the ends of the bobbin 21. A pair of flat end springs 24 disposed in the housing normal to the axis of the bobbin 21 abut against shoulders 15 and 16 formed from increasing the thickness of the walls around the apertures 13. Each of the end springs 24 (see FIGURE 8) is provided with an aperture 24a and a pair of slots 24b on opposite sides of the apertures 24a define a depending tongue 24c. A pair of stub shafts 23b extending axially outwardly from the end members 23 is journaled in the apertures 24a provided in the end springs 24. Axial end play of the bobbin 21 is minimized by maintaining the distance between the end springs, i.e., between the shoulders 15 and 16, less than the distance between the end members for biasing the tongues 24c toward the end members 23. The ends of the resistance wire 22 are fixedly secured to each of the annular members 23a in a suitable manner such as by welding. Inadvertent rotation of the bobbin is prevented by suitably securing to the end springs 24 a pair of U-shaped tension members 25 with the legs 25a of each of the tension members frictionally engaging the end members 23. By varying the angle of preform of the legs 25a against the end members 23 and the thickness of the tension members 25, rotational torque of the bobbin 21 can be precisely controlled. Improved current transfer means is obtained between the end members 23 and the end springs 24 by fixedly securing, e.g., by welding, a slip ring 26 of precious metal against the outer ends of the end members 23 and around stub shafts 23b. Lead wires 28a and 28b extending outwardly from end wall 11e of the housing 11 are secured to the end springs 24 for electrically connecting the ends of the resistance wire 22 into a circuit.

In accord with the present invention, collector means 30 comprising an elongated stationary collector 31 of U-shaped cross section disposed around the bobbin 21 and a movable contactor or collector 32 is employed for connecting a center lead wire 28c to a movable contact wire 33 wipingly engaging the resistance wire 22 intermediate

the ends thereof. The movable collector 32 with the contact wire 33 secured thereto slideably engages the bight portion 31a of the stationary collector 31. Friction between the stationary and movable collectors is reduced by providing a pair of runners or ribs 32a on the movable collector 32. In the alternative, the runners can be provided on the stationary collector. The runners not only decrease contact area, but also increase contact pressure breaking down any oxide film produced by a lubricant applied between the stationary and movable collectors and prevent other foreign particles generally producing a high resistance from becoming lodged between the collectors. It will be appreciated that a low contact resistance between the stationary and movable collectors is desirable. Therefore, in a preferred form of the invention, a precious metal insert 34 is disposed along the bight portion 31a of the stationary collector 31 in continuous engagement with the runners 32a of the movable collector 32.

As best shown in FIGURE 2 of the drawings, the width of the movable collector 32 is substantially less than the inside width of the bight portion 31a. With such relationship, lateral shifting as well as forward and rearward motion of the movable collector within the stationary collector is obtained, i.e., when the bobbin is being turned in a clockwise direction to drive the movable collector rearwardly, the movable collector is urged laterally toward one side of the stationary collector and, when the bobbin is turned in a counterclockwise direction to drive the movable collector forwardly, the movable collector is urged laterally toward the opposite side of the stationary collector. The difference between the widths of the stationary and movable collectors also enables the contact wire 33 carried by the movable collector to adjust to imperfections such as nicks in the helical groove on the bobbin. Such imperfections frequently occur when a narrow groove is formed on the outside surface of a bobbin of alumina or steatite. It will be appreciated that any imperfections in the sides of the groove moving into engagement with the contact wire 33 impart an upward component of travel thereto. Lateral shifting of the movable collector, however, prevents the contact wire 33 from being lifted off of the resistance wire 22 when the contact wire engages an imperfection in the groove. In a control built in accord with the present invention, the width of the movable collector 32 was $.197 \pm .002$ inch and the width of the channel in the stationary collector 31 was $.216 \pm .001$ inch leaving a space of $.010$ inch, i.e., approximately 5 percent on each side of the movable collector 32.

Preferably the contact wire 33 is formed from spring wire, e.g., music wire, into a U with the bight portion 33a disposed at an angle α (see FIGURES 4 and 5) slightly greater than the pitch of the helical groove 21a. The angle α is slightly greater than the pitch of the grooves in order to keep the front corners of the movable contactor 32 from catching in the sides or legs of the stationary collector 31. By making the bight portion 33a with an embossed wire segment 33b in direct contact with the resistance wire 22, the ends of the bight portion on each side of the wire segment do not catch in the imperfections of the helical groove. As the bobbin is rotated shifting the movable collector toward one side of the stationary collector, electrical contact between the bight portion 33a and the resistance wire also shifts toward one end of the bight portion 33a. Similarly, when the bobbin is rotated in the opposite direction, electrical contact shifts toward the other end of the bight portion 33a. By shifting the movable collector, the wear on the wire segment 33b is distributed over a larger portion of the wire segment as the wire segment wipes the resistance wire rather than being concentrated along a certain line. A pair of legs 33c (see FIGURE 6) of the U-shaped contact wire 33 extends upwardly from the bight portion 33a, then outwardly at right angles toward the front corners of the movable collector 32 (see FIGURE 5).

The supported portions 33d (see FIGURE 8) of each of the legs are reversely bent in the form of a hairpin curve and extend rearwardly along the sides of the movable collector. The ends 33e of the legs of the contact wire are also reversely bent to prevent the contact wire from being pulled away from the movable collector. The center portion 32b of the movable collector 32 is secured to the supported portions 33d of the legs by rolling over edges 32c over the supported portions 33d as best shown in FIGURES 6 and 8 of the drawings. The hairpin curves formed in the legs of the contact wire are preferable to maintain the wire segment 33b under uniform contact pressure against the resistance wire intermediate the ends thereof even though bobbin eccentricity and other tolerances cause the contact wire 33 to shift from the axis of the bobbin.

In a device built in accord with the present invention, the diameter of the contact wire 33 was .004 inch, the length of the segment was .036 inch, and the wire segment 33b formed an angle of $94^{\circ} \pm 1^{\circ}$ from the center axis of the bobbin while the grooves formed an angle of 91.5° from the center axis of the bobbin. The probability of imperfections in the grooves will become apparent when it is realized that for a 2000-ohm control built in accord with the present invention, the width of the groove is $.0026 \pm .0002$ inch, the depth of the groove is $.003 \pm .0005$ inch and the angle between each of the side walls of the groove and the central axis of the bobbin is 60° . The length of the bobbin is less than one inch long having a diameter of .2 inch. As best shown in FIGURE 7 of the drawings, one side of the wire segment 33b rides on the wall of the groove while the other side engages the resistance wire. It is critical that the relative dimensions between the diameter of the contact wire 33b, the diameter of the resistance wire 22, and the width of the groove 21a are such as to prevent the wire segment 33b from riding on the two walls of the groove at one time. For optimum results a line through the center of the wire segment 33b and the center of the resistance wire 22 should be at an angle β less than 45° to a line parallel to the central axis of the bobbin.

For the purpose of limiting rectilinear movement of the movable collector 32 as the collector 32 approaches either end of the resistance wire, a pair of clutch fingers 35 are fixedly secured to the annular members 23a for lifting the wire segment 33b out of the last groove and into the second last groove. The side walls of the groove preferably should form an angle of at least 60° with the central axis of the bobbin; otherwise, the wire segment will not ratchet properly when the movable collector 32 approaches the end of the resistance wire. To prevent excessive wear between the wire segment 33b and the resistance wire 22, a lubricant is deposited in the grooves of the bobbin. Regular lubricants can be employed but tend to form a film on the resistance wire 22 and the contact wire 33 increasing the contact resistance therebetween and are generally unsatisfactory for applications where a precision adjustment is necessary. On the other hand a nonfilm forming lubricant generally causes excessive wear to the contact wire and the resistance wire. Silicon oils are satisfactory where adjustment of the control is at a minimum. Frequent adjustment of the control, however, causes the silicon oil to form a sludge resulting from the hot spot where the contact wire and the resistance wire are in contact. A synthetic grease, e.g., silicon dielectric grease, containing minute grains of synthetic silicon dioxide is extremely preferable. The minute grains of silicon dioxide apparently function as ball bearings providing a rolling and polishing action allowing the contact wire and the resistance wire to maintain low contact resistance. The addition of 1 percent finely powdered graphite further improves the life of the contact wire and substantially reduces contact resistance although .1 to 10 percent can be used. Slight oxidation of the resistance wire may be prevented by using an oxide

inhibitor. The grains of silicon dioxide are preferably 25 to 50 microns in diameter but are acceptable within a range of 2 to 500 microns, depending upon the diameter of the resistance wire.

As will become apparent from the following description, it is preferable that the resistance wire be releasably wound in the groove 21a of the bobbin 21 to enable the resistance wire 22 to be forced into the corner of the groove 21a by the wire segment 33b. With such arrangement and especially since the length of the resistance wire tends to elongate slightly with respect to time, rotation of the bobbin causes the wire segment 33b to advance the wire in the grooves 21a ahead of the wire segment and automatically form a helix of greater diameter tending to keep the resistance wire taut and prevent pile-up thereof. This condition exists even if the substrate is noncylindrical, e.g., conical, when a non-linear function is desired.

To prevent the movable collector 32 from rocking against the metal insert 34, e.g., of gold, silver, platinum and palladium, as the bobbin is rotated, the thrust line, i.e., a line passing transversely through the center of the wire segment and the top front of the movable collector 32, should form an angle of less than 45° with the central axis of the bobbin. Moreover, the angle between the thrust line and the side wall of the groove in engagement with the wire segment should form an angle of less than 90° to prevent the contact wire from being thrust downwardly as the bobbin is rotated.

Contact wire pressure upon the resistance wire is very critical. If the pressure is too high, the movable collector stretches the resistance wire and, if the pressure is too low, minimum contact resistance cannot be maintained. In a device built in accordance with the present invention where the resistance wire wound on the bobbin had a total resistance of 2,000 ohms and the diameter of the resistance wire was .0012 inch, a pressure in the range of 1 ounce is sufficient to stretch the resistance wire. Minimum acceptable contact resistance is impossible below .6 ounce. It is, therefore, necessary that the contact pressure be maintained in excess of .6 ounce and below 1 ounce. Consequently, the design of the pressure producing means, i.e., the movable collector 32, and more specifically the design of the contact wire 33 is critical.

Preferably and as illustrated in FIGURES 3 and 8 of the drawings, a molded knob 40 of suitable dielectric material is employed for rotating the bobbin. The knob provided with a circumferential groove 41 rests in a corresponding slot 42 in the end wall 11f of the housing, the slot having an arcuate bottom portion 43 corresponding to the diameter of the circumferential groove 41, and the width of the circumferential groove corresponds to the thickness of the wall to prevent axial shifting of the knob. The inner end of the knob 40 is provided with an elongated slot 44 receiving the flattened end 45 of the shaft 23b constraining the shaft to rotate with the knob. A depending tongue 14a extending downwardly from one end of the cover 14 into the slot 42 and the circumferential groove 41 retains the knob 40 firmly secured to the housing and in axial alignment with the bobbin.

To prevent burrs and the like on not shown mounting screws from shorting against the end springs 24 or shafts 23b as the mounting screws pass through the apertures 13, a pair of insulators 46 are mounted against the end spring and the shaft. The insulators preferably comprise strips of insulation having a pair of slits extending upwardly from the bottom edge of each strip to a height slightly above the shafts 23b. The tabs 46a defined by the slits are folded upwardly normal to the strips and rest upon the shafts 23b.

As best shown in FIGURE 9 of the drawings the lead wires 28a and 28b extend downwardly through openings 17a and 17b provided in the bottom wall 11a of the housing 11 and then rearwardly in slots 18a and 18b communicating with the openings 17a and 17b. The center

lead wire 28c (see FIGURE 3) also extends rearwardly through an opening 17c permitting the controls 10 to be stacked vertically or horizontally without causing interference from lead wires.

From the above description, it will be apparent that an infinite resolution electrical control having a bobbin of less than one inch in length can be adjusted to introduce into a circuit maximum resistance at least in excess of 2,000 ohms.

While there has been illustrated and described what is at present considered to be a preferred embodiment of the present invention, it will be appreciated that numerous changes and 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. A variable resistance control comprising a housing, a cylindrical substrate of dielectric material supported in the housing and having an outer cylindrical surface provided with a helical groove, said groove having a pair of opposing sides, a resistance wire wound in the helical groove, collector means engaging the resistance wire and one side of the groove, said collector means urging the resistance wire against the opposite side of the groove and maintaining the resistance wire taut during operation, terminal means electrically connected to the ends of the resistance wire, and means for effecting relative rotation between the cylindrical substrate and the collector means, said relative rotation causing said one side of the groove to cooperate with the collector means and move said collector means along the substrate in said groove.

2. The control of claim 1, wherein a pair of shafts rotatably support the cylindrical substrate and extend outwardly from the substrate, a pair of flat end springs are mounted in the housing on opposite sides of the substrate, and the end springs are provided with apertures rotatably supporting the shafts.

3. The control of claim 1, wherein a pair of shafts rotatably support the cylindrical substrate and a pair of tension members secured in the housing frictionally engage the shafts for increasing rotational torque of the cylindrical substrate.

4. The control of claim 2, wherein the end of one of the shafts is flattened and a knob rotatably supported by the housing is provided with a slot, and the flattened end of the shaft is received in the slot constraining the shaft to rotate with the knob.

5. The control of claim 1, wherein a pair of end members are fixedly secured to the cylindrical substrate to provide electrical connection areas for the ends of the resistance wire, the ends of the resistance wire are electrically connected to the end members, a clutch member is fixedly secured to each of the end members, and a portion of each of the clutch members extends over a portion of the helical groove to limit movement of the collector means along the cylindrical substrate.

6. The variable resistance control of claim 1, wherein the collector means comprises a U-shaped contact wire and an embossed wire segment formed in the bight portion of the U-shaped contact wire wipably engages the resistance wire.

7. The variable resistance control of claim 6, wherein the axis of the wire segment of the contact wire is disposed in the helical groove, said axis forming an angle with a line perpendicular to the axis of the cylindrical substrate that is greater than the pitch angle of the groove.

8. The control of claim 2, wherein a slip ring is carried by each of the shafts for decreasing electrical resistance between the shafts and the end springs.

9. A variable resistance control comprising a housing, a substrate member disposed in the housing and provided with a helical groove and with a pair of end walls, a resistance wire releasably wound in the helical groove, a

pair of terminal leads, means connecting the terminal leads to the ends of the resistance wire, a first center collector disposed in the housing in spaced relationship to the substrate member, a terminal lead connected to the first center collector, a second center collector engaging the first center collector, an elongated contact member resiliently carried by the second center collector for wiping contact with an incremental section of the resistance wire and a side of the groove, the resistance wire releasably wound in the groove being free to form convolutions of increased diameter in the groove and ahead of the contact member, and means for moving one of said members relative to the other member, said relative movement between said members causing one side of said groove to advance the elongated contact member along the substrate in said groove thereby to effect changes in the setting of the control.

10. The control of claim 9, wherein a pair of ribs is formed on one of the center collectors spacing the other center collector therefrom.

11. The control of claim 9, wherein the diameter of the contact member is at least twice as large as the diameter of the resistance wire.

12. The control of claim 9, wherein the first center collector is of U-shaped cross section and the second center collector is slidable within the bight portion of the first center collector.

13. The control of claim 9, wherein a precious metal insert is interposed between the first and second center collectors.

14. The control of claim 9, wherein the substrate member has a pair of bores communicating with the end walls, and the means connecting the terminal leads to the resistance wire comprises a pair of end members secured in the bores, a pair of end springs mounted in the housing in electrical contact with the end members, each of the end springs being provided with an aperture, and a stub shaft integral with each of the end members journaled in the aperture, the ends of the resistance wire being secured to the end members, the terminal leads being connected to the end springs.

15. The control of claim 14, wherein a tension member is fixedly secured to each of the end springs frictionally contacting the end members.

16. The control of claim 14, wherein a knob is rotatably supported by the housing, the inner end of the knob is provided with a slot, and the end portion of one of the shafts is flattened and disposed in the slot for constraining the shaft and the substrate member to rotate with the knob.

17. The control of claim 9, wherein a plane passing through the contact member and the top front of the second center collector forms an angle of less than 45° with the longitudinal axis of the substrate member.

18. The control of claim 12, wherein the bight portion of the first center collector is substantially greater than the width of the second center collector to permit shifting of the second collector transversely of the first collector upon altering the direction of motion of one of said members relative to the other member.

19. The control of claim 9, wherein a synthetic lubricant is interposed between the contact member and the resistance wire and silicon beads are suspended in the lubricant.

20. The control of claim 9, wherein the root of the groove is flat and lies in an imaginary cylindrical surface concentric to the axis of the substrate member, the diameter of the resistance wire is less than the width of the root, and the elongated contact member is generally circular in cross section and has a diameter greater than the diameter of the resistance wire.

21. The control of claim 9, wherein the angle between the side of the groove and the axis of the substrate member is approximately 60°, and a line passing through the axis of the elongated contact member and the axis of

the resistance wire intersects the axis of the substrate member at the angle of less than 45°.

22. In a variable resistance control, the combination of a housing, a substrate member mounted in the housing, means defining a resistance path carried by the substrate member, a contact member mounted in the housing wipably engaging the resistance path, a shaft connected to one of said members, the outer end of the shaft having a deformed portion, and a knob rotatably supported by the housing, said knob being provided with a radially disposed slot, the deformed portion of the shaft being received in the slot constraining the shaft to rotate with the knob, the slot permitting movement of the shaft relative to the knob in a direction normal to the axes of the knob and the shaft in order to secure axial alignment between the knob and the shaft.

23. The control of claim 22, wherein the housing comprises a first member having a pair of end walls and side walls defining a cavity and a second member closing the cavity, one of said end walls being provided with an opening, the knob being provided with a circumferential groove rotatably supporting the knob in the opening with the sides of the groove engaging the end wall, a tongue depending from the second member received in the opening for rotatably securing the knob in the opening.

24. In a variable resistance control, an extremely threaded substrate member of insulating material, a collector member mounted upon and in threaded engage-

ment with said substrate member, means for rotating one of said members relative to the other, a continuous length of resistance wire releasably wound upon said substrate member within portions of the threaded groove in flanking relation to said collector member, rotation of one of said members causing the collector member to advance the resistance wire in the groove ahead of the collector member and cause the resistance wire to form convolutions of increased diameter ahead of the collector member, and terminal leads electrically connected to the collector member and the ends of the resistance wire.

References Cited

UNITED STATES PATENTS

2,829,224	4/1958	Bell	338—163
2,830,161	4/1958	Wilentchik	338—148 X
2,839,643	6/1958	Vercesi	338—148
2,938,396	5/1960	Nicolosi et al.	338—143 X
3,108,244	10/1963	Nirenberg et al.	338—144
1,535,898	4/1925	Camp.	
2,399,060	4/1946	Puerner	171—242
2,443,020	6/1948	Beier	171—777
2,998,586	8/1961	Moore et al.	338—145
3,353,133	11/1967	Bellar	338—145

ROBERT K. SCHAEFER, *Primary Examiner*.

H. J. HOHAUSER, *Assistant Examiner*.