Aug. 24, 1948. O. J. UNDERWOOD ET AL 2,447,780

POTENTIOMETER ASSEMBLY

Filed May 3, 1947

Fig. 3.

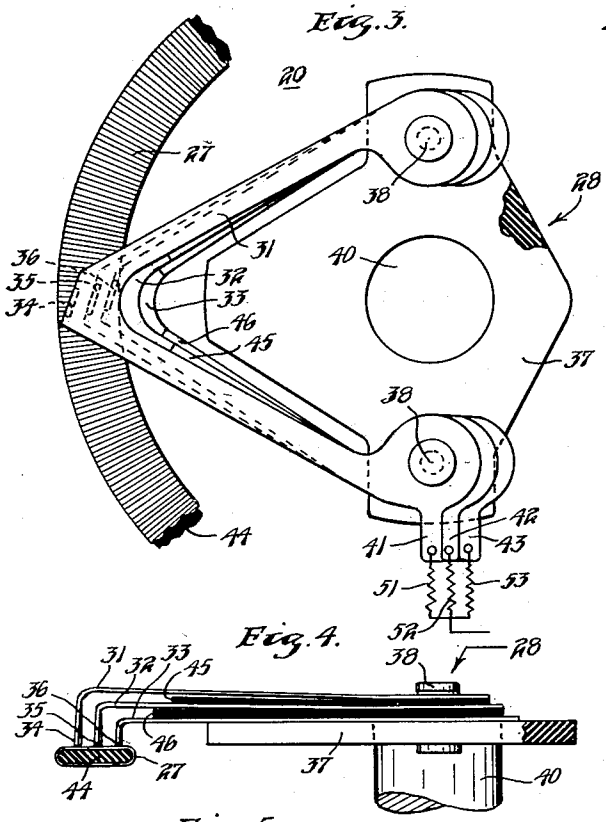


Fig. 1.

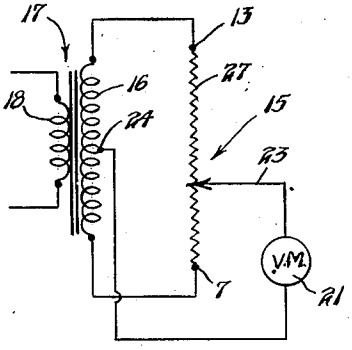


Fig. 2.

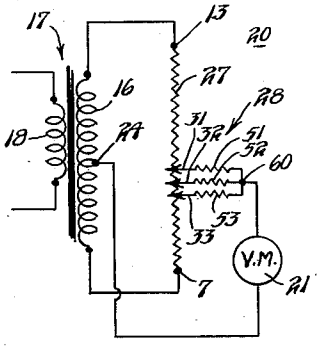


Fig. 4.

Fig. 5.

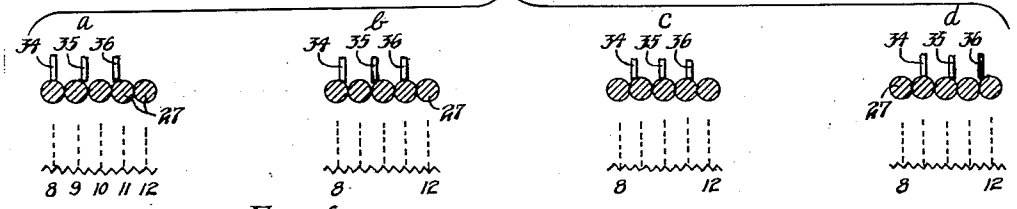
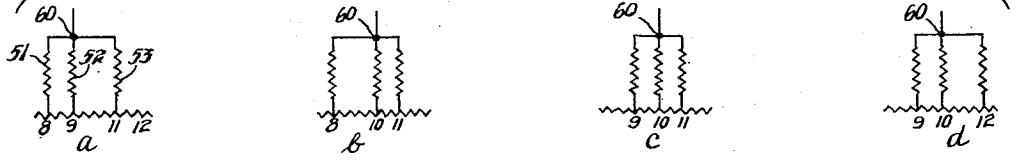


Fig. 6.



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POTENTIOMETER ASSEMBLY

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13 Claims. (Cl. 201—56)

1

This invention relates to an improved form of potentiometer for electrical regulating systems and other comparable applications, and it has particular relation to means for increasing the number of steps of resistance adjustment which such potentiometers are capable of providing. It is therefore an object of this invention to provide a potentiometer apparatus with a multiple fingered wiper arrangement which will increase the number of steps of resistance adjustment.

Multiple finger wiper arrangements are not new in the art of potentiometers, but their design has been directed towards a method of insuring that at least one wiper contact will be in electrical contact with a turn of wire of the resistance element of the potentiometer at all times so that the possibility of an open circuit at the potentiometer is thus eliminated. Such an arrangement, however, will not affect an increase in the number of steps of resistance adjustment over the adjustment which such elements are capable of providing, regardless of the number of wipers and the manner in which they are spaced. It is an object of this invention to provide a potentiometer apparatus in which each of the multiple fingered wiper arms possess an appreciable amount of resistance between a contact tip for each of the multiple arms and a point common to all of the multiple arms of the wiper apparatus.

It is a further object of this invention to provide such an arrangement in which the increased number of resistance adjustments are constant throughout the entire range of the potentiometer.

It is a still further object of this invention to provide a multiple fingered wiper arrangement which can be used with all forms of wound resistance elements.

Various other objects, advantages and features of novelty which characterize our invention are pointed out with particularity in the claims annexed hereto and forming a part, hereof. However, for a better understanding of the invention, its advantages, and objects attained by its use, reference should be had to the subjoined drawing, which forms a further part hereof, and to the accompanying descriptive matter, in which we have illustrated and described a preferred embodiment of our invention.

2

Figure 1 is a schematic electrical diagram of a conventional potentiometer used as a voltage divider so that the steps of resistance adjustment of the potentiometer can be readily measured.

Figure 2 is a schematic electrical diagram of the improved form of potentiometer used as a voltage divider so that the steps of resistance adjustment of the potentiometer can be readily measured.

Figure 3 is a top view of the multiple fingered wiper assembly.

Figure 4 is a side view of this multiple fingered wiper assembly showing the insulation between the wiper arms.

Figure 5 is a series of schematic views of the contacts of the wipers as they pass from one turn of wire of the resistance element to another turn.

Figure 6 is a series of schematic views of the variable resistance combinations which are obtained as the contact tips pass from one turn of wire of the resistance element to another.

In Figure 1 is shown a conventional potentiometer 15 which comprises a resistance element 27 and a wiper contact arm 23. The resistance element 27 has terminals 7, and 13 which are connected across the terminals of the secondary winding 16 of transformer 17. The primary winding 18 of transformer 17 is energized from any suitable A.-C. source (not shown). For the purposes of measuring the resistance or voltage adjustment to be obtained from this potentiometer, a voltmeter or galvanometer 21 is connected to wiper 23 and also to a midpoint 24 of the secondary winding 16 of transformer 17. With this arrangement, where the wiping contact 23 must pass from one turn of wire to another, it is found that the voltage variation as charted against the movement of the wiper 23 along the resistance element 27 results in a stepped voltage variation. As long as the wiping contact 23 is touching one specific turn of wire, a definite voltage prevails. When the contact 23 arrives at the valley or dip between the two windings and it, at that time, comes in contact with both windings, an instantaneous variation in voltage results which is so short-lived that it can be disregarded for practical purposes. This variation is caused by the shorting by this contact of the one turn of wire common to the contact tip. The wiper

however will move to the position of contacting the next adjacent turn with only a negligible amount of movement of the wiper and when in contact with this turn another definite and progressive voltage or resistance step occurs. Voltmeter 21 connected between wiper 23 and tap 24 of secondary winding 16 is used to indicate the variation in voltage which results above. This connection provides a well known voltage divider arrangement in which movement from a point of potential on winding 27 equal to voltage of secondary winding 16 at tap 24 creates a difference in potential between these points which is indicated by the voltmeter. A voltage change indicated by voltmeter 21 as wiper 23 is moved on winding 27 indicates the change in resistance between those respective points. Thus one definite step of voltage occurs caused by one step of resistance between any two turns of wire. This same situation will be true if the contact tip of contact 23 is large in comparison to the wire wound on the resistance element so that it will be in electrical contact with more than one turn at the same time. This condition will also occur in an arrangement where the wiper contact 23 is replaced by a wiper assembly carrying two or more wiping contacts if these wiper contact arms do not contain sufficient resistance to effect the operation of the potentiometer. This is true because only the wipers nearest the either extremities of resistance element are effective and resistance of potentiometer therebetween is shorted out as in a single wiper with a large contact surface. The wipers then touch points of equal potential and act as a single wiper.

The schematic diagram shown in Figure 2 is the electrical circuit used in testing this instant design. The potentiometer 20 comprises a resistance element 27 and a wiper assembly 28. Terminals 7, and 13 of the resistance element 27 are connected to the secondary 16 of the transformer 17 and primary winding 18 of transformer 17 is also energized from a constant A. C. source. For simplicity of drawing and explanation, we have shown the wiper assembly 28 of potentiometer 20 as having three wiper arms, 31, 32, 33. The schematic diagram figuratively shows that each of the wiper arms possess an appreciable amount of resistance as represented by resistors 51, 52 and 53. The diagram also shows that the individual wiper arms 31, 32, 33 are separated from one another and laterally spaced along the resistance element 27. This improved form of potentiometer design including the wiper assembly as described above provides an arrangement which will increase the number of steps of resistance adjustment over the number of steps of resistance adjustment which can be obtained from the conventional potentiometer in a manner which will become evident as the disclosure proceeds.

Figures 3 and 4 are detailed drawings of the potentiometer assembly 20 described above. The resistance element 27 of the potentiometer 20 is comprised of a plurality of turns of resistance wire wound around a core member 44. While the resistance element shown in Figure 3 in part is circular, it can be formed in any desired shape provided that the wiper assembly 28 can move relative thereto and in contact with this resistance element 27. Wiper assembly 28 comprises a plurality of wiper arms 31, 32 and 33 mounted together on a block of insulating material 37 so that the movement of the wiper arms 31, 32 and 33 is simultaneous with each arm moving the same distance. The wiper arm 31 includes a wiper contact 34 and a terminal lug 41. Wiper arm 32 includes a wiper contact 35 and a terminal lug 42. Wiper arm 33 includes a wiper contact 36 and a terminal lug 43. These wiper arms 31, 32, and 33 are assembled one on top of the other with insulating layers 45 and 46 positioned between said arms to separate and insulate them from one another. Insulating rivets 38 serve to mount these wiper arms with insulating layers therebetween on insulating block 37. A shaft 49 attached to insulating block 37 moves the wiper assembly 28 relative to the resistance element 27.

The wiper contacts 34, 35 and 36 of arms 31, 32, 33 respectively are also separated from one another by means of the insulating material 45 and 46 as seen in Figure 4. These contacts are spaced laterally from one another due to the position in which each is mounted on its respective wiper arm. In the present arrangement, it was found that wiper contacts 34, 35 and 36 should be spaced the distance equal to width of 1⅓ turns of resistance wire apart to obtain the greatest number of resistance combinations, which is three for three wipers as will be noted below, and as uniform resistance variations as possible. In like manner, should four or five wipers be used, the spacing between each contact tip to obtain the optimum results should be the distance of $1^1/_N$ turns apart wherein N is the number of wipers—that is, 1¼ turns apart for four wipers and 1⅕ turns apart for five wipers. While this desired spacing may be impractical when the size of the wire on the resistance element 27 becomes too small, an increased number of resistance adjustment steps can be obtained if the wipers are spaced more than one whole turn apart but not a distance which is not equal to any whole number of turns.

The schematic diagram of Fgure 2 indicates that there is a resistance associated with each of the contact wiper arms 31, 32 and 33 of the wiper assembly 28, these resistances being indicated by numerals 51, 52, and 53, respectively. This resistance in each of the wiper arms can be either internal or external or both. The limiting factor governing the size of this resistance is the requirement that the resistance associated with each wiper arm should be greater than the least amount of resistance of the resistance element 27 between any two adjacent contact tips or wiper contacts 34, 35 or 35, 36 in order that the effect of the increased number of steps shall become evident. Any resistance smaller than this amount appears to act as a short between the common terminal and the contact tips giving the effect of a single wiping contact. This is to say that the resistances 51, 52 and 53 as shown in Figure 2 may be either internal or external of the wiper arms 31, 32 and 33 but they each must be of a magnitude which is greater than that portion of the resistance element 27 which lies between wiper contacts 34, 35 or 35, 36. If the internal resistance of each wiper arm is greater than the minimum values identified above, then an assembly of such wiper arms which is properly spaced and tied together in the common point at one end will give the increased steps of resistance adjustment. From the practical standpoint, the conventional wiper assembly, whether it be multiple or not, would include wiper arms of insignificant resistance material to connect the wiping contact with the terminal lug. Such an arrangement amounts to a direct short between the contact tip and the terminal lug. Should a plurality of such wipers be used, and should

they be spaced laterally along the resistance element 27, the arrangement noted above would arise in that only the contacts which are closest to either extremity of the resistance element will be effective in contacting the resistance element, and the result is that such an arrangement would give no increased steps of resistance adjustment over the present form.

In the wiper assembly as shown in Figure 3, a 15 ohm resistor is attached to each of the terminal lugs 41, 42 and 43. Schematically the members 51, 52, 53 are applied to this external resistance and to any internal resistance of the wiper arm and wiper contact as a unit, but if the wiper arms are designed to include the necessary resistance no external resistance is necessary. Here the free ends of these 15 ohm resistors are together in a common point 60. Potentiometer winding 27 is wound with #37 A. W. G. Nichrome wire having a total average resistance of 1280 ohms for 520 turns or an approximate resistance of 2.5 ohms turn. With this amount of external resistance added the wiper arms, the ratio between the resistances in the wiper arms 31, 32 and 33 to the resistance of the portion of resistance element 27 between the contacts 34, 35 or 35, 36 is approximately 6 to 1. With 30 volts applied to the extremities 7, 13 of potentiometer winding 27, from secondary winding 16 of transformer 17, there is approximately a .0578 difference in voltage drop between each adjacent turn of wire. By using voltmeter 21 to measure this voltage variation which occurs as wiper 28 is moved across potentiometer winding, the actual number of steps is evident and the value of each of the resistance steps obtained can be determined. A milliammeter (not shown) inserted in circuit between the wipers and secondary tap in series with voltmeter 21 or millivoltmeter is necessary to complete this calculation. This arrangement was also tried with external resistances of three ohms and one hundred ohms, or approximately a ratio of 1 to 1 and 40 to 1 respectively with that resistance included between the contact tips. With three ohms added to each wiper arm the phenomenon of increased resistance adjustment steps became evident, but not until the external resistance was increased with these increased steps clearly defined. With one hundred ohms of resistance in each of the wiper arms, the steps were still clearly defined, but the rate of the change of the resistance steps were no longer uniform. The ratio which appears to give the most uniformity between steps is approximately 5 to 1 and a ratio greater or less than this will tend to vary the proportion of change between steps. Figures 5 and 6 include a series of sketches *a*, *b*, *c* and *d* which show the positions of the wiper assembly 28 with respect to the turns of the potentiometer winding immediately beneath the wiper assembly 28 as said wiper assembly is moved a distance equal to the width of one whole turn of resistance winding. For convenience in identifying the turns beneath and in contact with the wiper contacts of wiper assembly 28 during this movement, these turns are numbered 8–12 in sketches *a*–*d* of Figures 5 and 6. These reference numbers refer to the particular point on the individual turns of the potentiometer winding at which the cross section of Figure 5 is taken. The resistance shown in Figure 6 between these numbers indicates the value of the actual resistance of the turns between these points. Figure 6 is merely a series of schematic sketches of various resistance combinations occurring between

the wiper assembly and that section of the potentiometer winding immediately in contact with the wiping contacts of said assembly as the wiper assembly 28 is moved through a series of positions with respect to the turns of the potentiometer winding 27 over a distance of one whole turn. The axial movement between each sketch is equal to the distance of one third of the turn from each adjacent position. The sketches *a* of Figures 5 and 6 disclose the wiping contacts 34, 35, and 36 in contact with the turns numbered 8, 9, and 11 respectively. As noted above, these wiping contacts are spaced a distance of 1⅓ turns apart. The actual value of the resistance combination shown in the sketch *b* of Figure 6 can be calculated by treating any two of the adjacent resistance arms 51, 52, and 53 and the resistance of the potentiometer winding 27 between the points of contact of these two resistance arms as a delta circuit combination. By simple mathematical calculation, this delta circuit can be converted into an equivalent star circuit. Two legs of this star circuit can be combined with the remaining resistance arm and turn or turns of resistance winding remaining in the network or combination to form another delta circuit which can similarly be resolved into a final resultant star circuit. In converting these resistance combinations from delta to star circuits the common point 60 must be kept as a terminal point. The resultant star circuit when combined with the remaining leg of the first star circuit will give a single resultant star circuit which is the equivalent of the circuit resistance combination shown in sketch 6*a*. The two legs of the resultant star circuit common to the potentiometer winding, that is, the legs terminating in points 8 and 11 are effectively part of the resistance of the potentiometer winding 27. The third leg of the resultant star circuit which is the resistance between the common point of the star and the common point of the wiper assembly 28 is effectively the resistance of the wiper. Thus the actual resistance of the potentiometer winding includes those portions of the winding on either side of the wiper assembly and the beforementioned legs of the star circuit. In measuring the resistance of a portion of the winding between the common point of the wiper assembly 60 and the extremity 7 or 13 of the winding 27, there will be included in the circuit that portion of the star circuit which is effectively the resistance of the wiper. In using a measuring instrument or device with sufficiently high inherent impedance, the amount of voltage drop due to this resistance between common point of the resultant circuit and the connection to the measuring instrument is negligible and can be disregarded, or calculated if necessary. Similarly, sketch *b* shows the wiper contacts 34, 35 and 36 in contact with turns 8, 10, and 11 respectively; sketch *c* shows these wiper contacts 34, 35 and 36 in contact with turns 9, 10 and 11 respectively; and sketch *d* shows these wiper contacts 34, 35 and 36 in contact with turns 9, 10 and 12 respectively. Sketch *d* shows the position of the wiper assembly after it has been moved along the direction of the higher numbered turns a distance equal to the width of one turn of resistance wire of the winding 27. The resistance combination of the sketches *b*, *c*, and *d* of Figure 6 can be similarly evaluated as indicated above. When computed these resistance combinations, with the 15 ohm resistance in each wiper arm, showed an increase in the value of the resistance between one ex-

tremity of said combination and this common point of the resultant star circuit over each preceding resistance combination by an amount which was approximately 33% of the change in the resistance between the same points during the total movement of the assembly a distance of one whole turn. By increasing or decreasing this ratio which was approximately 6 to 1 when 15 ohms was used in each wiper arm, the amount of variation between the values for each position, or the steps obtained, is changed and they are no longer uniform although the number of steps still remain a fixed and definite number.

It follows that with four or five wipers, spaced preferably 1¼ and 1⅕ turns apart, respectively, that four or five steps of resistance variations are available. This is, of course, eliminating and disregarding any variations which might occur when one of the wiper contacts shorts out a turn or a number of turns of the resistance element **27**. In the above illustration, reference to the effect of change in the value of resistance of the potentiometer winding or a portion thereof between one extremity and the common point of the wiper assembly when one of the wipers shorts out a turn of the potentiometer winding **27**, has been omitted since this occurrence is only instantaneous and has no noticeable effect on the operation of such voltage or resistance varying devices.

In considering this invention it should be kept in mind that the present disclosure is intended to be illustrative only and the scope of this invention is to be determined only by the appended claims.

We claim:

1. In a potentiometer, a resistance element comprising a plurality of turns of resistance wire, a wiper assembly including a plurality of contact members movable relative to said resistance element in electrical contact therewith, said contact members being laterally spaced along said resistance element by a distance which is not equal to any whole number of turns, and said wiper assembly having resistance members connecting each of said contact members to a common junction point, the value of each of said members being greater than the smallest value of resistance of said resistance element between the points of engagement of any two of said contact members.

2. In a potentiometer, a resistance element comprising a plurality of turns of resistance wire, a plurality of contact wiper members each having a wiper arm and a contact tip, means mounting together said contact wiper members as a unit for movement relative to said resistance element and in electrical contact therewith, said wiper arms being connected together at a common point, said contact tips being laterally spaced along said resistance element by a distance which is not equal to any whole number of turns, said contact members having an internal resistance between the point of contact to said resistance element and the point common to the wiper arms which is greater than the resistance of the turns of wire of resistance element between two adjacent contact tips, and means including said contact wiper members for moving each of said contact tips laterally along the resistance element, the value of the portion of said resistance element between one extremity thereof and a common point on the wiper arms being varied by two or more stepped variations as said contact tips move a distance equal to width of one turn of wire exclusive of any resistance variation which occurs when any one or more of said contact tips momentarily short out one or more turns of said resistance element.

3. In a device of the class described, in combination, a resistance element comprising a plurality of turns of resistance wire, a source of power connected to the extremity of said resistance element, a plurality of contact wiper members each having a wiper arm and a contact tip, said wiper arms being connected together at a common point, said contact tips being laterally spaced along said resistance element by a distance which is not equal to any whole number of turns and mounted for movement relative to said resistance element and in electrical contact therewith, said contact members having an internal resistance between the point of contact to said resistance element and the point common to the wiper arms which is greater than the resistance of the turns of wire of resistance element between two adjacent contact tips, and means including said contact wiper members for moving each of said contact tips laterally along the resistance element, a voltage drop being obtained between one extremity of the resistance element and the common point of the wiper arms which varies by more than two stepped voltage variations as said contact tips move a distance equal to the width of one turn of wire exclusive of any voltage variation which occurs when any one or more of said contact tips momentarily short out one or more turns of said resistance element.

4. In combination, a coiled resistance element comprising a plurality of adjacent turns of resistance wire, a plurality of contact members movable along said element and spaced apart along the direction of movement by a distance which is different from the width of any whole number of turns and connections between each of said contact members and a common junction point, each of said connections including a resistance member having a resistance greater than that of said resistance element between the points of engagement of two of said contact members.

5. In combination, a coiled resistance element comprising a plurality of adjacent turns of resistance wire, a plurality of contact members movable along said element and spaced apart along the direction of movement by a distance which is equal to the $1^{1}/_{N}$ turns where N is the number of contact members used, and connections between each of said contact members and a common junction point, each of said connections including a resistance having a resistance greater than that of said resistance element between the points of engagement of two of said contact members.

6. In combination, a resistance element comprising a plurality of turns of resistance wire, a plurality of contact wiper members each having a wiper arm and a contact tip, said contact members being insulated from one another and mounted to move relative to said resistance element in electrical contact therewith, said wiper arms being connected together in a common point, means including said contact wiper members for laterally spacing along said resistance element said contact tips, each of said contact wiper arms having an internal resistance between said contact tips and a point common to the adjacent wiper arm which is greater than the smallest amount of resistance of the resistance element between any two adjacent contact tips.

7. In combination, a resistance element comprising a plurality of turns of resistance wire, a plurality of contact wiper members each having

a wiper arm and a contact tip, said contact wiper members being insulated from one another and mounted to move relative to said resistance element in electrical contact therewith, means including said contact wiper members for spacing said contact tips laterally along said resistance element a distance not equal to any whole number of turns, an external resistance the value of which is greater than the smallest amount of resistance of the resistance element between any two adjacent contact tips connected in series with each of said wiper arms, and said opposite ends of said external resistances being connected together to form a common point for said contact wiper member.

8. In a potentiometer, a resistance element comprising a plurality of turns of resistance wire wound around a core member, a plurality of contact wiper members each having a contact arm and a contact tip, said contact wiper members being insulated from one another and mounted to move relative to said resistance element in electrical contact therewith, means including said contact wiper members for laterally spacing along said resistance element said contact tips a distance equal to $1^{1}/_{N}$ turns where N is the number of wipers used, said wiper arms being connected together in a common point with each of said contact wiper arms having an internal resistance between said contact tips and a point common to the adjacent wiper arm which is greater than the smallest resistance of the resistance element between any two adjacent contact tips, and means including said contact wiper members for moving each of said contact tips laterally along said resistance element, the resistance between an extremity of the resistance element and a common point of the wiper arms being varied by two or more resistance variations as said contact tips move a distance equal to the width of one turn of wire exclusive of any variations which occur when one or more contacts momentarily short out one or more turns of the resistance element.

9. In combination, a resistance element comprising a plurality of turns of resistance wire wound around a core member, a source of power connected to the extremities of said resistance element, a plurality of contact wiper members each having a contact arm and a contact tip, said contact wiper members being insulated from one another and mounted to move relative to said resistance element in electrical contact therewith, means including said contact wiper members for laterally spacing along said resistance element said contact tips a distance equal to $1^{1}/_{N}$ turns where N is the number of wipers used, said wiper arms being connected together in a common point with each of said contact wiper arms having an internal resistance between said contact tips and a point common to the adjacent wiper arm which is greater than the resistance of the resistance element between two adjacent contact tips, and means including said contact wiper members for moving each of said contact tips laterally along the resistance element, a voltage drop being obtained between one extremity of the resistance element and the common point of the wiper arms which varies by two or more voltage variations as said contact tips move a distance equal to the width of one turn of wire exclusive of any variations which occur when one or more contacts momentarily short out one or more turns of said resistance element.

10. In combination, a resistance element comprising a plurality of turns of resistance wire, a source of power connected to the extremities of said resistance element, a plurality of contact wiper members each having a wiper arm and a contact tip, said contact members being insulated from one another and mounted to move relative to said resistance element in electrical contact therewith, means including said contact wiper members for laterally spacing along said resistance element said contact tips a distance not equal to a whole number of turns, an external resistance the value of which is greater than the smallest amount of resistance of the resistance element between any two adjacent contact tips connected in series with each of said wiper arms, said external resistance having its free ends connected in a common point, and means including said contact wiper members for moving each of said contact tips laterally along the resistance element, a voltage drop being obtained between one extremity of the resistance element and the common point of the external resistances which varies by two or more voltage variations as said contact tips move a distance equal to the width of one turn of wire exclusive of the voltage variations which occur when one or more of the wiper contacts momentarily short out one or more turns of said resistance element.

11. In a potentiometer, a resistance element comprising a plurality of turns of resistance wire, a plurality of contact wiper members each having a wiper arm and a contact tip, said contact members being insulated from one another and mounted to move relative to said resistance element in electrical contact therewith, means including said contact wiper members for laterally spacing along said resistance element said contact tips a distance not equal to a whole number of turns, an external resistance the value of which is greater than the smallest unit resistance of the resistance element between any two adjacent contact tips connected in series with each of said wiper arms, said external resistance having its free ends connected in a common point, and means including said contact wiper members for moving each of said contact tips laterally along the resistance element, the resistance between an extremity of the resistance element and the common point of the external resistances being varied by two or more resistance variations as said contact tips move the distance of one whole turn exclusive of any variations which occur when one or more contacts momentarily short out one or more turns of wire of the resistance element.

12. In combination, a resistance element comprising a plurality of adjacent turns of resistance wire, energized at its extremities by a source of power, a plurality of contact members movable relative to said element in electrical contact therewith to form a voltage producing device whose voltage output varies with movement of said contact members, said contact members being spaced apart along the direction of movement a distance which is greater than the width of one whole turn but is different from the width of any whole number of turns, connections between said contact members and a common junction point each of which includes a resistance element whose resistance value is greater than that of said resistance element between the points of engagement of two of said contact elements, and means for moving said contact members along said resistance element, said output from said voltage producing device varying by a plurality of voltage variations as said contact

members are moved a distance of one whole turn.

13. In combination, a coiled resistance element comprising a plurality of adjacent turns of resistance wire, a plurality of contact members movable along said element and spaced apart along the direction of movement by a distance which is different from the width of any whole number of turns, connections between each of said contact members and a common junction point, each of said connections including a resistance member having a resistance greater than

that of said resistance element between the points of engagement of two of said contact members, and means for moving said contact members along said resistance element, the resistance of said resistance element between an extremity thereof and the common junction point being varied by two or more resistance variations as said contact members are moved the distance of one turn.

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