Jan. 4, 1966 A. M. SERDAHELY ET AL 3,227,986

SINGLE-TURN ANNULAR RESISTANCE ELEMENTS

Filed June 22, 1962 2 Sheets-Sheet 1

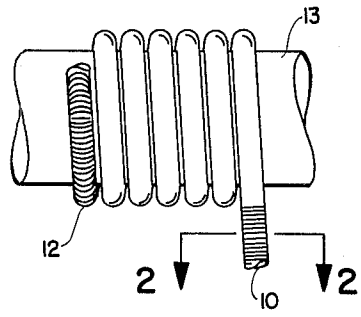


FIG. 1

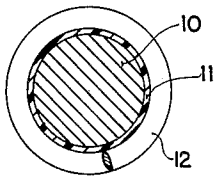


FIG. 2

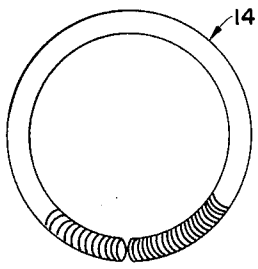


FIG. 3 A

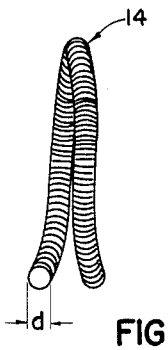


FIG. 3 B

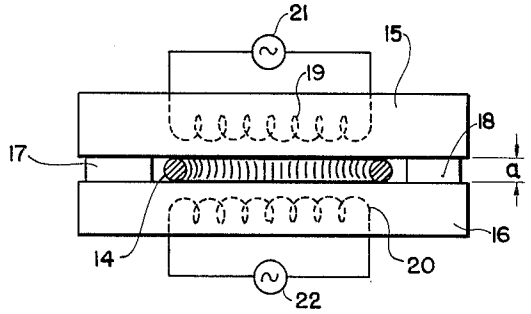


FIG. 4

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SINGLE-TURN ANNULAR RESISTANCE ELEMENTS

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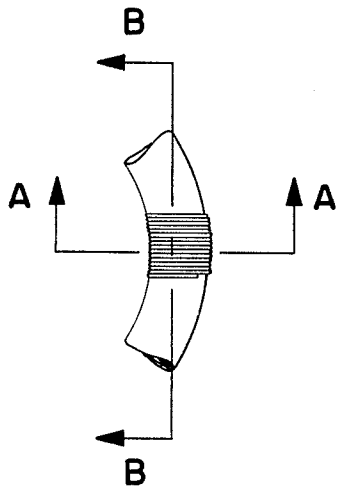
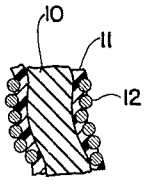
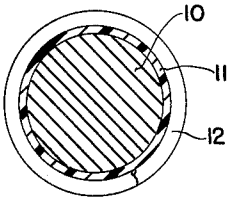


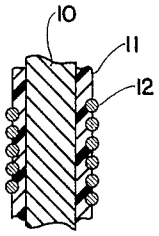
FIG. 5



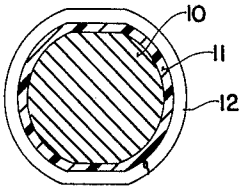
B-B FIG. 6A



A-A FIG. 6 B



B-B FIG. 7A



A-A FIG. 7B

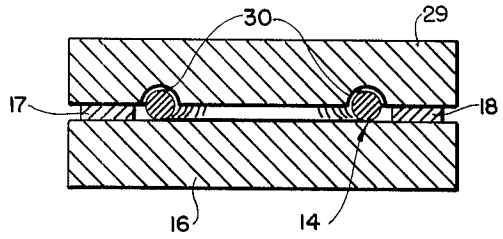


FIG. 8

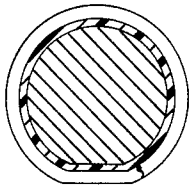


FIG. 9

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3,227,986

SINGLE-TURN ANNULAR RESISTANCE ELEMENTS

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3 Claims. (Cl. 338—302)

The present invention relates generally to single-turn resistance elements and, more particularly, to such elements formed from individual helix turns.

Many potentiometers, variable resistors, rheostats and the like are presently constructed with a cavity in which the resistance element is retained in a closed path, usually shaped in the form of an annulus. Said components are commonly denoted as single-turn potentiometers, variable resistors, etc.

Many potentiometers, variable resistors, rheostats, and the like employ resistance wire wound about and supported by a cylindrical support, or mandrel as is known in the art. It is this type of resistance element with which this invention is particularly concerned. Such elements are customarily formed by helically winding the resistance wire upon long, straight lengths of an insulated malleable metal rod or core. This long length of wound mandrel is then helically wrapped around a round arbor. The resultant helix is then cut apart into individual helix turns. The resultant individual helix turns have not, however, been entirely satisfactory as a single-turn resistance elements because of the helix shape retained in the elements, i.e., the respective ends of the element are not juxtaposed and the element does not lie in one plane.

One solution known in the prior art for diminishing or eliminating the retained helix shape is to wind the length of resistance element upon the round arbor with a back angle, so as to form a tightly closed spring. For a mandrel core constructed of steel or like metal having a well defined yield point, each helix turn when cut from the helixed element will "spring" back and assume a substantially flat annular shape with the ends correctly juxtaposed. However, this procedure is only successful with core materials having a well defined yield point. Copper, a preferred core material has a very poorly defined yield point and does not spring or twist into correct alignment. Instead, a copper mandrel which has been back-helixed assumes a permanent set in the shape of a single-turn helix.

There are also other considerations which vitiate the above procedure for de-helixing the single-turns. Thus, helixing the resistance element with a back angle tends to distort the resistance wire helically wound upon the mandrel. Moreover, close winding of the mandrel causes the individual resistance wire turns to rub against one another thereby deleteriously wearing the individual turns. Another circumstance when this procedure is not satisfactory is when it is necessary to varnish or apply some other coating to the helically wound mandrel before it is cut into individual helix turns. In such instances, it is necessary to space wind the mandrel so that the varnish may be introduced between the individual turns thereof.

Another procedure previously used to de-helix the windings is to individually align them by hand. However, because the alignment twist required is concentrated in the center 30° of the winding rather than being uniformly distributed around the winding, the resulting element does not lie flat in a single plane but rather displays a double S curve.

Accordingly, it is the object of the present invention

to provide an improved method and apparatus for forming single-turn resistance elements lying in a single plane from individual helix turns.

Another object of this invention is to provide a method and apparatus for de-helixing individual resistance turns which does not require that the resistance material be wound with a back angle so as to form a tightly closed spring.

Still another object of this invention is to provide an improved method and apparatus for de-helixing individual turns of resistance elements suitable for elements wound upon a mandrel which does not have a defined yield point, i.e., suitable for a core material such as copper wire.

Other and further objects, features and advantages of the invention will become apparent as the description proceeds.

Briefly, in accordance with a preferred form of the present invention, a single turn resistance element may be produced having an extremely uniform surface by placing an individual helix turn of resistance wire, wound on a malleable core, between two planar plates and bringing the plates together by a hydraulic press. The thickness of the shims is preselected so that the press slightly flattens the mandrel by moving or distorting material. This displacement of material "locks" the resistance turn in the desired shape so as to form a true circle lying in a single plane with the ends juxtaposed each other. Thus, the procedure removes any "memory" of its previous helix form.

This results in a single-turn resistance element lying in a single plane and also produces an element in which the individual turns of resistance wire are of uniform height where the material was displaced. Moreover, the individual resistance wire turns are locked firmly into the insulating coating placed upon the mandrel. The resultant resistance element provides an excellent surface for a movable electrical contact, providing both improved life and smoothness of operation.

A more thorough understanding of the invention may be obtained by the following detailed description taken in connection with the accompanying drawings in which:

FIG. 1 illustrates a length of resistance element helically wound upon a round arbor;

FIG. 2 is a cross-sectional view taken along the lines 2—2 of FIG. 1;

FIGS. 3A and 3B illustrate an individual helix turn before de-helixing;

FIG. 4 illustrates an apparatus for de-helixing single-turn resistance elements constructed according to this invention;

FIG. 5 illustrates an enlarged portion of a single-turn resistance element;

FIGS. 6A and 6B illustrate cross-sectional views taken along the lines A—A and B—B of FIG. 5 before de-helixing;

FIGS. 7A and 7B illustrate cross-sectional views taken along the respective lines A—A and B—B of FIG. 5 after de-helixing;

FIG. 8 illustrates an alternative apparatus for dehelixing single-turn resistance elements according to this invention; and

FIG. 9 illustrates in cross-section the resistance element formed by the apparatus shown in FIG. 8.

Referring now to FIGS. 1 and 2, there is shown a mandrel 10 having a cylindrical cross-section. The mandrel 10 is preferably formed from a core of round wire of a malleable metal such as copper and insulated with a layer 11 of an appropriate insulating enamel such as polyvinyl formal polyester or phenolic-epoxy resin.

The mandrel 10 is normally maintained in long straight lengths when the resistance wire 12 is wound thereupon

to a predetermined pitch. Preferred apparatus and methods for accomplishing this operation are described by D. G. Marlow in U.S. Patent No. 2,334,880, entitled "Apparatus for Winding Cores," and H. H. Cary et al. in U.S. Patent No. 2,620,790, entitled "Method and Apparatus for Winding Resistance Elements," each of which is assigned to Beckman Instruments, Inc. The wound mandrel is wound around a round arbor 13 to form the helix shown in FIG. 1. Each of the turns of the helix is then cut to form a plurality of individual helix turns, a representative one of which is shown at 14 in FIGS. 3A and 3B.

The individual helix turn 14 illustrates the helix shape retained by each of the turns when cut from a long resistance element wound in the form of a helix. As described above, previous efforts to de-helix these turns have been generally unsatisfactory, particularly when a material such as copper has been used for the mandrel.

Referring now to FIG. 4, there is shown upper and lower flat plates 15 and 16 of a hydraulic press. The individual helix turn 14 (shown in cross-section) is first placed between these plates and the plates then drawn together a predetermined amount so as to slightly flatten the mandrel of the element 14 by moving or distorting its material. This removes any "memory" of the helix form so as to produce a flat element lying in a single plane. Because of the relatively small amount of displacement required for the plates 15 and 16, a precise control for limiting the minimum plate separation or distance "*a*" in FIG. 4 is to insert flat shims 17 and 18 having a thickness "*a*" between the plates 15 and 16. These shims are thinner than the cross-sectional diameter "*d*" of the coil by a distance "*x*," a distance equal to the amount of squeeze required to produce a flat resistance element. Stated in equation form,

$$a=d-x \qquad (1)$$

Since the shims have a much larger area than the resistance element, they are not deformed by the pressure applied to the plates 15 and 16.

The bottom pressure plate 16 preferably incorporates a resistance heating element 20 connected to a power source 22. The upper plate 15 may or may not incorporate a like heating element 19 connected to power source 21. These elements heat one or both of the metal pressure plates a sufficient amount so as to slightly soften the insulating layer 11 of the mandrel 10. As described in further detail below, this procedure results in a uniform embedding of the individual turns of the resistance wire into the layer 11 so as to produce an improved resistance element. Without such heating, the individual resistance turns tend to be displaced erratically, thus affording a rough surface for the movable electrical contact of the complete variable resistance element.

FIG. 6A illustrates a cross-sectional view of the single-turn resistance element of FIG. 5 prior to the de-helixing operation. As shown, the resistance turns 12 are not uniformly embedded in the resistance coating 11. As distinguished therefrom, FIG. 7A illustrates the resistance element after the de-helixing operation wherein the mandrel 10 is then retained flat in a single plane and each of the turns of resistance wire 12 are uniformly embedded in the insulating coating 11. The resistance wire turns are then of uniform height and are locked firmly in the insulating coating. This surface provides a substantially improved contact track for the movable contact element providing improved life and smoothness of operation.

The actual displacement or distortion of the element is illustrated by comparing FIG. 6B with FIG. 7B, these figures showing an enlarged cross-sectional view of the resistance element in which the flattening or distortion of the mandrel core is clearly evident in FIG. 7B. As shown, a substantial portion of the core cross-section defines a circle and the remainder opposed flattened generally planar sections. Although the mandrel core is deformed as shown, the deformation occurs through the insulating coating 11 which prevents the individual turns of resistance wire 12 from contacting the bare surface of the core.

As described above, the amount that the resistance wires embed in the insulating coating is determined both by the pressure applied by the press and the temperature to which the pressure plates 15 and 16 are raised by the resistance heaters. The heaters in the pressure plates are preferably of a sufficiently low output and the resistance element is heated for a sufficiently short time that only the outer portion of the insulation coating is slightly softened. This heating operation is generally not critical since the insulation coating is usually thick enough that the portion near the mandrel core remains hard for a relatively long period of time. Also, the copper core serves as an excellent heat sink thus further serving to maintain lower temperatures for the insulation adjacent the core. It is through this hard, substantially unsoftened insulation near the mandrel core that the pressure is applied to deform the mandrel. Also, this portion of the insulation effectively prevents the resistance wire turns from being forced into engagement with the mandrel core.

A representative example of a single-turn resistance element constructed in accordance with the above-described apparatus and method is as follows: a mandrel having an outside diameter of 80.80 mils corresponding to a wire gauge number 12 (according to the American Wire Gauge or AWG) is coated with insulation so as to increase its diameter to approximately 83.80 mils. This insulated mandrel is wound with resistance wire having an outside diameter of 2 mils. The resultant total diameter of the resistance element is then approximately 87.8 mils. The distance x is 3–4 mils; accordingly, from Equation 1, the shims are provided with a thickness "*a*" of 83.8 to 84.8 mils or .0838 to .0848 inch. After the squeezing operation, the final outside diameter of the resistance element is some 1–2 mils less than its initial outside diameter, or 85.8 to 86.8 mils.

Another embodiment of an apparatus suitable for performing the methods of this invention is shown in FIG. 8, wherein the upper pressure plate 29 is provided with a groove 30 corresponding to the resistance element 14. Since the resistance element 14 has a cylindrical cross-section, the groove 30 is provided with a semi-cylindrical cross-section. The shims 17 and 18 are necessarily thinner for the same resistance element because of the portion of the element within groove 30. Otherwise, the apparatus of FIG. 8 may be similar to that shown in FIG. 4.

The resistance element constructed with the apparatus of FIG. 8 is illustrated in cross-section in FIG. 9. As shown, only the bottom portion of the resistance element is deformed or flattened, due to the flat surface of the lower pressure plate 16. It will be further understood that the invention is not restricted to those resistance elements having a cylindrical mandrel. Any shaped mandrel may be employed and de-helixed according to the invention, the surface of one or both of the pressure plates 16 and 17 being formed with a corresponding groove in those instances when the original shape of the mandrel is to be maintained.

Although exemplary embodiments of the invention have been disclosed and discussed, it will be understood that other applications of the invention are possible and that the embodiments disclosed may be subjected to various changes, modifications and substitutions without necessarily departing from the spirit of the invention.

We claim:

1. A single-turn annular resistance element lying in one plane comprising:

a malleable metal core having a peripheral annular portion;

a coating of insulation encompassing said core; and

a resistance wire helically wound upon said core externally of said insulation, said resistance wire turns, insulation and core being flattened on at least one

portion thereof after said resistance wire is wound on said core so that said turns of resistance wire are uniformly embedded in said insulation in said flat portion and present a uniform planar surface.

2. A single-turn annular resistance element lying in one plane comprising:

a malleable metal core having a substantially circular cross-section;

a coating of insulation substantially encompassing said core; and

a resistance wire helically wound upon said substantially circular core externally of said insulation, said resistance wire turns, insulation and core being flattened to deform a portion of said core after said resistance wire is wound on said said core so that said turns of resistance wire in said flattened portion are partially embedded in said insulation and present a uniform planar surface.

3. A single-turn annular resistance element lying in one plane comprising:

a malleable metal core having a substantially circular cross-section with flattened planar sections on opposite sides of said core;

a coating of insulation substantially encompassing said core; and

a resistance wire helically wound upon said core externally of said insulation, said resistance wire turns being embedded in said insulation coating over said flattened portions of said core by means of a planar force pressing opposite sides of said core, insulation and resistance windings thereby forming opposed flattened planar surfaces.

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