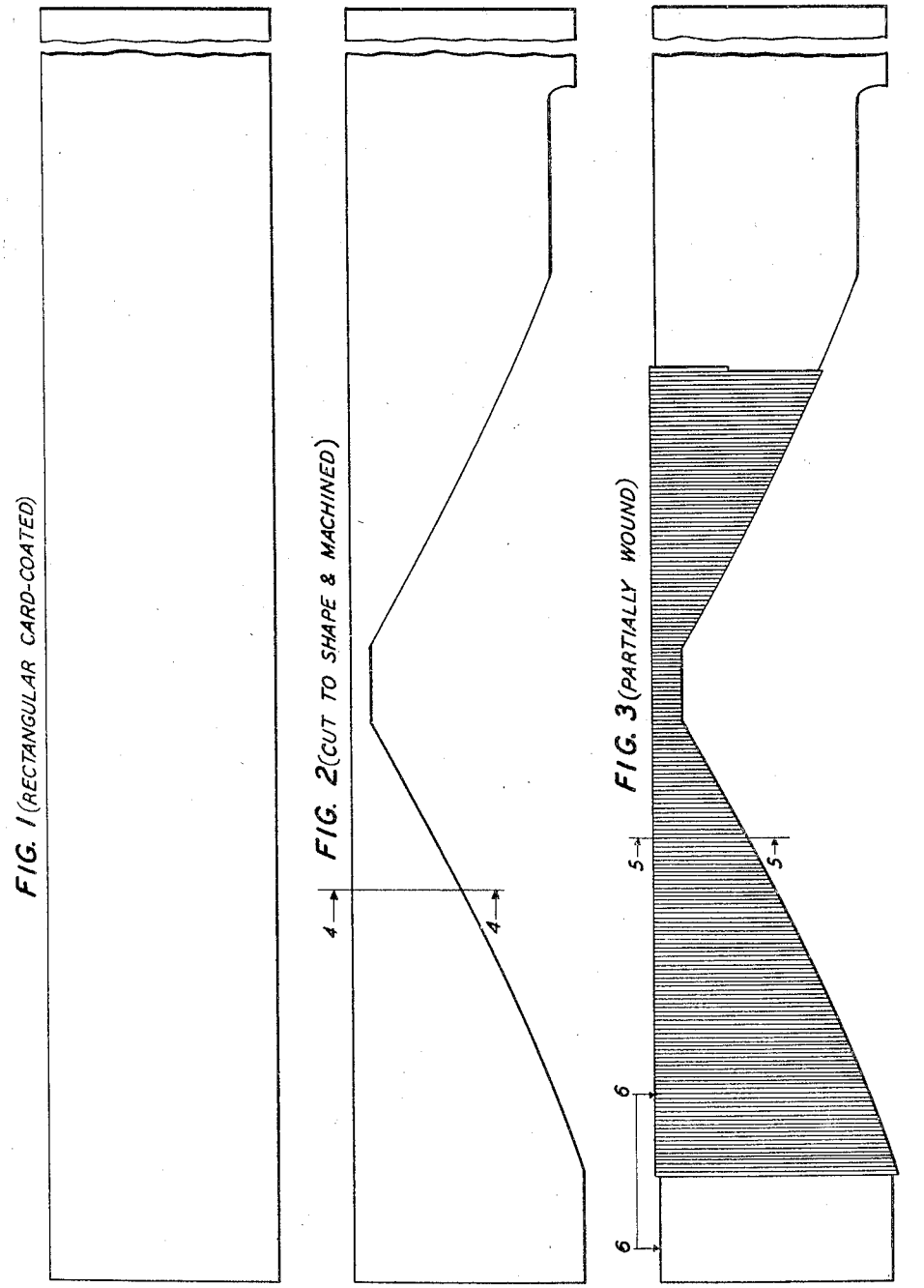
Jan. 10, 1950 R. G. McCOY ET AL 2,494,051

PROCESS FOR MAKING ELECTRICAL RESISTANCES

Filed Nov. 30, 1945 2 Sheets-Sheet 1



INVENTORS R. G. McCOY
W. W. WERRING
BY John E. Cassidy

ATTORNEY

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Filed Nov. 30, 1945 2 Sheets-Sheet 2



FIG. 4

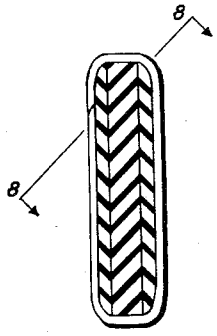


FIG. 5

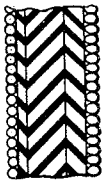


FIG. 8

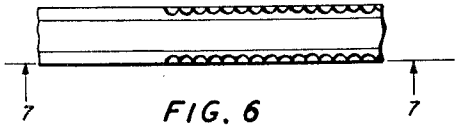


FIG. 6

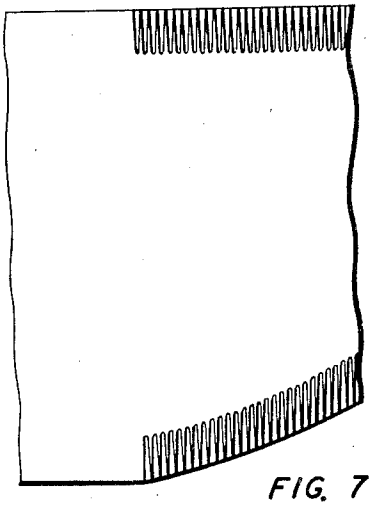


FIG. 7

INVENTORS R. G. McCOY
W. W. WERRING
BY John E. Cassidy
ATTORNEY

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PROCESS FOR MAKING ELECTRICAL RESISTANCES

Robert G. McCoy and Walter W. Werring, New York, N. Y., assignors to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application November 30, 1945, Serial No. 632,049

3 Claims. (Cl. 201—63)

1

This invention relates to improvements in potentiometers having resistance elements of wire wound on flat card-like bases. The cards may be rectangular or shaped to provide linear or non-linear voltage changes. More particularly the invention relates to improvements in the methods of manufacturing the resistance structure as well as to improvements in the resistance structure per se. Ordinarily the flat card-like element has one long edge which is straight and an opposed edge which is also straight for linear voltage changes or contoured, that is, formed in some particular predetermined pattern, such as a continuous curve or a number of straight lines of different slope, to provide desired non-linear potential changes. In the case of certain contoured cards, the slopes may be steep, forming an angle ranging up to 40 degrees with respect to the opposed straight edge. The cards are wound with resistance wire which is ordinarily but not invariably covered with a thin coating of insulation. The cards are sometimes mounted so that they are flat and at other times may be flexed to form circular bands or hoops. The contoured cards are of varying width and have one uniplanar edge. The flexed bands may be secured in any convenient manner and are frequently secured in a groove in a potentiometer housing.

When the bands are flexed to form a hoop a rotatable arm, pivoted at the axis of the band, is arranged to engage the resistance wire wound helically on the card as the arm traverses the uniplanar edge thus affording linear or non-linear potential variations in accordance with a predetermined pattern.

The resistance wire is tapped at its ends and frequently is tapped also at definite points intermediate the ends to provide potential ranges of desired magnitudes varying as required. The magnitudes of the desired potential for certain applications must be fixed within exceedingly close limits, such as within a small fraction of one per cent. In a particular application the potentiometer of the present invention is used in electrical computers which may be employed, for instance, in determining the instant of burst of a shell which is directed at a fast moving target, such as an airplane or a rocket, moving at high speed. Small percentage variations in the voltage derived from a particular setting of one of the potentiometers in a computer may result in considerable variation in the angle of elevation of a gun or in the length of the trajectory of a shell to the point of burst. As many as forty to one hundred and forty straight and contoured potentiometers

2

having cards of many different shapes may be employed in a single computer. Their particular function is to translate the magnitude of a quantity which is one of the parameters of the desired resultant into a potential of a corresponding magnitude within the closest possible limits.

It is an object of the present invention to improve the manufacture of resistance elements both linear and non-linear, particularly contoured or shaped resistance elements of potentiometers.

It is a more specific object of the present invention to provide either a straight or contoured resistance element which affords desired output voltages within closer limits of variation than heretofore obtainable.

It is a further object of this invention to improve the machining qualities of the element on which the resistance is wound.

It is a further object of the invention to provide a card resistance element, either rectangular or contoured, having a large number of turns which will withstand a higher operating temperature without deformation than any wound contoured cards heretofore available.

It is a further object of the invention to provide a wound contoured card on which the resistance wire may be retained on steeper slopes than possible heretofore when the mathematical design of the card requires steeper slopes for particular applications.

In the manufacture of the cards on which the resistance wire is wound it has been found essential that the variation in the card be maintained within .001 inch in a width of three inches. The reason for this becomes apparent when it is pointed out that not infrequently 320 turns of the resistance, and on occasions a larger number, are wound per inch of the card. In a card approximately ten inches in length, which is a common length, there are approximately 3200 turns. A card .001 inch wider than the specified width would have approximately 6.4 inches of additional resistance wire would thereon due to this factor alone and this is but one of a number of factors, others of which will be described below.

In the case of wound contoured cards, with regard to the manufacture of the element on which the resistance is wound, there are two basically different methods heretofore followed in the art: (*a*) The element may be formed of a material such as hard rubber accurately machined to shape; (*b*) the element may be a stratified structure having a middle layer of a material such as a phenol condensation product, known in the art and hereinafter referred to, as phenol fiber, coated

on its opposing surfaces with cellulose acetate which is molded to provide serrations to accommodate the wire and maintain the turns in position.

The use of hard rubber presents a difficulty due to the fact that when subjected to the winding of the many turns of the resistance wire under sufficient tension to secure each turn in a fixed position, the shape of the hard rubber element is distorted. This changes the configuration of the contoured element and tends to affect the results. This is particularly true in cases where the design of the card, to obtain particular characteristics, requires that the area of the cross-section of the card be considerably reduced at a particular position along the length of the card which is very frequently the case. This has been cared for heretofore by estimating the amount of the distorting for particular designs from experience gained in experimentation and making allowance for the expected deformation in the shaping of the card before winding. Since, as mentioned above, elements of a wide variety of shapes, many quite irregular, are required and the elements may be wound with different numbers of turns of wire of different sizes, it is difficult to estimate the amount of distortion for each case within the allowable tolerances which, as explained above, are small. This difficulty is greatly minimized in the present invention.

There is another very important factor which controls the design of a potentiometer card made of hard rubber or similar material which limits its field of usefulness and that is the susceptibility of the card to distortion due to melting as a result of heat generated in the resistance wire during operation. Slight melting of the surface which changes the conformation of the card may seriously affect the results. This limits the application of the contoured card of hard rubber to circuits and equipments in which the temperature does not exceed 140° F., unless specifically treated by the "cycle weld" process, which raises the upper temperature limit somewhat. The present invention extends the safe operating upper temperature limit considerably beyond the limits hitherto attainable.

Mention was made of another technique practiced heretofore in the manufacture of contoured potentiometers, namely, that in which a flat contoured card is coated with cellulose acetate. The cellulose acetate coating is molded under heat in a helical grooved pattern to accommodate the turns of resistance wire. This process has been effective, however, only in cases wherein a relatively small number of turns, 200 or less to the inch, are to be wound on the element and is completely ineffective for winding resistance structures wherein the number of turns exceeds 300 to the inch.

The molding process mentioned above is further limited by the difficulty of controlling the flow of the molded material when it is hot and plastic. This tends to affect the resulting dimensions such as the thickness and width of the molded card. A particularly difficult factor to control is the dimension of the extrusions beyond the edges of the card which serve to retain the wire. Both of these variations obviously affect the length of the turns. While it is possible to control these factors, the molding process requires great skill in the regulation of the heat, the amount of pressure applied, the length of the interval during which the molding pressure is applied, etc. This is also complicated by the fact,

as mentioned above, that the cards are of many different shapes and sizes.

In the present invention the base or supporting element of a rectangular or contoured resistance is formed of a three-layer stratified structure. The middle layer may be any one of a number of substances but preferably phenol fiber. The middle layer has applied to each of its broad surfaces a relatively thin semi-hard homogeneous layer of material which is preferably built up of successive thin coatings of baked varnish to a thickness of approximately .003 inch. The edges of the card are thereafter subjected to a special machining process to afford a card of exact size within very close limits and having strictly square corners free from all irregularities, on which card the resistance wire when wound will be of fixed predetermined length per turn and of uniform pitch and on which the wire will be securely retained. The security of retention of the wire in position is important when the nature of the service in which the apparatus of the present invention may be applied is considered. As mentioned above, an important application of the apparatus of the present invention is in computers which are ordinarily located at the firing positions of guns of large caliber. The apparatus may be mounted on naval ships, etc., and is subject to heavy impact and to rapid acceleration.

The invention may be understood from the following description when read with reference to the associated drawings, which description and drawings disclose a preferred embodiment of the invention, which embodiment is not to be understood as the only form which the invention may take as it may be incorporated in other forms which will readily suggest themselves to those skilled in the art.

In the drawings:

Fig. 1 is a plan view of a rectangular card;

Fig. 2 is a plan view of the card per Fig. 1 after it has been cut to shape and machined;

Fig. 3 is a plan view of the card per Fig. 2 after it has been partially wound with resistance wire;

Fig. 4 is a vertical cross-section through the line 4—4 of Fig. 2;

Fig. 5 is a vertical cross-section through the line 5—5 of Fig. 3;

Fig. 6 is a partial edge view in the direction of the arrows 6—6 of a portion of the card per Fig. 3, assuming the wiring removed, showing the effect of wiring under tension on the front and rear upper edges of the coating on the card;

Fig. 7 is a view of the portion of the card corresponding to Fig. 6 in the direction of the arrows 7—7, assuming the wiring removed, showing the effect of the wiring on the upper and lower portion of the surface of the card per Fig. 3; and

Fig. 8 is a sectional view of Fig. 5 taken at a 45° angle in the direction of arrows 8—8 showing the wires secured at the bottom edge and free at the intermediate portion of the broad surfaces between the top and bottom edges.

In practicing the invention we prefer to use a phenol fiber card as the material for the base structure. However, the invention is not limited to phenol fiber. Any insulator which may be machined successfully including rubber as well as metal noninsulators may be employed. Where rubber is employed it is pointed out that it is subject to deformation due to winding as well as to melting at temperatures above 140° F. as mentioned above.

A wide sheet of phenol fiber is sprayed or roller

coated on its opposing surfaces with varnish. We have found that a phenolic resin combined with an oil to provide a varnish of the heat reactive type is preferable to varnishes of the oleoresinous type. The heat reactive type varnish after curing is more homogeneous than the oleoresinous type varnish. When subjected to heat treatment the heat reactive varnish cures uniformly. The inner portion of the coating is of the same consistency as the outer skin, whereas, the oleoresinous varnish, which is cured by oxidation, cures from the outside surface toward the inner surface. The inner surface tends to remain softer than the outer surface. This affects the depth of the groove resulting from the winding of the resistance under tension and results in slight variations in the lengths of the turns.

The heat reactive varnish also provides a stronger bond between the varnish and the base material. The extruded projections formed by winding are also stronger. The strength and the bond are both better when heat-curing varnish is employed. For these reasons the heat reactive varnish is recommended. We have found that a varnish made by the "Schenectady Varnish Company" and known as "Schenectady Varnish 160" is a satisfactory varnish for the practice of this invention.

First, a coating .001 inch thick is applied to each of the surfaces of the phenol fiber sheet. Then the sheet is baked for about one hour at a temperature of 275° F. Thereafter a second coating of the same thickness is applied to each of the surfaces and the baking is repeated at the same temperature for the same length of time. Finally a third coating is applied of such a thickness as to make the total thickness of the coating on each surface as near as possible to .003 inch. The coated sheet is then baked a third time at the same temperature. The best results are obtained when the third baking is carried on for eighteen hours. Care must be taken that the temperature does not exceed 275° F. or the qualities of the phenol fiber may be impaired if the baking is carried on for long intervals at higher temperatures.

Where close limits of potential variation are required it is very important that the coating not only be of uniform hardness and homogeneous throughout, but that it be of uniform thickness in cards of the same contour for the same application so that the product be uniform and reproducible. It has been found that best results are obtained when the thickness of the coating on each surface is maintained at approximately .003 inch. Such a thickness affords the best results in the subsequent winding. A thinner coating does not afford a sufficiently large extrusion or projection to properly hold the wires. Further, it has been observed that with thinner coatings the wiring tends to cut completely through the coating. This affects the uniformity of the pitch and, what is more important, it affects the capacity of the coating to retain the wire turns in individual positions especially where the slope of the card is steep. Thicknesses exceeding .004 inch have been found unsatisfactory.

It is difficult to make heavier coatings homogeneous and they are expensive to apply, especially if built up layer on layer about .001 inch at a time, with baking after the deposition of each layer. A coating of .003 inch adapts itself, when the resistance wire of from .001 to .005 inch diameter is wound on the card element under tension,

to the formation of individual grooves at the edges of the card and on the broad surfaces of the card near the edges to accommodate the individual turns. A substantial layer of the coating is compressed beneath the wire at and near the edges to form well defined individual guiding supports for the individual turns.

After the coating has been applied, as above described, to the large sheets, the sheets are cut in any convenient manner to the approximate overall dimensions of the individual cards leaving an excess in the width for machining accurately to size according to a special process.

A front view of a card which has been cut from a larger sheet of fiber which has been finished on each surface in the manner described in the foregoing is indicated in Fig. 1. A front view of a card machined to a particular contour is indicated in Fig. 2.

With regard to the production of the profiled card per Fig. 2 before winding, it has been found that it is not possible to make a relatively wide card having a contoured shape to the limits of accuracy required by any of the usual methods which suggest themselves. For instance, it is not possible to make an accurate template and to either scribe or cut the card using the template as a guide, because of the difficulty of scribing or cutting around the template, without some variation from the template. Further, it is not economical to produce the great variety of cards in any of the well-known profiling machines employing an ordinary template alone as a control. The machining of the card to the desired width and shape of contour is carried out in the manner described in Patent 2,412,916 granted to W. J. Kinderman and W. W. Werring, December 17, 1946, which is made part of the present disclosure, by reference, as though fully set forth herein.

Attention is particularly called to the fact that, in the present invention, the contouring operations described in Patent 2,412,916 are carried out on a card which has previously been coated on each side in the manner described, with the semi-hard coating. The combination of the special profiling operation after the special coating process is one of the important aspects of the present invention.

The final card, produced by means of the special machine and in accordance with the method of the Patent 2,412,916 is accurate within the required limits and the edges of the contour along the outer surface of the coating are sharp and well defined. When viewed through a microscope of about 50X it is apparent that the edge is neither burred nor rounded. There are no irregularities to present local slopes and prevent regularity in winding. The edge is clean and straight and the coating material is of uniform thickness so that it presents a square sharp corner in which the resistance wire may be partially embedded to a uniform depth at a uniform pitch. The wiring is retained in position even when wound at slopes up to 40 degrees with respect to the uniplanar edge. This has been unattainable with cards produced by other methods presently known in the art.

In Fig. 2 the card shown has a particular contour for a specific application. It is particularly pointed out that whereas one long edge of the card, in this case the upper edge, is generally straight as indicated, the other edge, the lower edge in Fig. 2, may be shaped in any of a wide variety of patterns to suit particular conditions.

Attentiton is called particularly to the narrowed portion of the card. When the calculations for a particular card require that a section of the card be so reduced, which is frequently the case, the contour of the card if made, as formerly, of a material such as hard rubber, is subject to deformation when wound under tension. The magnitude of the deformation is sufficient to affect the potential obtained to a considerable degree. This deformation must be taken into consideration in the design of cards made of such material. The dimensions of cards having constricted sections, when made of material such as phenol fiber or metal and coated in accordance with the present method, are practically unaffected by winding. This is one of the important advantages obtained by the method of the present invention.

Fig. 4 shows a section through the line 4—4 in Fig. 2 viewed in the direction of the arrows. The middle layer, preferably of phenol fiber, is coated with a semihard material to a thickness, which has been exaggerated in Fig. 4, but which it is recommended be as close as possible to .003 inch if it is built up as described of successive baked coatings of heat reactive varnish. Such a procedure affords a coating which is semihard, having the approximate texture of horn or fingernail, for instance. The coating has good adhesion and good machining characteristics and, while differing materially from rubber, has also certain rubbery characteristics in that it is sufficiently impressionable to yield in a semiplastic manner to accommodate the wire under tension in individual grooves.

Fig. 3 indicates a front view of a card partially wound with resistance wire. In actual practice the card will be wound closer than indicated in Fig. 3. The number of turns per inch of length of the card are usually 120, 160 or 320. However, for special applications it is sometimes desirable to be able to wind as many as 500 to 600 turns per inch on cards having slopes up to 40 degrees. This is possible by following the recommended procedure of the present invention. This is attributable to the combination of physical characteristics resulting from building up the coating of successive heat-reactive thin layers of varnish, which produces the semihard but plastic substance which is sufficiently resistant to shear to maintain the wire turns in individual positions.

Fig. 5 shows a cross-section through line 5—5 of Fig. 3. In this figure the thickness of the coating is exaggerated. The figure illustrates that the coating is grooved as a result of the winding only at and near the four corners in which it is partially embedded. Intermediate the retaining portions, that is, across the broad surfaces of the card, the wire is not embedded in the coating but is relatively displaceable. This is also apparent in Fig. 8.

Fig. 6 is a partial edge view of a portion of the card per Fig. 3 in the direction of the arrows 6—6 assuming that the card has first been wound and then unwound. This view shows the grooves made in the coating by the wiring. The thickness of the coating and the size of the grooves have been enlarged to illustrate this feature. The characteristic of the coating is such that if the wiring is removed the grooves remain in the coating and their regularity is observable under a microscope.

Fig. 7 is a view of the portion of the card per Fig. 6 as seen in the direction of the arrows 7—7 with the wiring removed as in Fig. 6. This figure,

in which the grooves have been enlarged, is intended to illustrate the positions of the grooves near the edges of the card as formed by the winding of the wire. As indicated, the grooved impressions are formed in the coating only in and near the edges of the card while a large area on the broad face of the card intermediate the limits of the grooves remains unchanged.

While the coating and winding described in the foregoing will generally be combined with the profiling process described in Patent 2,412,916, in the production of improved profiled resistances for non-linear potentiometers and the invention herein in one of its important aspects is embodied in the combination with the particular profiling process, it is particularly pointed out that the invention is not limited to the combination with the particular profiling process of Patent 2,412,916, but may be embodied in a combination with any profiling process which will afford the desired accuracy of contour for resistance elements for any particular application.

Further, for resistances which must be wound at close pitch and in which it is important that the turns be maintained in fixed position and that the length of each turn be of fixed uniform length, rectangular cards of material such as phenol fiber, coated in the manner described herein, are particularly advantageous in that they are, as a practical matter, not subject to the deformation under the applied tension and because, due to the relative hardness of the coating, the depth of the grooved impressions are very uniform so that the length of each turn of wire is predictable and unchanging. No other known coating method, so far as applicants are aware, permits such close winding within such narrow limits of wire length variation, while providing individual grooves for the individual turns. The advantage of operation at higher temperature range than possible with a rubber card without deformation is obtainable whatever the card shape.

What is claimed is:

1. The method of manufacturing an electrical resistance, or resistance element of a potentiometer, which comprises the following steps in the following order: 1, coating a flat card-like structure with a semihard plastic material; 2, machining said card so coated to a precise contour with square edges having sharp corners; 3, winding a resistance wire under tension around said coated and machined card so as to form grooves in said plastic material at said edges to retain the turns against slippage.

2. The method of manufacturing an electrical resistance, or resistance element of a potentiometer, which comprises the following steps in the following order: 1, coating the broad surfaces of a substantially non-extensible card-like element on its opposed broad surfaces with a semihard coating comprising a plurality of individually applied and individually baked layers of heat reactive varnish; 2, machining a pair of opposed edges of the card substantially square with respect to said surfaces, one of said edges sloped up to forty degrees with respect to the other of said edges, said edges spaced one from another to within one thousandth of an inch per inch of separation with respect to a desired predetermined spacing of said edges; 3, winding a resistance wire about said square edges under tension to form grooves in said varnish to retain said wire against slippage.

3. The method of manufacturing an electrical resistance, or resistance element of a potentiom-

eter which comprises the following steps in the following order: 1, coating a substantially rigid element with a semihard surface; 2, forming substantially square, sharp, opposed edges in said element so coated; 3, winding a resistance wire under tension about said edges in said element so surfaced so as to form grooves in said surface to retain said resistance element against slippage.

ROBERT G. McCOY.
WALTER W. WERRING.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,019,999	Schellenger	Nov. 5, 1935
2,021,802	Mucher	Nov. 19, 1935
2,114,330	Borden	Apr. 19, 1938
2,398,892	Kelly	Apr. 23, 1946
2,408,093	Patterson	Sept. 24, 1946