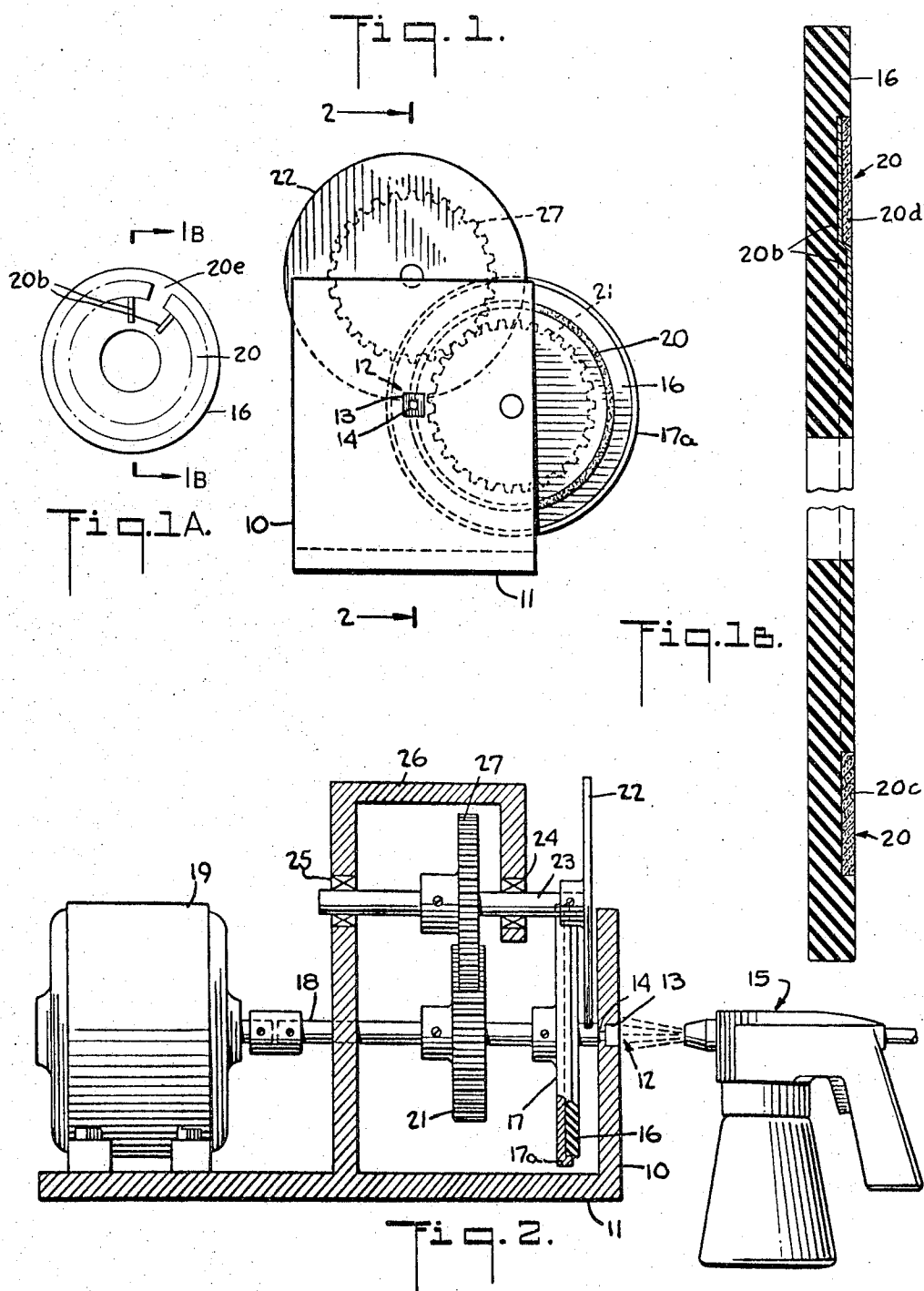


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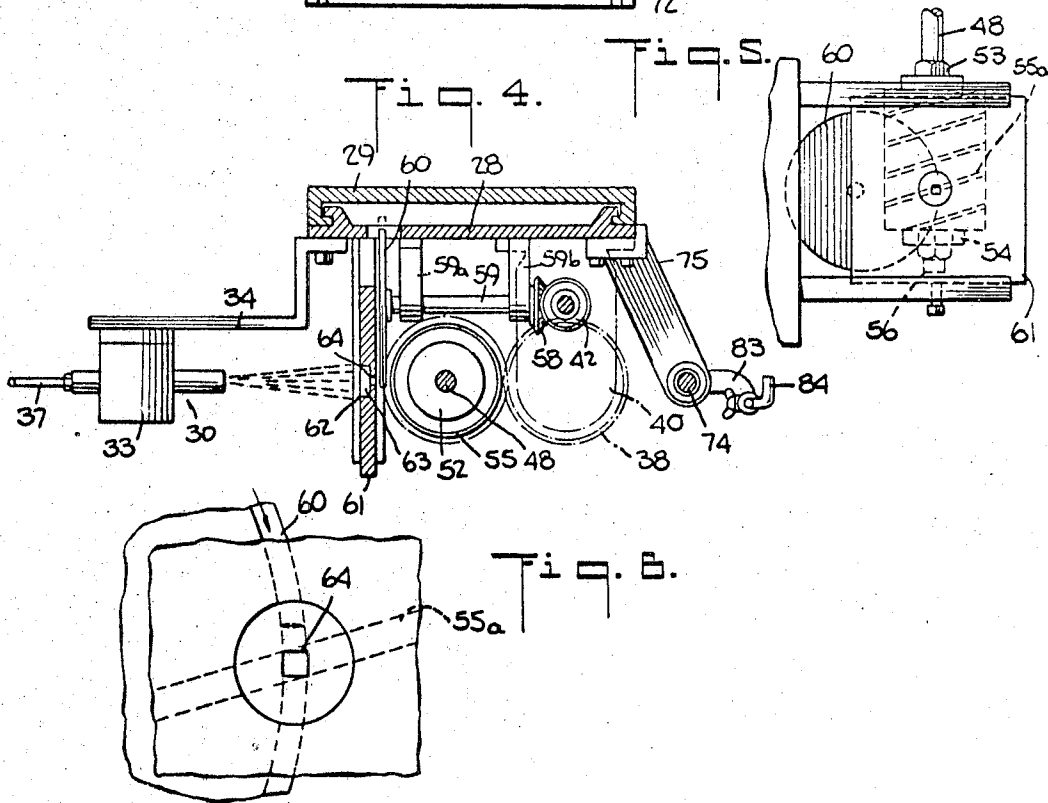
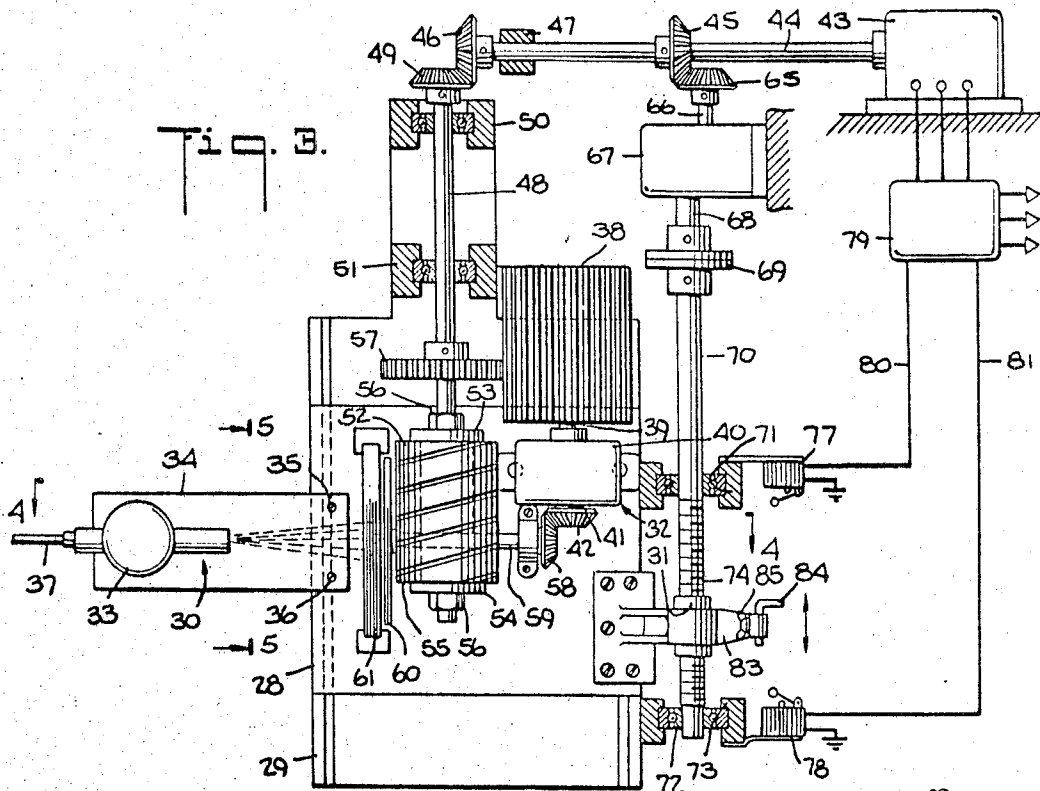
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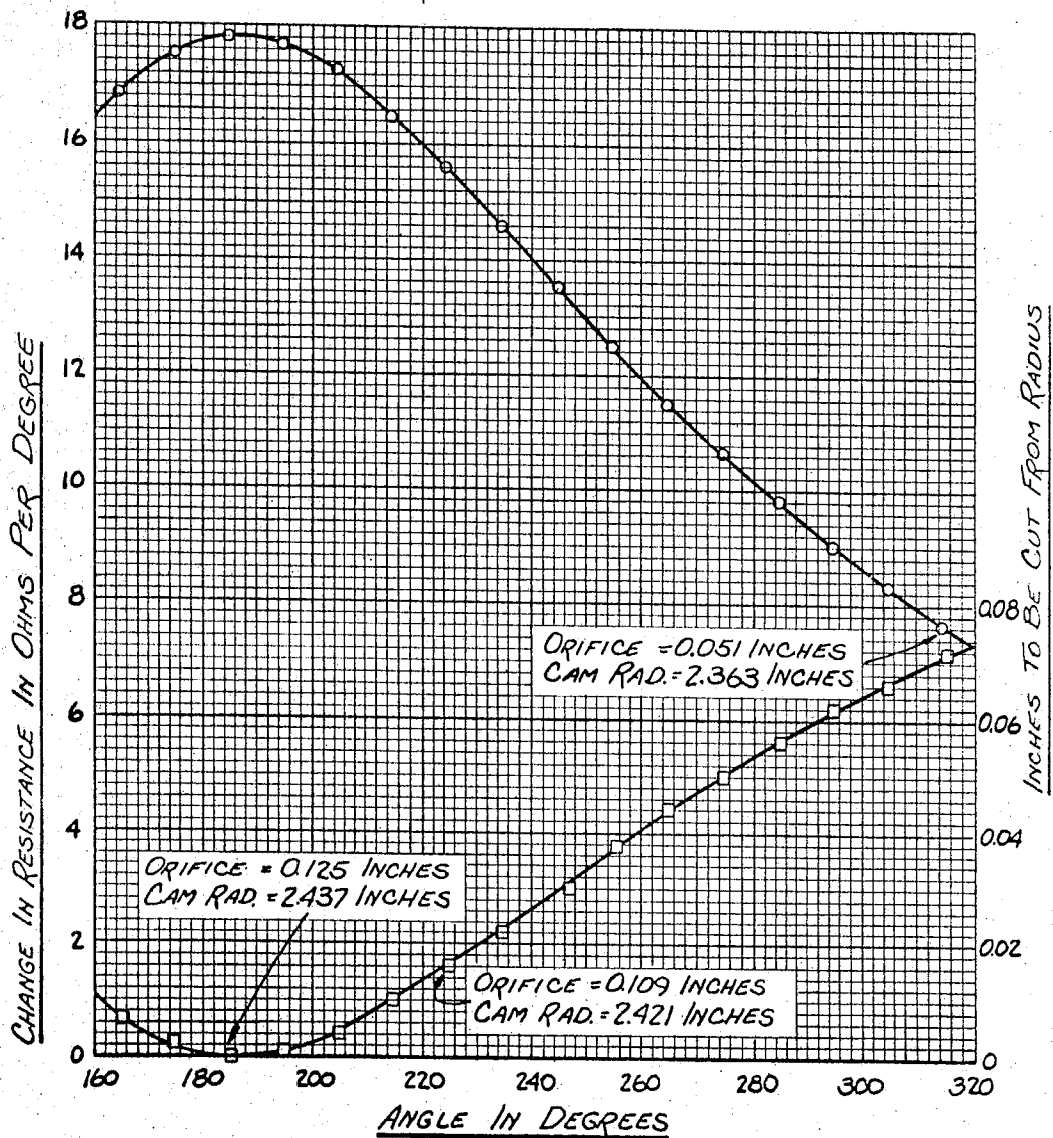
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Fig. 7.



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Fig. 8.

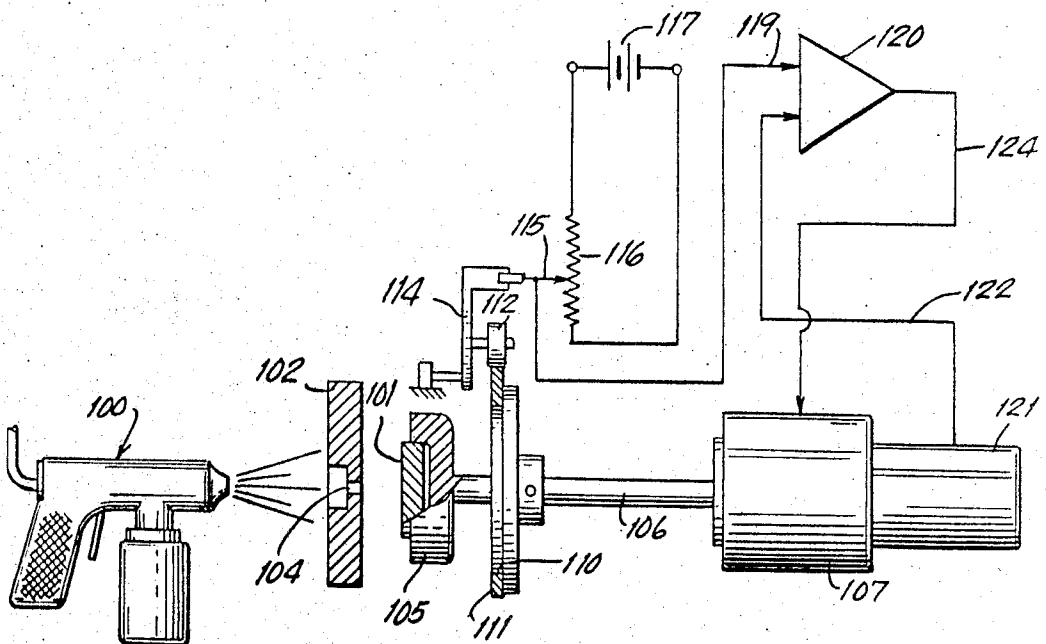
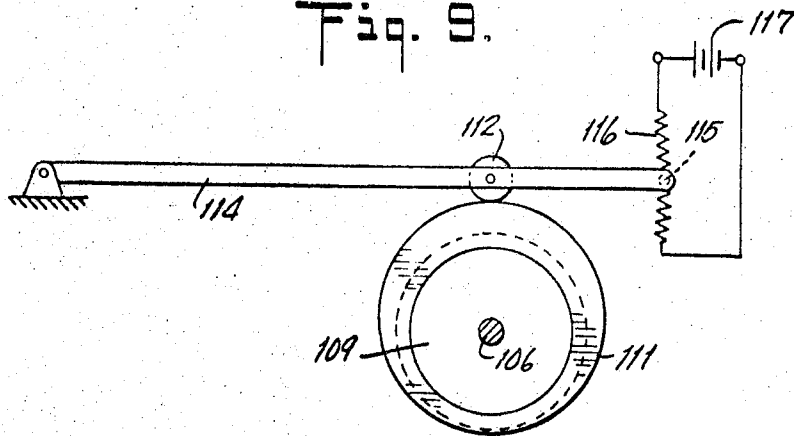


Fig. 9.



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VARIABLE RESISTANCE POTENTIOMETER OF THE TYPE HAVING A CONDUCTIVE PLASTIC TRACK ON AN ELECTRICALLY INSULATING BASE

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Continuation of abandoned application Ser. No. 264,130, Mar. 11, 1963. This application Oct. 24, 1965, Ser. No. 504,459

2 Claims. (Cl. 338—309)

This application is a continuation of our copending application Ser. No. 264,130, filed Mar. 11, 1963, now abandoned.

This invention is concerned with potentiometers and with methods and apparatus for making potentiometers. More particularly, it is concerned with variable resistance potentiometers and with methods and apparatus for making such potentiometers of the class in which a track of conductive plastic is deposited on a base of insulating material and a movable wiper or contact arm or brush rides on the surface of the track to provide a variable resistance or voltage.

It is known that variable resistance potentiometers may be prepared by depositing a track of conductive plastic material on an insulating base as a viscous solution or suspension in a volatile solvent. The conductive plastic material is usually a thermosetting resin such as a phenol-formaldehyde or a urea-formaldehyde resin having finely divided carbon or other conductive material suspended therein. Other resins including vinyl and polyester resins, such as polystyrene or condensation products of dibasic acids and dibasic alcohols such as phthalic acid and ethylene glycol can be employed. After the track has been thus deposited, the resulting product is compression molded with the application of heat to produce the final potentiometer.

In any case, such potentiometers are frequently of the crowned type in which the track projects upwardly from the base in crowned configuration, or of the projected track type in which a flat track also projects above the base. Each of these types is inherently disadvantageous in that the projecting portion adds to the space occupied by the instruments, and additionally the tracks are readily damaged because of their exposed positions. Both types of potentiometers also lend themselves to manufacturing difficulties.

Heretofore, it has been the practice in the art to adjust the resistance characteristics of the potentiometer along its length by trimming the width of the conductive track. However, this procedure is not entirely satisfactory since the range of resistance characteristics which can be built into a potentiometer by trimming the width of the conductive track is limited, such as by the minimum width of the contact arm or brush, available space, etc.

In arranging a known potentiometer of the aforementioned class for operation, a wiper arm or contact forms a moveable junction with the track, and various leads appropriate to the electrical circuit in which the potentiometer is to be employed are connected to the conductive track and the arm.

It will be appreciated by those persons skilled in the art that the resistance of a particular unit length of the track depends upon the resistivity of the conductive plastic and the width, depth and length of the track; i.e. the greater the volume, the smaller the resistance because as the volume increases, the number of paths for the flow of current through the plastic increases. Additionally, to reproduce a non-linear function, it is necessary for the resistance to vary in a non-linear manner throughout the

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length of the track. In other words, the volume of the track must vary from unit length to unit length. This can be achieved by varying either the depth or the width and it has been the practice to produce such variation in resistance by trimming the width of the track. It is known that for efficient operation, the track should be at least as wide as the contacting portion of the wiper arm, and the minimum width of the arm is set by various factors such as mechanical requirements, contact resistance, current carrying capacity, etc. Space and size considerations usually limit the maximum permissible width of the track.

To illustrate this by practical example, one may consider a known potentiometer as having a track of uniform depth and a maximum width of 0.125 inch forming a junction with a contact arm whose width is 0.025 inch. Minimum resistance will be observed in a unit length where the width of the track is at its maximum, i.e. 0.125 inch. Maximum resistance will be observed in a unit length where the width of the track is at its practical minimum, i.e. 0.025 inch. The resistance can be varied, therefore, only in the ratio of 0.125 inch to 0.025 inch, or 5 to 1.

However, the resistance per unit length of the track can also be varied without varying the width of the track by varying the depth of the track, and this introduces another parameter which makes it possible to markedly increase the aforesaid ratio. For example, if the depth is varied from a value ten times as great in one unit length as in another, the resistance can be varied in the ratio of 10 to 1 for a given width. If both width and depth can be varied, the range of resistance variability is the product of the aforesaid ratios, i.e. 50 to 1.

Heretofore a practical method and apparatus for varying the depth of the potentiometer track has not been available.

Accordingly, the present invention contributes a practical potentiometer which is free of the aforementioned difficulties and disadvantages, as well as a method and apparatus for varying the depth of the potentiometer track, thus to produce potentiometers having considerably wider ranges of resistance characteristics for predetermined operating conditions than has been obtainable heretofore.

Thus, an important feature of the present invention resides in the provision of potentiometers having tracks of wide range resistance characteristics and in which the track itself is flush with the base surface thus to reduce the space occupied by the instrument and to eliminate track damage.

As a particular feature of the present invention, we provide an apparatus in which a conductive plastic spray of substantially constant density is directed through an orifice in a masking plate and adheres to a potentiometer base which is rotated by suitable means, such as a motor. Actually, a pressure gun utilizing substantially constant air pressure, for example, may be employed for directing the plastic spray. In any case, a conductive plastic track is deposited on the base, and with repeated application of the plastic, the track depth will increase.

Since the spray density is substantially constant and the motor rotates at substantially constant speed, a particle area of the surface of the track is exposed to spray of substantially uniform density for a substantially constant period of time during each revolution of the motor. The depth of spray deposited on the base is proportional to the size of the masking plate orifice, and the size thereof is varied by means, such as a cam, driven in the desired relation to the rotation of the base.

Thus, as a further feature of the invention, we provide a spray-throttling cam which is positioned behind the orifice in the masking plate, and which is driven in a man-

ner to vary the size of the masking plate orifice. This cam can be designed, as will be described hereinafter, so that varying amounts of spray will be deposited on different areas of the track during each revolution of the base. The result is that the resistance increments per unit of annular movement of the base can be varied over a wide range and in such a manner that potentiometers having wide variations of resistance characteristics can be produced.

There has thus been outlined rather broadly the more important features of the invention in order that the detailed description thereof that follows may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims appended hereto. Those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for the designing of other structures for carrying out the several purposes of the invention. It is important, therefore, that the claims be regarded as including such equivalent constructions as do not depart from the spirit and scope of the invention.

A specific embodiment of the invention has been chosen for purposes of illustration and description, and is shown in the accompanying drawings, forming a part of the specification, wherein:

FIG. 1 is an end elevation view of one form of the apparatus of this invention;

FIG. 1A is a plan view of a potentiometer base showing the track and terminals;

FIG. 1B is a very greatly enlarged sectional view of the potentiometer base taken along the line 1B—1B of FIG. 1A;

FIG. 2 is a sectional view taken along the line 2—2 of FIG. 1 and illustrating a drive motor and spray gun;

FIG. 3 is a plan view, partly in section, of another form of the apparatus of this invention;

FIG. 4 is a sectional view taken along the lines 4—4 of FIG. 3;

FIG. 5 is a front view of a portion of the apparatus taken along the lines 5—5 of FIG. 3;

FIG. 6 is an enlarged detail view of the orifice of the apparatus of FIG. 3;

FIG. 7 is a graph illustrating by way of example the change in resistance per degree of a potentiometer prepared in accordance with this invention, and the configuration of a cam used to prepare the potentiometer;

FIG. 8 is a schematic view of another embodiment of the invention; and

FIG. 9 is a detail view of portions of the structure of FIG. 8.

Referring to FIGS. 1 and 2, the drawings show a masking plate 10 supported by a base 11 and formed with an interiorly located throughbore generally designated by reference numeral 12 comprising two communicating square apertures or orifices 13 and 14, the former facing the spray gun and being of greater cross sectional area than the latter. A constant pressure spray gun generally designated by reference numeral 15 sprays the conductive plastic through the apertures 13 and 14 onto a potentiometer base 16 rotatable with a chuck 17 mounted on a shaft 18 which is rotated by a constant speed or synchronous motor 19. The base 16 may be made of any desired insulating material and may, for example, be made of a thermosetting resin with or without fillers or cloth laminations. The base 16 is held on the chuck 17 in any well known manner and may, for example, have its periphery in frictional engagement with the inner periphery of the lip 17a on the chuck 17. The base 16 and chuck 17 are aligned behind the throughbore 12 so that a track 20 (FIG. 1) of conductive plastic is deposited on a selected portion of the base. A spur gear 21 is mounted on shaft 18 for a purpose to be described later.

A spray throttling cam 22 is positioned between the masking plate 10 and the base 16 so that a marginal zone thereof interrupts the path of the spray passing through the orifice 14 to a greater or lesser extent depending on its angular position with the result that greater or lesser amounts of conductive plastic are deposited on the base 16, depending on the extent of interruption. Thus, the cam 22 is located so that the effective height of aperture or orifice 14 is varied.

The cam 22 is mounted on shaft 23 which is journaled in bearings 24 and 25, preferably on a support 26 which is integral with base 11, as shown in FIG. 2. A spur gear 27 is mounted on shaft 23 and meshes with gear 21 on shaft 18. The gear ratio between the two gears 18 and 27 may, for example be 1 to 1 but other ratios may be employed depending on the resistance characteristic desired.

In the operation of the apparatus to produce one type of potentiometer, a fixed amount of conductive plastic spray comprising a particulated conductive material such as carbon suspended in a thermosetting plastic-liquid mixture, e.g., a thermosetting polyester in benzene, is sprayed through the aperture 14 onto the selected area of the base 16 while it is rotating at constant angular velocity with the chuck 17. In the absence of cam 22, the result would be that a circular track of conductive plastic of uniform width and depth would be deposited on the base 16 since the width and height of the aperture 14 and the length of the plastic track 20 are all fixed. The resistance increment per unit length, i.e., the change in resistance per degree of angular rotation of the conductive track 20 would therefore be constant.

As has been stated, the effect of the cam 22 is to vary the effective height of the orifice 14. Since the cam 22 and base 16 are rotated at the same constant velocity by the constant speed motor 19, the same track areas of the base 16 and the periphery of the cam 22 are exposed to exactly the same amount of spray each time the respective areas pass the orifice 14. If the periphery of the cam 22 does not interrupt the spray, a track area of the base 16 will be exposed to spray during its entire traverse of the aperture 14 and the maximum possible amount of spray will be deposited on that area. If the cam 22 does lessen the effective height of the aperture during the passage of a particular track area, that particular area will be exposed to a lesser amount of spray for a shorter period of time and therefore a smaller amount of spray will be deposited on such area. The variability of the depth of the track 20 is controlled by the contour and dimensions of the cam 22 and the number of revolutions of the base 16. The maximum and minimum depths are controlled by the number of rotations at the fixed spray density.

If there is a requirement for one or more breaks in the potentiometer track 20, this can be readily accomplished by masking the area where the break is desired, as by a section of masking tape before application of the spray. Removal of the masking tape after deposition of the spray will leave the desired breaks.

FIGS. 3 to 6 show another embodiment of this invention illustrating apparatus adapted to the manufacture of a multi-turn potentiometer, i.e., a potentiometer in which the conductive track is helically disposed on the surface of a cylindrical potentiometer base. Potentiometers of this design have a number of well known uses.

As shown in FIGS. 3 and 4, the apparatus comprises a movable plate 28 reciprocally mounted on a base member 29. A spray gun assembly generally designated by reference numeral 30, a threaded nut 31, a gear train generally designated by reference numeral 32 and various other parts to be more fully described hereinafter are attached to the plate 28. The spray gun assembly 30 includes the spray gun 33 and the support plate 34 which is secured to the movable plate 28 by bolts 35 and 36. An air line 37 is connected to a compressed

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air source (not shown) for example, for actuating the spray gun. The gear train 32 comprises an elongated gear 38 mounted on a shaft 39 extending to a gear box 40. A shaft 41 extends from the gear box 40 and a bevel gear 42 is mounted at the end thereof.

The apparatus also includes a constant speed or synchronous motor 43 having a shaft 44 with a first beveled gear 45 intermediate its ends and a second beveled gear 46 at its end. The shaft 44 is journaled at 47. A second shaft 48 extends substantially at right angles to the shaft 44 and carries a bevel gear 49 meshing with bevel gear 46 so that the motion of the shaft 44 is transmitted to shaft 48. The gear ratio between these two gears 46, 49 may be 1 to 1. Shaft 48 is supported by journals 50 and 51 respectively.

A mandrel 52 is removably mounted between plates 53 and 54 on shaft 48 by nuts 56, and the potentiometer base 55 is mounted on the mandrel 52 (FIGS. 3 to 5). A spur gear 57 is carried on shaft 48 and meshes with gear 38 in a 1 to 1 gear ratio, wherefore the constant speed motor 43 drives the gear train 32 and the potentiometer base 55 rotates at substantially constant speed about a fixed axis.

Bevel gear 42 of gear train 32 meshes with bevel gear 58 on an end of shaft 59 which, as shown, passes behind the potentiometer base 55 and is supported by journals 59a and 59b respectively. At the opposite end of shaft 59 a spray throttling cam 60 is mounted which, therefore, is rotatable by motor 43. Again, this cam 60 has the desired dimensions and contour.

A masking plate 61 formed with an interiorly located throughbore generally designated by reference numeral 62, consisting of two communicating preferably square orifices 63 and 64 is positioned between the spray gun 30 and cam 60. The orifice 63 faces the spray gun and is of greater cross sectional area than the orifice 64. The purpose of the spray throttling cam 60 in this embodiment is the same as the corresponding cam 22 in the previously described embodiment. As shown in FIG. 6, a marginal zone of the cam is aligned between the orifice 64 and the potentiometer base 55 so that as it rotates, it effectively changes the dimensions of the throughbore 62 with the result that greater or lesser amounts of spray are deposited on particular areas of the base 55.

A further bevel 45 carried by shaft 44 meshes with a bevel gear 65 mounted on the upper end of a shaft 66 at a 1 to 1 ratio. This shaft 66 extends into a gear box 67. Shaft 68 extending from the gear box 67 transmits the motion of shaft 65 as modified by the gear train (not shown) in the gear box 67, and is coupled to screw member 70 journaled in two support members 71 and 73. The traveling nut 31 threadedly engages the threaded portion 74 of screw member 70 and is secured to movable plate 28 by a brace 75 (FIG. 4).

Microswitches 77, 78 are connected to a reversing control apparatus 79 by wires 80 and 81 respectively. The reversing control apparatus 79 is connected to a power source (not shown) and to the constant speed motor 43. The purpose of this arrangement will be explained more fully hereinafter.

In operation of the apparatus shown in FIGS. 3-6 for the production of a multi-turn potentiometer, the potentiometer base 55 is rotatable with the shaft 48 but does not undergo any vertical movement as viewed in FIG. 3. Reciprocating plate 28 does undergo vertical movement controlled by the movement of traveling nut 31 activated by the turning of the screw member 70. Screw member 70 is in turn rotated by the motor 43 through shaft 44 and bevel gears 45 and 65. Movement of the plate 28 is modified by the gear train in gear box 67 to control the number of turns of the resistance track 55a on the potentiometer base 55 as will be explained more fully hereinafter. The reciprocal motion of moving plate 28 is of course imparted to all of the

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parts which are attached to it. Thus, spray gun assembly 30, gear train 32, masking plate 61, spray throttling cam 60, shaft 59 and bevel gear 58 all undergo reciprocating up and down motion. As gear 57 rotates, it remains in operative engagement with gear 38 while the latter reciprocates vertically. The constant density spray from the spray gun 33 passes through the orifice 64 onto the potentiometer base 55. Since the potentiometer base 55 is rotating, the spray is deposited as a helical track 55a on the base 55. The thickness or depth of the track is controlled by the spray throttling cam 60 whose marginal zone is contoured effectively to vary the width of the orifice 64.

In the embodiment of FIGS. 1 and 2, the effect of the cam 22 is to change the effective height of the orifice 14. As shown in FIGS. 3-6, the cam 60 changes the effective width of the orifice 64. The effect on the thickness of the conductive track 55a, however, is exactly the same, and since, as will be explained more fully hereinafter, the same particle area of the potentiometer base 55 is exposed to the same amount of spray with each complete upward and downward movement of the reciprocable plate 28, the result is that a potentiometer having a conductive track 55a of variable depth is produced.

It will be seen that the number of turns of the helical track 55a on the potentiometer base 55 will depend upon the number of complete revolutions made by the base 55 during each upward or downward movement of the plate 28. This reciprocal motion in turn is controlled by the rotation of the screw member 70 which is controlled through the gear box 67 the latter being actuated by the constant speed motor 43. The rotation of the motor 43 is transmitted to the potentiometer base 55 by the shafts 44 and 48 and by the bevel gears 46 and 49. Since both the potentiometer base 55 and the screw member 70 are rotated by the constant speed motor 43, it is apparent that by proper selection of the gear ratio in gear box 67 and the lead of threaded portion 74, potentiometer base 55 could undergo any number of complete revolutions for each upward and downward movement of the reciprocating plate 28. Thus, potentiometers with any number of turns per fixed length of base 55, say for example, 5, 10, 20, etc. can be prepared. If the pitch of the threaded portion 74 is such that at a gear ratio of 1 to 1 in gear box 67 screw member 70 makes twice as many turns as potentiometer base 55 during a fixed length of movement of traveling nut 31 and it is desired to make a potentiometer having 10 turns in the fixed length, it is necessary to change the gear box ratio from 1 to 1 to 2 to 1 so that screw member 70 will make 10 turns instead of 20 turns during the fixed length of travel of the nut 31. The length of travel of the nut 31 is equal to the lateral distance between the top and the bottom of the helical track 55a.

As in the previous embodiment, it is important to the apparatus illustrated in FIGS. 3 to 6 that the same particle area on the surface of the potentiometer base 55 be exposed to a substantially uniform spray density for a substantially constant period with each upward and downward motion of the reciprocating plate 29. This result is achieved by controlling the degree of rotation of the spray throttling cam 60 and its dimensions and contour and also by adapting synchronous motor 43 to be reversible. In the manufacture of a 10 turn potentiometer, the gear ratio in the gear box 40 is 10 to 1 so that for each complete revolution of the gear 57, the cam 60 will rotate 36°, i.e., one-tenth of a complete revolution. At the end of 10 complete revolutions of the gear 57 and the potentiometer base 55 the movable plate 28 will have made one complete upward or downward movement and will reverse its direction in a manner to be described. At the same time, the direction of rotation of the cam 60 and the potentiometer base 55 will be re-

versed so that the last particle area on the potentiometer track to be exposed to spray during the movement in one direction will be the first particle area to be exposed to spray during the movement in the opposite direction. Furthermore, since the spray throttling cam 60 is reversed at the same time, the last effective width of the orifice 64 during one vertical movement of the plate 28 will be the first effective width during vertical movement of the plate 28 in the opposite direction. Therefore, each particle area on the potentiometer base is exposed for exactly the same period of time to spray of constant density through an orifice of the same dimensions during each upward and downward movement of the movable plate 28.

For the manufacture of a 20 turn potentiometer the gear ratio in the gear box 40 would be 20 to 1 and the cam would make one-twentieth of a complete revolution with each complete revolution of the potentiometer base 55. For a 5 turn potentiometer the corresponding angular rotation of the cam would be one-fifth of 360° for each complete revolution of the potentiometer base 55. In these instances, the potentiometer base 55 would make 20 and 5 complete revolutions respectively for each complete vertical movement of the reciprocating plate 28. The angular velocity of the cam is equal to the reciprocal of the number of turns of the conductive plastic track 52a multiplied by the angular velocity of the potentiometer base.

The reciprocating motion of the plate 28 is controlled by means of the reversible synchronous motor 43, the reversing control apparatus 79 and the switches 77 and 78. The reversing control apparatus 79 is well known in the art and is controlled by stable switching means operated in response to application of voltages upon either of the two leads 80 and 81 to switch the power supply leads to the motor 43 in a manner such that the synchronous motor is driven in a direction corresponding to the lead 80 or 81 last receiving a finite voltage. It will be readily understood by one skilled in the art that such a reversing means may take any of a variety of known forms. Switches 77 and 78 are located on the support members 71 and 73 and are oriented so that their movable contact member is closed whenever the traveling nut 31 reaches either extreme of its operating movement. Upon closure of the switch contacts, a finite voltage is supplied to lead 80 or 81 of the reversing control apparatus 79 to cause it to switch the input supply leads to the synchronous motor 43 so that the motor drives the shaft 44 in the opposite direction. This in turn reverses the direction of rotation of the potentiometer base 55 and the spray throttling cam 60.

It will be apparent from the foregoing and from a study of the figures that effective operation of the embodiment of FIGS. 3 to 6 requires that the height of gear 38 and of the threaded portion 74 of screw member 70 be at least equal to the height of the potentiometer base 55, or at least that portion of the potentiometer base 55 on which the potentiometer track is to be deposited.

In practice it is expedient to make both gears 38 and threaded portion 74 long enough to accommodate the longest potentiometer base 55 and to provide control means to permit the manufacture of shorter potentiometers.

Such control means may take a variety of forms but a simple form thereof is illustrated in FIGS. 3 and 4. As shown, the control means comprises a horizontal base portion 83 attached to the support for the traveling nut 31. An adjustable rod 84 is secured to the base portion 83 by wing nut 85. The rod is in the plane of the controls of the microswitches 77 and 78 and activates them by striking the controls at the end of each vertical motion of the traveling nut 31. A number of rods 84 of different lengths may be provided for the manufacture of variable length potentiometers.

FIG. 7 illustrates the calculations involved in the prepa-

ration of a flat, circular potentiometer track in accordance with this invention such as the track 20 in FIG. 1. For the preparation of a particular potentiometer track the pressure in the spray gun 15 and therefore the spray density, will be substantially constant, and the angular velocity of the spray throttling cam 22 and the potentiometer base 16 and the actual dimensions of the orifice 14 in the masking plate 10 will be constant. The variable depth of the potentiometer track 20 is achieved by varying the effective height of the orifice 14 in the masking plate 10 and this in turn is achieved by properly designing the spray throttling cam 16. For a minimum effective height of the masking orifice 14 the radius of the cam 16 must be at a maximum and for a maximum effective height the radius must be at a minimum. Infinite resolution between these two limits is possible. The maximum resistance per degree of angular rotation with respect to the potentiometer track 20 is attained with minimum exposure of a particular particle area under which condition the smallest amount of conductive material is deposited. Conversely, as the amount of conductive material deposited increases, the resistance decreases.

The cam is designed to permit manufacture of a potentiometer that will reproduce a function expressing some natural phenomenon in terms of the variables involved in the phenomenon. By calculations well known to those skilled in the art the variables are converted to a change in resistance per degree of rotation of a potentiometer arm. With this information available it is possible to design a cam which will give the required potentiometer.

In FIG. 7 the upper curve represents the change in resistance in ohms per degree of rotation for a flat circular potentiometer prepared in accordance with this invention. The lower curve is the "cutting information curve," that is, it illustrates the inches to be removed from the radius of the base circle of the cam 22 in order to produce the desired change in resistance per degree rotation. The radius of the base circle is the maximum radius of the cam 22, that is, it is the radius at the point at which the effective height of the orifice 14 in the masking plate 10 is at a minimum and therefore, the radius at the point of maximum resistance. In the graph, the abscissa designates the angular rotation and the ordinate of the upper curve designates the change in resistance per degree of rotation. The ordinate of the lower curve designates the number of inches by which the base circle of the cam must be reduced to produce the desired change in resistance in the potentiometer.

Since the graph is intended only to illustrate the principles involved, it covers the cam from the 160° point to the 320° point only and not the complete cam. The calculations for the balance of the cam are identical.

The graph of FIG. 7 is calculated on the basis of the cam 22 having a maximum radius of 2.437" and a minimum radius of 2.363" the difference being 0.074". The cam passes between the potentiometer base 16 and a masking plate orifice 14 having an actual height of 0.125". The dimensions of the cam are selected so that when the section of the periphery of the cam having the smallest radius passes between the potentiometer and the orifice the actual height of the orifice will correspond to its effective height, and when the section of the periphery of the cam having the largest radius passes between the potentiometer and the orifice the effective height will be at its minimum value. The effective height of the orifice 14 will vary between these limits as the cam 22 rotates.

It will be noted that in the potentiometer represented in FIG. 7 the ratio of maximum change in resistance to minimum change in resistance is 17.8 to 7.3, or 2.45:1. The ratio of effective heights of the orifice in the masking plate is also equal to 2.45:1. The maximum effective height is 0.125. The minimum effective height is the difference between 0.125 and 0.074 or 0.051. The ratio of effective heights, therefore, is 0.125 to 0.051 or 2.45:1. In an apparatus of this invention the ratio of maximum

to minimum effective heights (or widths if the apparatus is designed for a multi-turn potentiometer) is always the same as the ratio of maximum to minimum changes in resistance per degree of angular rotation.

It will be apparent that one complete revolution of the cam in the potentiometer will not produce a potentiometer track having a change in resistance per degree of 17.8 at 185° and 7.3 at 320°. It will, however, produce a track in which the respective changes in resistance are in the ratio of 2.45:1. It will require several revolutions of the cam and the potentiometer base to build up the desired resistance level. Thus, it is possible to calculate the number of revolutions which will be required based on the total resistance required, the pressure of the spray gun, the resistivity of the conductive plastic and the molding temperature and pressure. It is best, however, to arrive at the required number of revolutions by actual testing, since this procedure cancels out possible anomalies in the operation of the apparatus. Thus, after the apparatus has been in operation for a short period the potentiometer blank is removed, molded and its resistance measured. The necessity of further exposure to spray will be determined on the basis of the resistance value found. The total resistance of the potentiometer decreases during the molding step but the ratio of changes in resistance remains constant. Once the required number of revolutions has been determined, subsequent potentiometers can be prepared using this number of revolutions.

Calculations similar to those illustrated in graph 7 are employed in designing the cam 60 for the production of a multi-turn potentiometer in accordance with the embodiment illustrated in FIGS. 3-6.

Potentiometers having resistance characteristics of any practical desired value can be prepared utilizing the apparatus of this invention. Most potentiometers are prepared by rotating the cam and the potentiometer base at from about 30 to about 100 r.p.m. for from about one-half to about one and one-half minutes, utilizing a spray gun pressure of from about 30 to 40 lbs. per square inch. Once the spray has been deposited, the potentiometer blank is compressed and molded in accordance with known practice to produce the finished product.

The compression temperature and pressure depend on a variety of factors well known to those skilled in the art and are in no way critical to the operation of this invention. Some of the factors which enter into the selection of a particular molding temperature and pressure include the identity of the conductive plastic, the amount of conductive materials suspended in the plastic, the shape and size of the particles of conductive material and the resistance decrease desired during the molding operation. Many potentiometers are prepared at a temperature of from about 250° F. to about 350° F. and at a pressure of from about 500 to about 4,000 lbs. per square inch. In any case, it will be appreciated that potentiometers produced according to the present concept have tracks of wide range resistance characteristics which are flush with the base surface to which they are applied.

The distance between the masking plate and the spray throttling cam is kept at a minimum to avoid unnecessary spray dispersion. The preferred distance is from about 0.005 to about 0.010" although this is not critical and somewhat larger or smaller distances can be employed.

The exact effective dimensions of the orifice in the masking plate are not critical provided that the ratio of maximum effective dimension to minimum effective dimension is at least equal to the ratio of the maximum to minimum changes in resistance per degree of rotation. For example, if the maximum change in resistance is 18 ohms per degree and the minimum is 3 ohms per degree, it must be possible to obtain effective dimensions having maximum and minimum values of at least 6 to 1. One practical manner of effecting this result is to make the orifice as large as practically possible and to vary the effective dimension by varying the size of the cam. In

normal operations, therefore, the actual dimensions of the orifice will be such that either the height or the width will be greater than the required effective dimension so that the cam interrupts the spray in every position. Another approach which can be used is to provide a series of interchangeable masking plates with orifices of different dimensions for use with a cam of fixed dimensions. For example, a series of masking plates having square orifices with actual heights of from 0.050" to about 0.250" can be provided for use in the preparation of potentiometers having a variety of resistance characteristics.

In this disclosure reference is made to the actual dimensions and effective dimensions. The actual dimensions of the orifice refer to its exact physical dimensions. The effective dimensions refer to the actual dimensions as modified by the cam. If there is no interference by the cam, the actual dimensions and effective dimensions are equal.

Referring now to FIGS. 8 and 9, there is shown another embodiment of the invention wherein a spray gun 100 similar to the gun 33 may be mounted in the same manner to direct its discharge at a potentiometer element 101 through a stationary apertured masking plate 102. The apertures or orifices represented by numeral 104 may be identical with the apertures 13 and 14 already described, for example.

The potentiometer element 101 is supported in a chuck 105 mounted at the end of a shaft 106 driven by a servomotor 107. The shaft 106 also carries a cam adaptor 109 having a cam 110 mounted thereon and having a cam surface 111 contoured and dimensioned as desired for a purpose to be made apparent.

A cam follower 112 in the form of a roller is mounted for rolling contact with the cam surface 111 and is free to move vertically. This roller is conveniently connected to a pivotally mounted follower lever 114 which thus is also free to move with the roller. The lever 114 carries a contact 115 that engages a speed control resistance 116 electrically connected in circuit with a power source 117.

The speed control resistance 116 and contact 115 deliver a speed voltage signal through line 119 to a servoamplifier 120 which also receives a response voltage signal through line 122 from a conventional voltage generating tachometer 121 in driven connection with the servomotor 117. The servoamplifier 120 supplies a speed control voltage to motor 107 through line 124.

In the operation of this embodiment, the masking plate is stationary, but the motor 107 causes the chuck 105 and potentiometer element 101 to rotate behind the orifices 104. The cam adaptor 109 and cam 110 rotate with the chuck 105 and, because of the selected contour and dimensions of cam surface 111, the roller 112, lever 114 and contact 115 move vertically in a manner to cooperate with the resistance 116 to impress a speed voltage signal on the servoamplifier 120 through line 119 while a response voltage signal is supplied to the amplifier 120 from tachometer 121 for comparison with the speed voltage signal to assure precise variations in speed control. The amplifier thus supplies a speed control signal to motor 107 to control the speed thereof according to the selected contour and dimensions of the cam surface 111.

It will be appreciated that the cam surface may be designed to control variations in the speed of rotation of the chuck 105. Thus, according to the present concept, the speed of rotation is varied as desired to expose the track area of the potentiometer element 101 behind the masking plate 102 to a spray of constant density such that selected amounts of spray will be deposited on different areas of the track during each revolution of the element 101. It will be understood of course, that all the revolutions of the chuck are identical in that the same speed variations occur at the same annular positions of the chuck in each revolution. In this way, a conduc-

tive plastic track having desired characteristics is deposited on the base or potentiometer element, and with repeated applications, or revolutions, the track depth increases with a potentiometer having a track of necessary depth is produced.

The basic concept on which this invention is based is the concept of spraying the conductive plastic on the insulator base while controlling the amount which is permitted to accumulate on a selected particle area. It makes possible the production of a new class of flat track potentiometers in which the conductive track is flush with the insulator base surface. Moreover, these new potentiometers, by the use of the methods and apparatus of this invention, can be prepared with hitherto unattainable efficiencies.

Heretofore potentiometers have been prepared by first preparing molds with track indents. The terminations were then placed in the mold cavity and the conductive plastic either sprayed into the indents or loaded therein as a dry powder. The bridges were then installed and the cavity filled with insulator powder. The potentiometer blank was then molded with the application of heat and pressure. It will be apparent that each time a potentiometer of different performance characteristics was required a new mold had to be manufactured.

However, in the practice of this invention only molds having flat surfaces are necessary. The contours of the conductive plastic track are controlled by the spraying techniques. Any number of insulator bases may be prepared by simply compressing the insulator plastic into any desired shape, e.g., a circular disc or a cylinder. As best seen in FIGS. 1A and 1B, the leads and terminals 20b are then scribed onto the surface of the base 16, for example with a lettering pen and then the conductive plastics sprayed onto the base 16 forming the track 20. It will be appreciated that various areas of the track have various depths. As seen in FIG. 1B, the depth of the track at 20c is substantially greater than the depth of the track at 20d. Any breaks in the track can be attained by the use of masking tape as described above. In this manner a bridge 20e (FIG. 1a) is formed. The base with the deposited track is then compressed in a mold having a flat surface. It will be seen that it is not necessary to prepare special molds each time a new potentiometer design is required. As is clearly shown in FIG. 1B, the conductive plastic terminals 20b are in electrical connection with the underside of the track and flush with the surface of the base outside of the track width.

While the description of the invention has been given in terms of what are presently considered to be the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications can be made therein without departing from the

spirit and scope of the invention. It is the intention, therefore, that the appended claims cover all such changes and modifications as fall within the spirit and scope of the invention.

5 What is claimed is:

1. A potentiometer of the class described integrally comolded and comprising a non-flexible electrically insulating plastic base having an uninterrupted planar surface, a wafer thin spray coating of particles deposited on said surface of the base forming a variable resistance conductive plastic track varying in its depth dimension in proportion to the resistance characteristic at given points on said track, said track being flush with said surface of the base and the particles of said coating being pressed into comingling association with respect to the surface particles of said surface of the base for receiving a movable wiper thereon, and conductive plastic terminals in electrical connection with the underside of said track and flush with said surface of the base outside of the track width.

2. A potentiometer of the class described integrally molded and comprising a non-flexible electrically insulating plastic base having an uninterrupted planar surface, a wafer thin spray coating of particles deposited on said surface of the base forming a variable resistance conductive plastic track of uniform density across its width and varying in its depth dimensions along the length of said track between maximum and minimum values in proportion to the resistance characteristic at given points on said track, said track being flush with said surface of the base and containing a plastic insulating bridge flush with said surface of the base and the particles of said coating being pressed into comingling association with respect to the surface particles of said surface of the base for receiving a movable wiper thereon, and conductive plastic terminals in electrical connection with the underside of said track and flush with said surface of the base outside of the track width.

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Notice of Adverse Decisions in Interferences

In Interference No. 97,036 involving Patent No. 3,299,389, A. A. Vercesi and R. R. Segerdahl, VARIABLE RESISTANCE POTENTIOMETER OF THE TYPE HAVING A CONDUCTIVE PLASTIC TRACK ON AN ELECTRICALLY INSULATING BASE, final judgment adverse to the patentees was rendered July 27, 1971, as to claims 1 and 2.

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