

Feb. 27, 1968

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3,371,138

METHOD AND APPARATUS FOR PRODUCING FUNCTION POTENTIOMETERS

Filed Feb. 28, 1966

4 Sheets-Sheet 1

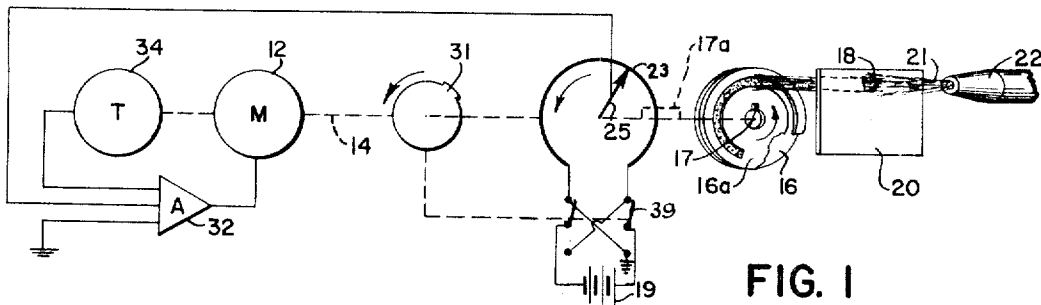


FIG. 1

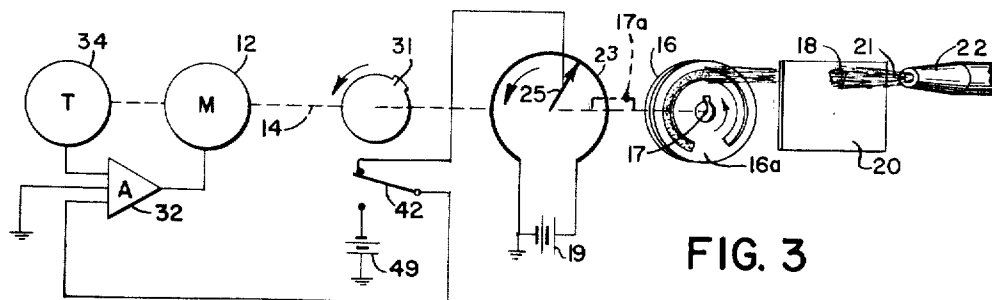


FIG. 3

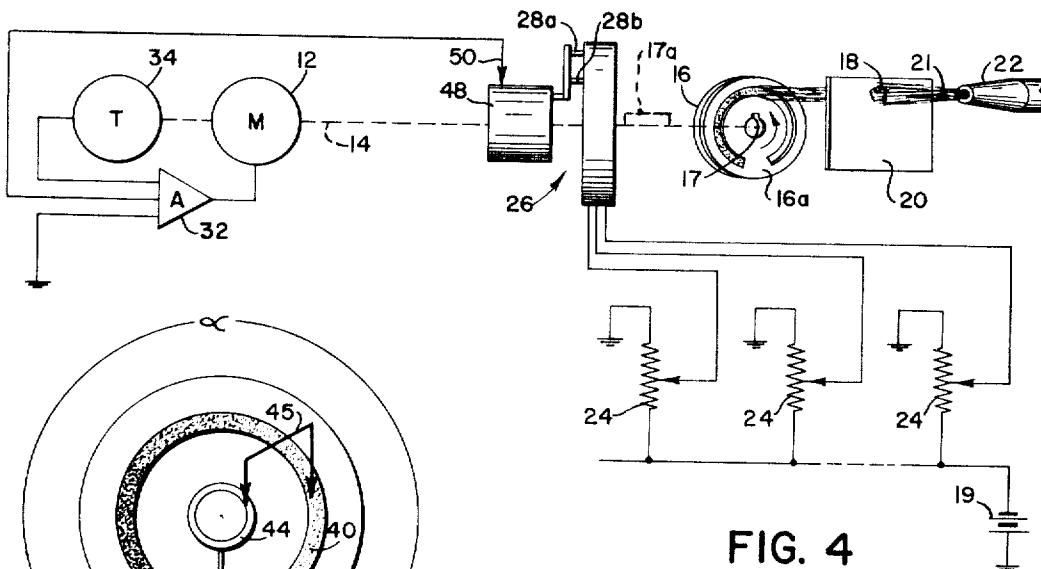


FIG. 4

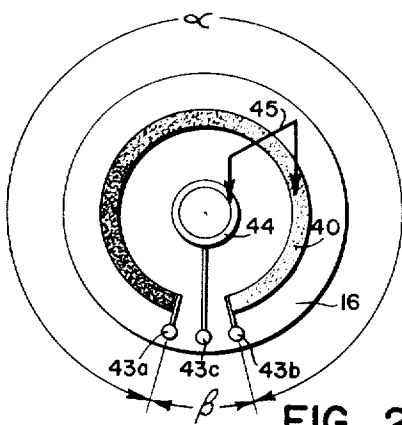


FIG. 2

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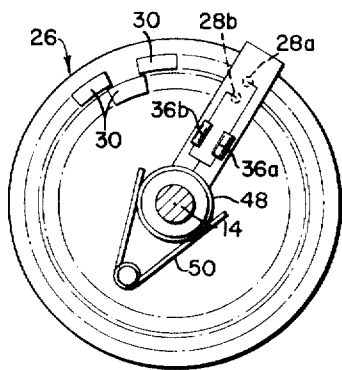


FIG. 5

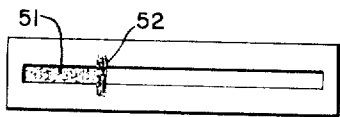


FIG. 6

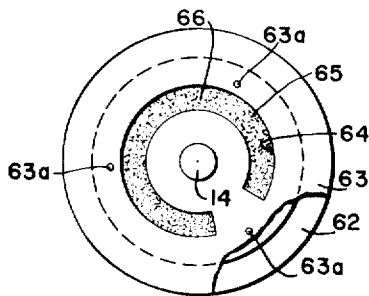


FIG. 7

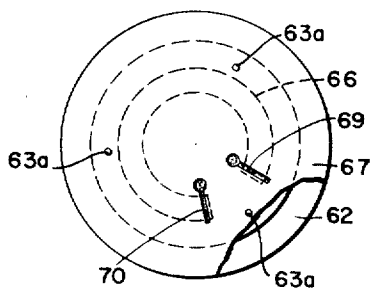


FIG. 8

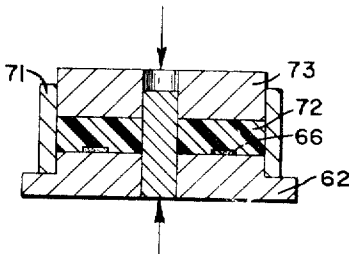


FIG. 9

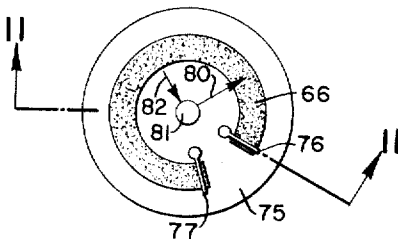


FIG. 10

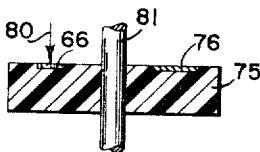


FIG. 11

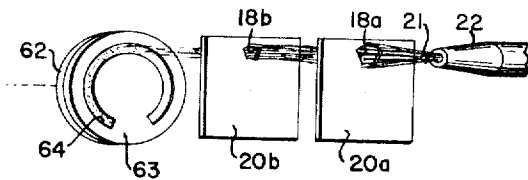


FIG. 12

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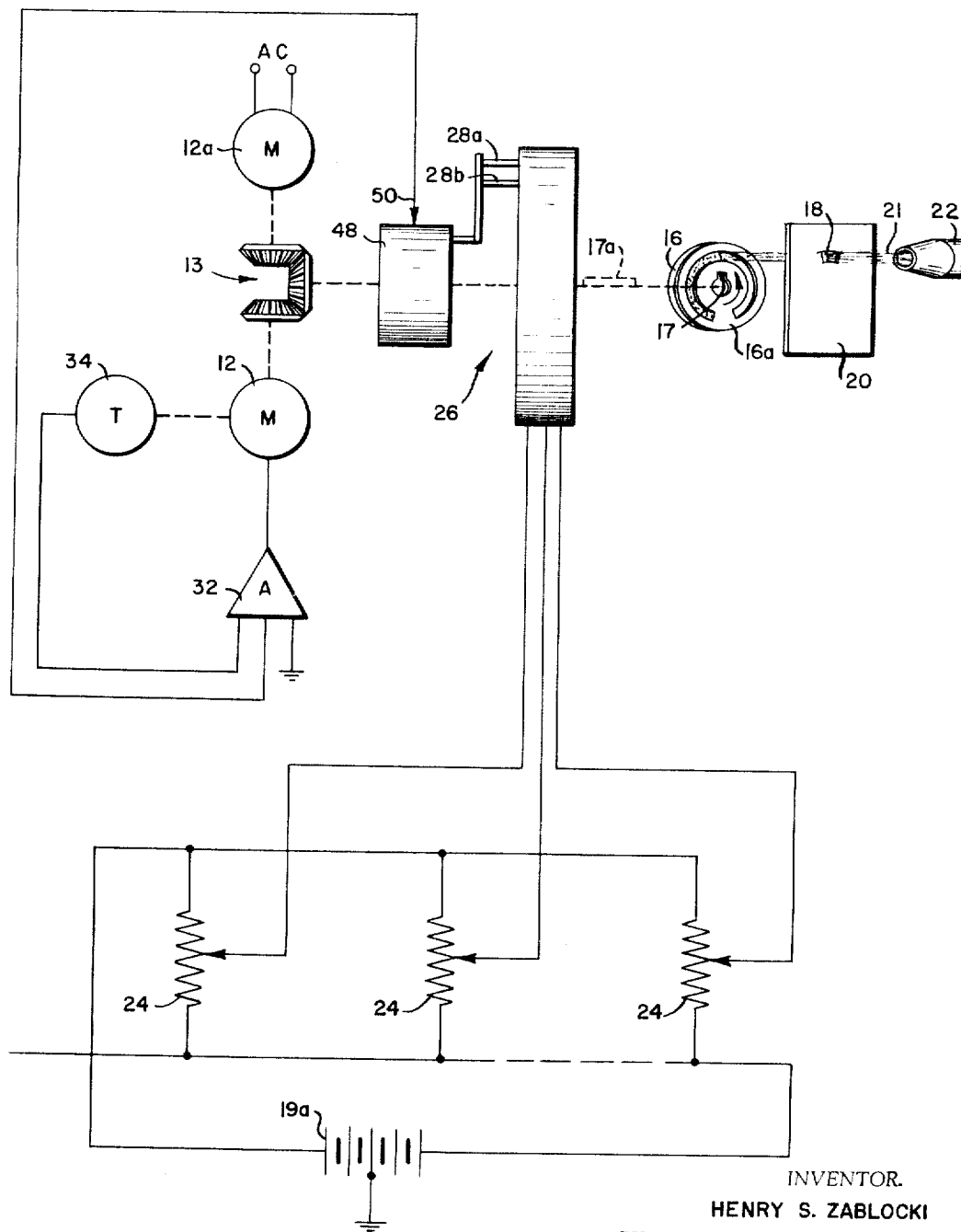
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FIG. 13



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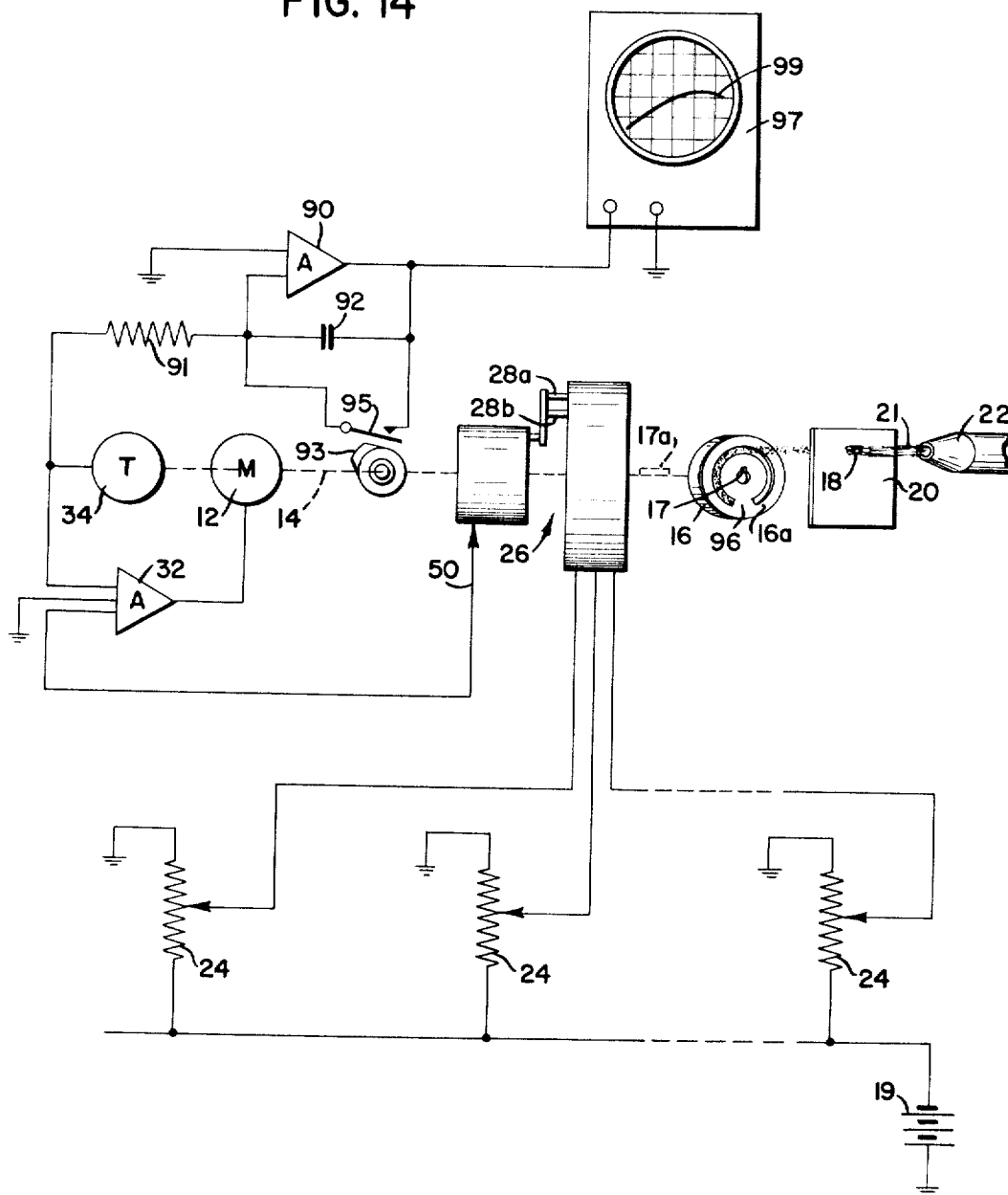
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FIG. 14



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3,371,138 METHOD AND APPARATUS FOR PRODUCING FUNCTION POTENTIOMETERS

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Continuation-in-part of application Ser. No. 434,180,
Feb. 23, 1965. This application Feb. 28, 1966, Ser.
No. 530,465

21 Claims. (Cl. 264—134)

This application is a continuation-in-part of my co-
pending application Ser. No. 434,180, filed Feb. 23, 1965,
and now abandoned, entitled, "Method and Apparatus
for Producing Function Potentiometers."

This invention relates to methods, and apparatus em-
ploying such methods, for making precision function
potentiometers of the conductive composition type. By
precision potentiometers, it is intended to encompass that
class of potentiometer characterized by a high conformity
with the desired function, that is, a deviation from the
function of less than plus or minus two percent. Preci-
sion potentiometers are often required to have a con-
formity as close as 0.03% to function.

One conventional method of making potentiometers
of the carbon composition type is by coating an insulator
plastic or ceramic base by spraying with a composition
containing conductive carbon particles dispersed in a
resinous binder. Most commonly, the resulting resistance
element is in the form of an annular path which is formed
by spraying a dispersion of the composition through a
mask. Conventionally, an axially located shaft is rotated
to move a wiper making contact to the resistance element.
Suitable takeoff means, common to the art, are employed
for providing electrical connection to the potentiometer
terminals.

In order to provide a function potentiometer, e.g., one
whose output voltage varies in a nonlinear fashion with
variation of the shaft angle, the resistance of the coating
per unit length must be made to vary in accordance with
the desired function. Conventionally, this is done by
judiciously varying the width of the coating so as to pro-
vide a path of greater or lesser conductivity per unit
length. This technique has proved adequate for producing
low cost variable resistance devices for use as gain and
volume control means, such as commonly found in radio
receivers and the like. In applications of the latter class,
the variable resistance device is adjusted to provide a
desired output level. Once the desired level is attained,
the setting is not normally disturbed. The degree of preci-
sion of the potentiometer is not material; dial settings
are used merely as a guide in such applications. However,
this procedure is not suitable for producing precision
potentiometers. Precision potentiometers are often em-
ployed in feedback type servo systems, and in analog
computers as position sensing means and as a balancing
control means where continuous precise and sensitive ad-
justment in accordance with a signal is required. Obvious-
ly, for such applications a high degree of precision and
accuracy is required. Briefly stated, one aspect of this
invention comprises the forming of a resistance track by
means of a collimated source of material and moving the
substrate and said source, one relative to the other, while
automatically varying the velocity in relation to a desired
function in a manner to be more fully described hereinafter.
Another aspect of this invention relates to an
apparatus for carrying out the said process.

Accordingly, it is an object of this invention to provide
a process for economically producing composition type
function potentiometers of the precision class.

A further object of this invention is to provide an ap-
paratus for depositing a coating on a substrate in a con-
trolled nonlinear fashion.

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It is an object of this invention to provide an apparatus
for automatically forming function potentiometer ele-
ments.

It is still a further object of this invention to provide
an apparatus for accurately forming function potentiome-
ter elements.

A particular object of this invention is to provide an
improved servo controlled potentiometer-forming appara-
tus.

A further object is to provide an apparatus for form-
ing a multilayer sprayed function potentiometer element.

A particular object of this invention is to provide means
for monitoring the actual function being generated by the
potentiometer-forming apparatus.

Still other objects and features of this invention will,
in part, become obvious and will, in part, be pointed out
with particularity as the following description proceeds
when taken in conjunction with the accompanying draw-
ing.

In the drawing:

FIG. 1 shows schematically one embodiment of the
apparatus of this invention.

FIG. 2 is a plan view of a potentiometer produced by
the teachings of this invention.

FIG. 3 is a schematic showing of another embodiment
of the claimed apparatus.

FIG. 4 shows schematically still another embodiment
of the apparatus.

FIG. 5 is a plan view of a sampling switch used in
the embodiment of FIG. 4.

FIG. 6 is a plan view of a rectilinear potentiometer
element in the process of being coated.

FIG. 7 is a plan view of a flat mold force suitable for
molding an arcuate variable resistance device with an
apertured masking member affixed to the mold force. The
portion of the mold member exposed through the mask
aperture is shown coated with a resistive composition.

FIG. 8 shows the mold force of FIG. 7 with another
masking device employed in a subsequent operation.

FIG. 9 shows in a vertical section, a mold assembly
producing the molded resistance element of FIG. 10.

FIG. 10 is a plan view of a molded resistance element
produced by the apparatus of this invention.

FIG. 11 is a cross sectional view taken along lines
11—11 of FIG. 10.

FIG. 12 shows in perspective an improved collimator
of this invention.

FIG. 13 shows schematically a coating apparatus hav-
ing means incorporated for preventing stalling.

FIG. 14 shows schematically an apparatus for provid-
ing continuous monitoring of the operation.

The conductivity of a track of uniform material, theo-
retically at least, is directly proportional to the thickness
of the track. This is expressed by the classic formula for
conductance of a uniform bar of material

$$G = \frac{wt}{\rho l}$$

where w , t , l and ρ are the width, thickness, length and
specific resistivity, respectively.

Where an insulator substrate is coated with a resistive
track of a uniform material, the conductivity is directly
proportional to the thickness of the layer of material ap-
plied. Where the coating is applied by painting, some
finite thickness is required before conductivity is estab-
lished. However, for practical purposes this minimum
thickness may be disregarded.

Consider now the manufacture of a potentiometer whose
output voltage, E , is proportional to a function of the
angular position of the shaft and thus of the angular

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position of the wiper on the resistive track, expressed thus:

$$E \propto f(\theta)$$

Kirchoff's law states that the total voltage drop in a series circuit is equal to the sum of the individual voltage drops. Expressed in differential terms,

$$E \propto \int_0^\theta r(\theta) d\theta$$

where $r(\theta)$ expresses the resistance of a differential length of track as a function of θ . Differentiating,

$$\frac{dE}{d\theta} \propto r(\theta)$$

and since $E = f(\theta)$

$$\frac{dE}{d\theta} \propto r(\theta) \propto f'(\theta)$$

Thus, given a collimated spray of resistive material, and a surface moving at a given velocity relative to an orifice from which the spray is emanating, the amount of material deposited is inversely proportional to the given velocity and accordingly the resistance of the track is directly proportional to the given velocity, and the incremental resistance is likewise directly proportional to the velocity of the mold or substrate upon which the resistive material is being deposited.

Thus,

$$r(\theta) \propto V(\theta) \propto f'(\theta)$$

Therefore, the resistance from the start of the resulting track to any point thereon is defined by the following equation:

$$R(\theta) = \int_0^\theta V(\theta) d\theta = f(\theta)$$

This relationship provides a convenient means for monitoring the accuracy of the process.

Referring now to FIG. 1, there is shown a motor 12 coupled to shaft 14 upon which is keyed a potentiometer insulator base 16. A reinforced plastic, such as glass fiber cloth impregnated with epoxy resin, is suitable for this purpose. A thin sheet metal mask 16a provided with a slot, conforming with the shape of the resistance track, is secured to the face of the base 16 by means of pins inserted into holes therein. The mask also shields the area between terminals so that it is not coated. As motor 12 rotates shaft 14 at a moderate speed, say, 10 r.p.m., member 16 rotates past orifice 18 in mask 20. This orifice, approximately 5° wide, permits conductive carbon dispersion 21 from spray gun 22, to be deposited on substrate 16. It will be appreciated that the faster the motor rotates, the less material will be deposited during a given pass. By depositing a plurality of thin layers of resistance material, a more uniform and smooth coating is obtained than by depositing one thick layer as would result if the base were rotated, for example, but once during the coating cycle.

A master control signal is obtained from a constant voltage power source 19 which energizes master potentiometer 23. Potentiometer 23 is provided with a function proportional to the derivative of the function desired in the potentiometer under production. It should have a higher degree of conformity with function than the potentiometer element under production. As shaft 14 rotates substrate 16, the potential of wiper 25 will vary in accordance with the derivative of the desired function and provide a master control signal to amplifier 32. Motor 12, under the control of amplifier 32, is forced to change speed in response to the master control signal. A feedback loop is provided which includes a D.C. tachometer 34 coupled in tandem with shaft 14 to servo motor 12. The output of the D.C. tachometer 34 is arranged so that the voltage signal is of opposite polarity with respect to the master control signal. The two signals are then compared

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in amplifier 32 and the difference voltage amplified to drive servo motor 12 at a velocity which will minimize the input signal to the amplifier; or, stating this another way, the servo motor 12 will tend to rotate at a velocity proportional to the voltage obtained from potentiometer 23.

The completed potentiometer element is shown in FIG. 2. It is composed of the insulator base 16, resistive track 40, terminals 43a, 43b and 43c. Terminal 43c is connected to a precious metal takeoff ring 44. A rotatable wiper assembly 45 (shown diagrammatically) makes connection from the resistive track to the takeoff ring.

One method of making electrically conductive connections between the resistive track and the terminal is by the use of an electrically conductive lacquer.

This disclosure of a simple embodiment is merely for the purpose of aiding the understanding of the apparatus and method of making such devices and it is to be understood that more elaborate mechanical configuration and construction in keeping with the state of the art may be employed.

It will be noted that the potentiometer drawing shows the angle α and angle β , the angle α being the angle of rotation covered by a wiper traversing the resistance element between terminals and the angle β corresponding to $360^\circ - \alpha$.

Since the completed potentiometer is provided with a pair of end terminals 43a, 43b, it is necessary that the coating be deposited so that the terminals occur at the proper point on the resistance track. This is accomplished by phasing the substrate in relation to the shaft and the master potentiometer. This is readily accomplished by providing a keyway 17 in base 16 which engages a mating key 17a on shaft 14.

Coupled to shaft 14 so as to rotate with it, there is provided a cam 31. This cam is so shaped that as the end of the track 10 passes the spray, switch 39 is triggered, reversing the leads to the master potentiometer 23 from the power supply 19. By thus reversing the polarity of power supply, the servo motor 12 is caused to reverse and rotate the element 16 being coated in the opposite direction. This arrangement has the advantage of washing out any minor inaccuracy resulting from normal time lags in system response.

In FIG. 3, an alternate switching arrangement is shown wherein upon actuation of switch 42 by the cam 31, the output of master potentiometer 23 is disconnected from the amplifier 32 and voltage source 49 substituted. The potential of voltage source is sufficiently high to cause the shaft 14 to rotate through the angle β at a high speed. When the angle has been traversed, the cam no longer engages switch 42 and control is restored to the master potentiometer.

In the embodiment of FIG. 4, master potentiometer 23 is replaced by a series of individually adjustable voltage dividers and a sampling switch 26. A constant voltage power supply 19 energizes the adjustable voltage dividers 24. The adjustable taps of the potentiometers 24 are set to provide a voltage proportional to the derivative of the function desired at a particular point on the potentiometer. Sampling switch 26 is provided with wipers 28a and 28b, coupled to shaft 14. Thus the wipers rotate in synchronism, and phase, with the potentiometer base 16. Wipers 28a and 28b sequentially contact switch segments 30 (FIG. 5), the latter being connected to respective ones of voltage dividers 24. It will be appreciated that switch 26 serves as a sampling switch to pick out the voltage proportional to the velocity desired over a particular segment of the track. This voltage is then fed into servo amplifier 32. A feedback loop is provided which includes a D.C. tachometer 34 having its output fed (in bucking relationship to the command signal) to servo motor 12. The output of the D.C. tachometer 34 is compared with the command signal voltage from the sampled potentiometer 24 and the difference voltage is amplified

to drive servo motor 12 at a velocity which will minimize the input signal to the amplifier; or, stating this another way, the servo system will tend to rotate at a velocity proportional to the voltages on the switch.

Contacts 30 are arranged in two concentric rows with a staggered arrangement shown in FIG. 5. Two wipers 28a and 28b are employed in tandem. The two wipers are isolated from each other by a pair of series connected 1000 ohm resistors 36a, 36b. The voltage output of the wipers is taken from the junction of the two resistors and fed to takeoff ring 48 which, in turn, is contacted by wiper 50. As the wipers traverse the contacts, they alternately establish connection with the next successive contact before breaking contact with the preceding contact. At one instant, when contact is made simultaneously by both wipers to the two switch segments, the output voltage will be the average of the two potentials. It is desirable to restrict the overlap to the minimum so as to prevent the average value from significantly changing the curve. Minor averaging serves to smooth the function curve. This arrangement avoids interruption of the circuit between contact of successive contacts and prevents the servo motor 12 from stopping between segments.

The preferred sampling switch design employing staggered contacts is not available as a standard component and accordingly the conventional type with radially aligned contacts may be employed in combination with a pair of wipers (corresponding to wipers 28a and 28b) which are circumferentially offset from the longitudinal axis of their supporting brush block, the longitudinal axis being a radial line extending from the center of rotation. While as pointed out above, the slight overlap between contact points is intended to prevent motor 12 from stalling between segments, slight inaccuracies in manufacture of switches, particularly mass produced switches, wear, tweaking of the wipers which are generally fine precious metal wires, and other related irregularities can cause occasional malfunctioning of the equipment. For instance, simultaneous entry of wipers 28a and 28b onto insulator segments of sampling switch 26 can cause the motor 12 to stall whereby rotation of mold 16 ceases. The embodiments shown in FIGS. 1, 3 and 4 provide no means for restarting rotation of the mold. The result is a large build-up of conductive material at the corresponding point on the resistive path which is being coated by the apparatus. In order to overcome this problem there is provided the system shown in FIG. 13 which adds a constant speed motor 12. Both motors 12 and 12a are coupled to the sampling switch 26 through a mechanical differential 13 which algebraically adds the velocities of the two motors. Battery 19 of the prior embodiment is replaced by a center tapped battery 19a and the resistors 24 connected across the 19a battery which serves to rotate motor 12 in either of two directions responsive to the information stored in resistors 24. The characteristics of motor 12 are such that its maximum velocity is less than that of motor 12a. Accordingly the net velocity of sampling switch 26 never reaches zero. Thereby the problem of stalling of the motor is eliminated.

The servo system should have a response time of the order of 40 milliseconds time constant and should have sufficient response to overcome inertia of the system. The design criteria for accomplishing this are well known to those engaged in the art of designing servo systems.

In carrying out this invention a collimator is employed for forming a shaped coating beam. The term "collimator" is used herein in a sense somewhat different from, but related to, its use in optics. It describes a device which serves to define the direction and limit the area and deviation from parallelism of a portion of the stream of material issuing from a spray gun. In this respect the device acts as an optical collimator selects and defines the path of a portion of a stream of light. As described herein, a suitably shaped and positioned orifice acts in cooperation with a spray nozzle to so define a stream of spray

material. In FIG. 1, there is shown the outline of the collimated beam as applied to a potentiometer of the rotational type. The side edges of the beam are radially aligned with respect to the axis of rotation; the top and bottom are arcuate. The beam is restricted to an angle of track coverage between 1° and 10°. It is important that the spray beam be centered with respect to the collimator opening to obtain a uniform spray pattern.

With respect to the dimensions of the collimator opening, a width of 0.01 inch is not impractical, though it is preferred to use one, two or three times as wide. There is some tendency for the material being sprayed to pile up around the orifice and then to collapse and pass through the orifice in a lump. It should be understood that many passes are required for coating a mold, or substrate 16, and that this operation may take from about ten minutes to about an hour. This requires that the collimators be cleaned quite frequently during operation. To minimize this difficulty, it is preferred to employ the double collimator 20a and 20b, shown in FIG. 12. This device is claimed in the copending application of Frank S. Rudo, now U.S. Patent No. 3,147,142, issued Sept. 1, 1964. In this device are two orifices 18a, 18b, of similar shape in line, the one closer to the gun orifice 18a being slightly larger than the one closer to the mold (orifice 18b). Orifice 18a collects most of the build-up and if a lump of it goes through the opening it hits the second collimator 20b and does not reach the mold. This device substantially reduces the number of times the collimator has to be replaced or cleaned during the coating operation. The same type of double collimator may be used for coating base 16.

On the other hand, FIG. 6 shows the outline of a beam 52 for forming a rectilinear track 51. In this case, the beam has parallel edges which are at right angles to the track. The width of the beam should be comparable to that used for rotary potentiometers.

A preferred method of making the potentiometer device is shown in FIGS. 7-11. Mold force 62 is mounted on shaft 14 in place of substrate 16 and covered with a mask 63. The mask 63 is formed of thin sheet metal and is provided with an arcuate slot 64. The mask is secured to the mold force by means on pins 63a which seat in bores in the mold force. A resistive composition 21 is then sprayed over the surface of the mold force exposed through the slot 64 to form a resistance track 66. It will be noted that the mask forms a gap between the ends of resistance track 66. Mask 63 is removed and a mask 67 positioned over the resistance track 66, as shown in FIG. 8. Cutoffs 69 and 70 outline terminal members which are formed by spraying the exposed surface with a highly conductive material such as a dispersion of finely divided silver flake and alcohol with about five percent by weight of silver of a resin binder. The mask is removed and the mold force inserted into a collar 71, as in FIG. 9. Insulator plastic 72 is added and an upper mold force 73 is inserted into the collar. Sufficient heat and pressure suitable for the particular resin employed is then applied to the mold to form the resistance element shown in FIGS. 10 and 11. Thus, there has been provided an insulator plastic base 75 having molded thereto a composition function resistance track 66 and terminal members 76 and 77. A conventional wiper means 80, shaft 81 and takeoff 82 are shown. The advantage of this method is that a flat surface is presented to the wiper 80 although the thickness of the resistance track varies in accordance with the requirements of the desired function.

In the day to day operation of the coating machines described heretofore, it has been found that occasionally the scheduling resistors are mis-set, or due to change in the resistance or for other reasons, the apparatus otherwise misfunctions so that the correct instantaneous speeds of rotation of the mold face or substrate are not maintained. The improvement shown in FIG. 14 makes it possible for the operator to monitor the integral of the actual

speed of rotation of the mold face. The integral of the actual speed is directly proportional to the desired function output of the completed potentiometer. It has been earlier pointed out that the resistance from the start of the track to any point is defined by the following equation:

$$R(\theta) = \int_0^\theta V(\theta) d\theta = f(\theta)$$

This relationship may be employed for monitoring the accuracy of the process. An integrating amplifier 90, such as is well known in the analog computer art, is connected to the output of tachometer 34, which has an output directly proportional to velocity. The output of the integrator is then a direct measure of the resistance of the track. If the integrator is reset at the end of each revolution, then the instantaneous output is a direct measure of the function output of the potentiometer. Any malfunctioning of the system or incorrect programming will show up as an output from the integrator that is different from the desired output. As shown in FIG. 14, the output from tachometer 34 is fed through resistor 91 to amplifier 90. A capacitor 92 is connected between the input and the output of the amplifier. The choice of constants for the resistor and capacitor is in accordance with conventional practice for an integrator. Cam 93 on shaft 14 closes switch 95 to discharge the capacitor whenever the spray of conductive material is directed on the closed portion 96 of mask 16A. The output from the integrator can be observed as oscilloscope 97 and the shape of the trace compared with a template 99 or a reference curve drawn on the oscilloscope face.

As brought out by FIG. 6, the method of making a rectilinear potentiometer is the same as employed for making a rotational type potentiometer.

If desired, a raised track may be made by employing a mold provided with a track receiving recess as is taught, for example, in U.S. Patent No. 2,700,719.

In this instance, the resistance composition is sprayed into the recess. The use of a mask is not necessary as it is a simple matter to scrape the surface of the mold adjacent to the recess to remove any excess material deposited thereon. This is not to say that the collimated spray source be dispensed with.

The use of a depression is preferred because in the later molding step, the track material is confined against sidewise movement by the walls of the depression. The gap area between the terminals may be protected by tape or by a small mask or the area may be cleaned out after application of the track material.

It is to be understood that while in the foregoing description of the preferred embodiment, reference is made to employment of a stationary spray source and a moving substrate, the substrate to be coated may be maintained in a fixed position and the spray source moved.

A preferred system has thus been described where control data is supplied as an electrical signal, feedback data is provided as an electrical signal from a tachometer, and actuation is through an electronic servo system. One skilled in Control System engineering will readily devise mechanical, hydraulic or pneumatic control systems answering similar functions. Thus, data may be provided in the form of cams which control sources of mechanical, hydraulic or pneumatic potential. Other velocity sensitive devices than tachometers, such, for instance, as governors or turbines may be used. Hydraulic or pneumatic servos may form part of the control system. The electrical system already described is preferred for its simplicity and reliability.

It is to be appreciated that the spray gun may have as an integral member collimating means to produce a beam of the desired pattern.

There has been disclosed heretofore the best embodiment of the invention presently contemplated and it is to be understood that various changes and modifications may

be made by those skilled in the art without departing from the spirit of the invention.

What is claimed is:

1. An apparatus for coating a base member for forming a nonlinear potentiometer element including a layer of resistive composition in the form of a track supported by an insulator substrate, comprising in combination:
 - means for temporarily supporting the base member during a coating operation;
 - means for providing a collimated spray of the resistive composition to be coated onto the base member to form the track;
 - means for providing relative movement between the spray and a reference point on the base member;
 - a source of voltage adapted to provide a reference voltage which varies nonlinearly with variation in the relative position of the spray with respect to the reference point; and
 - means responsive to the reference voltage controlling said means for providing relative movement between the reference point and the collimated spray to provide the movement at a velocity proportional to the magnitude of the reference voltage.
2. In combination with the apparatus of claim 1:
 - detecting means for detecting the speed of movement of said base member relative to the spray and providing an output signal indicative thereof;
 - integrating means connected to said detecting means for integrating the detected speed signal and providing an output signal indicative thereof;
 - display means connected to said integrating means and responsive to the output signal for continuously providing a display of the integrated signal.
3. The combination of claim 2 wherein said display means is an oscilloscope, having a reference line indicative of the desired function on the face thereof.
4. An apparatus for forming a nonlinear potentiometer element including a layer of resistive composition in the form of a track supported by an insulator substrate, comprising in combination:
 - a mold member adapted to temporarily support the track during molding to the insulator substrate;
 - means for temporarily supporting the mold member during a coating operation;
 - means for providing a collimated spray of the resistive composition to be coated onto the mold member to form the track;
 - means for providing relative movement between the spray and a reference point on the mold member;
 - a source of voltage adapted to provide a reference voltage which varies nonlinearly with variation in the relative position of the spray with respect to the reference point; and
 - means responsive to the reference voltage controlling the means for providing relative movement between said reference point and the collimated spray to provide the movement at a velocity proportional to the magnitude of the reference voltage.
5. An apparatus for forming a nonlinear potentiometer element including a layer of resistive composition in the form of a track supported by an insulator substrate, comprising in combination:
 - a mold member adapted to temporarily support the track during molding to the insulator substrate;
 - means for providing a collimated spray of the resistive composition;
 - means positioning the mold member in the path of the spray;
 - a rotatable shaft;
 - a source of voltage adapted to provide a reference voltage which varies nonlinearly with the angular position of said shaft; and
 - means controlled by said shaft for automatically providing relative movement between a reference point on the mold member and the collimated spray at a

velocity proportional to the magnitude of the reference voltage.

6. An apparatus for coating a base member forming a nonlinear potentiometer element including a layer of a resistive composition, in the form of a track supported by an insulator substrate, comprising in combination:

means supporting the base member;

means for providing a collimated spray of the resistive composition to be coated onto the base to form the track;

a plurality of individually adjustable voltage sources; means for sequentially sampling each of said voltage sources; and

means synchronized with said sequential sampling means, for automatically providing relative movement between a reference point on the base member and the collimated spray at a velocity proportional to the magnitude of the sampled voltages.

7. An apparatus for coating a base member forming a nonlinear potentiometer element including a layer of a resistive composition, in the form of a track supported by an insulator substrate, comprising in combination:

means to provide a collimated spray of the resistive composition;

a motor having a rotatable shaft;

means coupling said motor shaft to the base for rotating the base member, with the path of the track in the path of the collimated spray;

a plurality of individually adjustable voltage sources; means for sequentially sampling the voltage of each of said voltage sources in synchronism with rotation of the base member; and

means responsive to the sampled voltages for automatically varying the rotational velocity of the motor shaft in accordance with the sampled voltages.

8. In combination with the apparatus of claim 1:

detecting means for detecting the speed of movement of said base member relative to the spray and providing an output signal indicative thereof;

integrating means connected to said detecting means for integrating the detected speed signal and providing an output signal indicative thereof;

display means connected to said integrating means and responsive to the output signal for continuously providing a display of the integrated signal.

9. The combination of claim 8 wherein said display means is an oscilloscope having a reference line indicative of the desired function on the face thereof.

10. An apparatus for coating a base member for forming a nonlinear potentiometer element including a layer of resistive composition in the form of a track supported by an insulator substrate comprising in combination:

means for supporting the base member;

means for providing a collimated spray of the resistive composition to be coated onto the base member to form the track;

means for providing relative movement between the spray and a reference point on the base member;

a first source of voltage adapted to provide a reference voltage which varies nonlinearly with variation in the relative position of the spray with respect to the reference point;

a second source of voltage coupled to said means for providing movement, said second source of voltage providing a voltage proportional to the rate of the relative movement; and

means jointly responsive to said reference voltage and said second voltage controlling said means for providing relative movement between said reference point and said collimated spray to provide said movement at a velocity proportional to the magnitude of said reference voltage.

11. An apparatus for forming a nonlinear potentiometer element including a layer of resistive composition

in the form of a track supported by an insulator substrate, comprising in combination:

a mold member adapted to temporarily support the track during molding to the insulator substrate;

means for supporting the mold member;

means for providing a collimated spray of the resistive composition to be coated onto the mold member to form the track;

means for providing relative movement between the spray and a reference point on the mold member;

a first source of voltage adapted to provide a reference voltage which varies nonlinearly with variation in the relative position of the spray with respect to the reference point;

a second source of voltage, coupled to said means for providing movement, said second source of voltage providing a voltage proportional to the rate of the relative movement; and

means jointly responsive to the reference voltage and said second voltage controlling said means for providing relative movement between the reference point and the collimated spray to provide the movement at a velocity proportional to the magnitude of the reference voltage.

12. The apparatus of claim 11 wherein said source of reference voltage is adapted to provide a voltage which corresponds at all times to the first derivative of said track nonlinear function.

13. The method of forming a potentiometer element track characterized by a voltage output being a nonlinear function of angular position along said track comprising the steps of repeatedly rotating a base member in a repetitive nonlinear velocity pattern, in the path of a collimated spray of a resistive composition wherein the said nonlinear velocity corresponds at all times to the first derivative of said track nonlinear function.

14. The method of claim 13 wherein said resistive composition comprises conductive carbon and a resinous binder.

15. The method of claim 14 wherein said base member is an insulator.

16. The method of claim 13 wherein the nonlinear velocity is continuously detected, integrated and visually displayed in juxtaposition with a reference line.

17. The process of forming a nonlinear potentiometer element including a layer of resistive composition in the form of a track supported by an insulator substrate, comprising the steps of:

providing a collimated spray of a moldable resistive composition to form said track;

positioning a mold member in the path of said spray;

providing relative movement between said spray and a reference point on said mold member;

generating a reference voltage which varies nonlinearly with variation in the relative position of said spray with respect to said reference point, wherein said relative movement between said reference point and said collimated spray is at a velocity proportional to the magnitude of said reference voltage; and

placing the resultant sprayed mold member in juxtaposition with a moldable insulator composition and simultaneously subjecting said track and said insulator composition to conditions of heat and pressure suitable for comolding said resistive and insulator compositions.

18. The process of forming a nonlinear potentiometer element including a layer of a resistive composition in the form of a track supported by an insulator substrate, comprising the steps of:

providing a collimated spray of a moldable resistive composition;

rotating a mold member in the path of said spray to form said track thereon;

generating a reference voltage which varies nonlinearly with the angular position of said mold member;

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automatically providing relative movement between a reference point on said base and said collimated spray at a velocity proportional to the magnitude of said reference voltage; and

placing the resultant sprayed mold member in juxtaposition with a moldable insulator composition and simultaneously subjecting said track and said insulator composition to conditions of heat and pressure suitable for comolding said resistive and insulator compositions.

19. An apparatus for coating a base member for forming a nonlinear potentiometer element including a layer of resistive composition in the form of a track supported by an insulator substrate, comprising in combination:

- means for temporarily supporting said base member during a coating operation;
- means for providing a collimated spray of said resistive composition to be coated onto said base member to form said track;
- means for providing relative movement between said spray and a reference point on said base member;
- a source of information adapted to provide a reference signal which varies nonlinearly with variation in the relative position of said spray with respect to said reference point; and
- means responsive to said reference signal controlling said means for providing relative movement between said reference point and said collimated spray to provide said movement at a velocity proportional to the magnitude of said reference signal.

20. An apparatus for coating a base member for forming a nonlinear potentiometer element including a layer of a resistive composition in the form of a track supported by an insulator substrate, comprising in combination:

- means for providing a collimated spray of said resistive composition;

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means positioning said base member in the path of said spray;

a rotatable shaft;

a source of information adapted to provide a reference signal which varies nonlinearly with the angular position of said shaft; and

means controlled by said shaft for automatically providing relative movement between a reference point on said base member and said collimated spray at a velocity proportional to the magnitude of said reference signal.

21. An apparatus for coating a base member for forming a nonlinear potentiometer element including a layer of resistive composition in the form of a track supported by an insulator substrate, comprising in combination:

- means for temporarily supporting the base member during a coating operation;
- means for providing a collimated spray of the resistive composition to be coated onto said base member to form the track;
- a constant speed motor having an output shaft;
- a variable speed motor having an output shaft;
- a differential means having input means coupled to said output shafts and output means coupled to said base member, whereby said base member rotates at a speed which is the algebraic sum of the speeds of said motor output shafts; and
- a source of variable voltage arranged to provide an energizing voltage to said variable speed motor, the energizing voltage being characterized by a nonlinear variation in the relative position of the spray with respect to a reference point on the base member.

No reference cited.

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