Oct. 9, 1934. A. L. PUGH, JR 1,976,514

RESISTOR

Filed Sept. 12, 1930 2 Sheets-Sheet 1

Fig. 1.

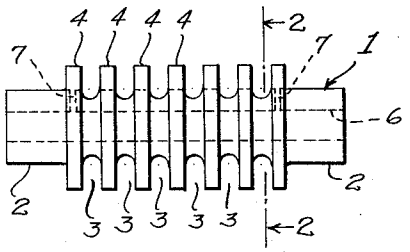
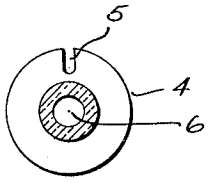


Fig. 2.



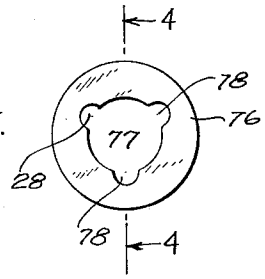


Fig. 3.

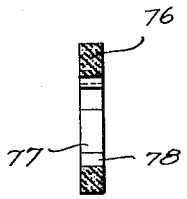


Fig. 4.

Fig. 6.

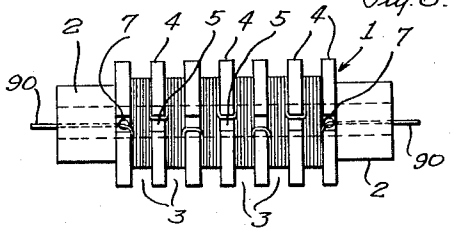
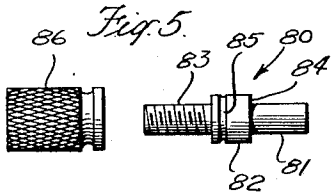


Fig. 5.



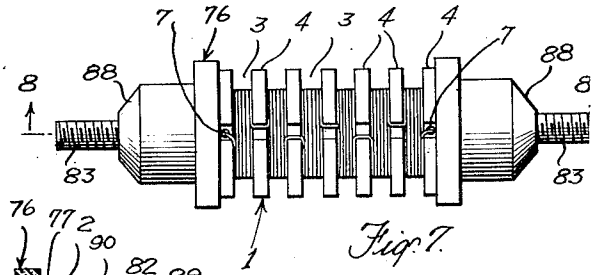
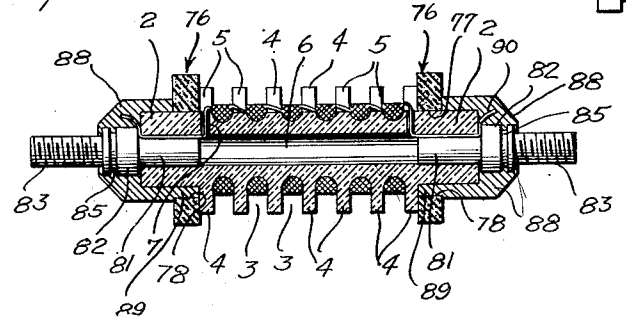


Fig. 7.

Fig. 8



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RESISTOR

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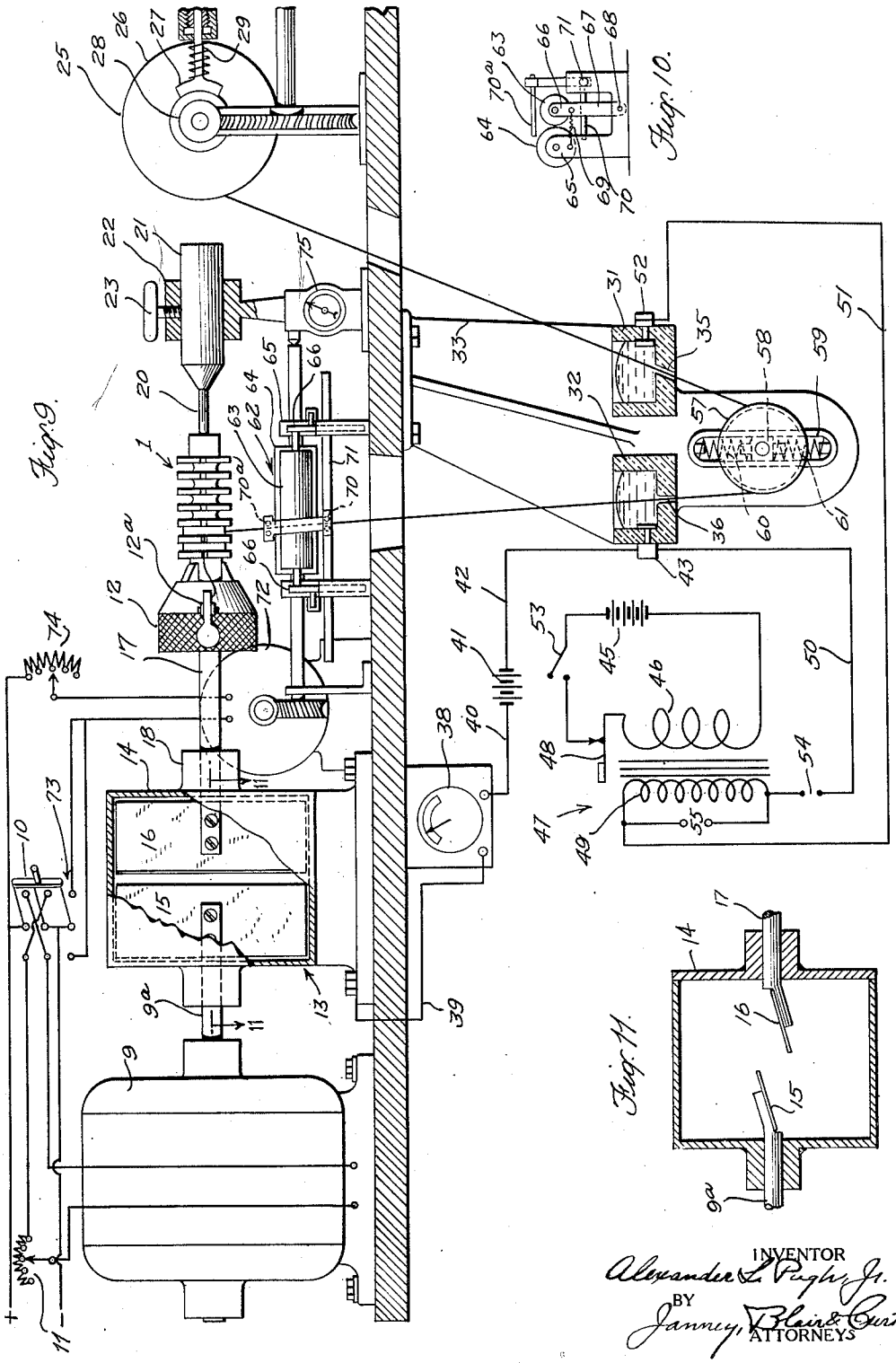


Fig. 9.

Fig. 10.

Fig. 11.

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UNITED STATES PATENT OFFICE

1,976,514

RESISTOR

Alexander L. Pugh, Jr., Pomona, N. Y., assignor to International Resistance Company, Philadelphia, Pa., a corporation of Delaware

Application September 12, 1930, Serial No. 481,378

2 Claims. (Cl. 201—63)

This invention relates to electrical resistances and an art of and apparatus for making and testing them.

One of the objects of this invention is to provide a simple, durable and inexpensive resistance or impedance device.

Another object of the invention is to provide a resistance construction that may be rapidly and inexpensively assembled and which, when assembled, is compact, unitary, and convenient for connection in an electrical circuit.

Another object is to provide a resistance device particularly adapted for use in radio circuits and that will be "noiseless" in such a circuit.

Another object of the invention resides in the attainment of a speedy and efficient method of winding the resistance coil, and a method that may be rapidly carried out in practice.

Another object is to provide a thoroughly practical method of producing a wound resistance that will be free, or substantially free, from inductive effects.

Another object is to provide an efficient and simple apparatus to carry out the method.

Another object is to provide a simple and practical method of and apparatus for measuring the electrical resistance of the resistance element used in the resistance device, particularly during the course of construction of the device.

Another object is to provide a method of and apparatus for rapidly and reliably determining the electrical resistance, at any desired stage during the winding operation, of the wire or like resistance element of a wound resistance device.

Another object is to provide an efficient and thoroughly practical method of and apparatus for measuring certain electrical characteristics of a conductor without necessitating severance of the conductor.

Another object is to provide a thoroughly practical method of producing wound resistors that will be free or substantially free from distributed capacity effects.

Another object is to provide a simple and efficient winding apparatus of constant torque.

Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations of elements, arrangements of parts and in the several steps and relation and order of each of said steps to one or more of the others thereof, all as will be herein illustratively described and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which is shown one of various possible embodiments of the mechanical features of this invention,

Figure 1 is a side elevation of a form before the resistance wire is wound upon it,

Figure 2 is a transverse sectional view taken on the line 2—2 of Figure 1,

Figure 3 is an elevation of a washer,

Figure 4 is a sectional view taken on the line 4—4 of Figure 3,

Figure 5 is a side view of a binding post and nut,

Figure 6 is a side view of the form of Figure 1 after it has been wound with wire,

Figure 7 is a side view of the device after the binding posts have been secured in place,

Figure 8 is an axial sectional view taken on the line 8—8 of Figure 7,

Figure 9 is a general view, partly in elevation and partly in section, showing the winding, testing and counting apparatus, with the electric circuits indicated diagrammatically.

Figure 10 is a side elevation of the wire feeding and guiding device, and

Figure 11 is an axial sectional view taken on the line 11—11 of Figure 9.

Like reference characters refer to like parts throughout the drawings.

Referring now first to Figures 1 and 2, I provide a form 1, preferably made of ceramic material. This form may be best described as a generally cylindrical member, having reduced end portions 2, 2 and a series of grooves 3 intermediate its ends. The grooves 3 desirably have rounded bottoms, as shown in Figure 1; they separate the main portion of the form into dividing walls 4.

Referring to Figure 2, radial slots 5 are cut in the dividing walls 4; preferably these slots are in line with each other, as shown in Figure 6, and preferably the end walls 4, as well as the intermediate walls, have slots therein.

Running the entire length of the form 1 is an axial bore 6. Near the ends of the form are transverse holes 7, 7 which penetrate to the bore 6. Desirably these transverse holes are formed in the end dividing walls 4, and desirably they start from the bottom of the notches 5 therein.

It is upon this form and into the grooves 3 that suitable resistance wire is to be wound, and it may at this point be noted that, in accordance with certain features of my invention, I avoid many peculiar difficulties not only in the actual

making of the physical resistance device itself but also in the ultimate functioning of the device itself. For example, I am enabled to prevent the terminal connections from causing changes in or interference with the intended ohmic value of resistance in the device. Also, by way of further example, I am enabled, particularly where very high ohmic resistance is desired and where it is necessary to use extremely fine wire, such as a nickel chrome wire as small as 0.001 inches in diameter, to achieve production of such a high resistance device with precision of result and, moreover, on a commercial scale, all in spite of the peculiar disadvantages and difficulties that the handling of such fine wire otherwise entails.

Considering now in detail certain features of my invention whereby I achieve such advantages as those noted above, reference may first be made to Figure 9; I first rotatably support and drive the form 1, and preferably I employ a chuck 12, carried and rotated by a suitably supported shaft 17, for holding one end, such as one of the reduced ends 2 (see Figure 1) of the form 1, and an arbor 20 for holding the other end and adapted to be received within the bore 6 at the opposite end of the form. The arbor 20 may be formed on the end of a plunger 21, or the like, that is supported in a standard 22 in any suitable way so as to be movable towards or away from the chuck, to permit the mounting or dismounting of the form 1 with respect to the driving apparatus. The arbor 20 may be held in adjusted position by any suitable device, such as a clamping screw 23. Thus the form 1 is first supported for rotation about its axis.

Rotation of the form 1 is effected by any suitable source of driving power, preferably reversible, applied to the chuck 12. Conveniently I employ a motor 9 connected to any suitable source of current by a switch 10 which functions also to reverse the direction of rotation of the motor, while a rheostat 11 may be utilized to control the speed of drive of the motor 9. The motor 9 drives the chuck 12, being connected thereto in any suitable manner, but preferably through a device, generally indicated at 13, adapted to prevent the torque that is effective to rotate the form 1 and to wind the wire onto the form from exceeding a certain value.

The constant torque device comprises preferably a generally cylindrical casing 14 suitably mounted on the base and surrounding a pair of impeller blades 15 and a pair of driven blades 16. The blades 15 are mounted upon the motor shaft 9*a*, while the driven blades 16 are fastened to the shaft 17 which supports the chuck 12, a journal 18 being provided to support the shaft 17 and therefore the blades 16 and chuck 12. The impeller blades 15, which are driven at relatively high speed, create a rapid rotational movement of the air inside of the casing 14, thus producing a torque on the driven blades 16 and causing rotation thereof. As shown in Figure 11, the plane of the blades 15 is preferably inclined with respect to its axis of rotation in order to cause also a longitudinal circulation of air in the casing 14, and thus also more effectively to bring the rotating air currents into the region of the blades 16. The blades 16 may be similarly inclined so as to respond also to axially moving air currents.

I have found that the device 13 causes a substantially constant torque to be effective upon the chuck shaft 17 and hence upon the form 1, even though the speed of rotation of the form may vary throughout relatively wide ranges as may be the case during the winding of the wire onto the form.

The wire to be wound is preferably enameled wire of high specific resistance, and low thermal electro-motive force relative to copper. By way of example, the wire may be made of nickel chrome alloy. In certain cases, for example when reactive impedance is desired, wire of low specific resistance may be used. The wire is supplied from a spool 25, which is mounted for rotation on journals 26. In order to prevent the spool 25 from over-running at the end of a particular winding operation, I provide a brake 27 which is urged against a brake surface 28 attached to the spool 25 by means of a spring 29. From the spool 25, the wire passes, generally speaking, over a pulley 57, and thence to the form 1.

The resistance device of my invention is adapted particularly for use in radio apparatus and in similar electrical circuits where an impedance of known amount is desired. Sometimes the resistance of the device must be accurate in value within a very small tolerance. It is highly desirable, therefore, that the resistance or impedance be readily and conveniently determined either at or during various stages of its construction or just before the article is finished, in order that more wire may be wound (or some wire unwound) to bring it to the desired amount; accordingly I provide a suitable resistance-indicating device, such as an ohmmeter 38, which may, at any desired point or stage in the construction, be brought into circuit with the wire that is being wound onto the form 1.

Considering now how the resistance-indicating device 38 is brought into play, and still referring to Figure 9, it may first be noted that the resistance wire, on its way to the winding apparatus, passes through liquid containers 31 and 32 which are preferably filled with mercury. The containers 31 and 32 are supported by means of a bracket 33, the containers being insulated one from the other or being made of insulating material. The resistance wire passes through slots 35 and 36 formed in the sides and bottoms of the containers 31 and 32. In this manner, the resistance wire may be readily placed in position so that it passes through the mercury or other liquid conductor without the necessity of threading through a hole. The slots 35 and 36 are narrow, and the surface tension of mercury is strong enough to prevent the mercury from running out through the slots.

In a manner that will be hereinafter more fully described, the end of the resistance wire that is first wound onto the form 1 is grounded on the chuck 12. One terminal of the ohmmeter 38 is grounded to a convenient portion of the machine such as the standard carrying the journal 18, by means of a conductor 39; thus one terminal of the ohm-meter 38 is connected to the end of the wire grounded onto the chuck 12. The other terminal of the ohmmeter 38 is connected by a conductor 40 to a battery 41, the other terminal of which is connected by a conductor 42 to one of the containers, preferably the container 32, being attached to a binding post 43. In this manner, the total resistance of the wire wound upon the form 1 may be readily calculated at any time,

as the resistance length of the wire between the container 32 and the form 1 is a known quantity.

The induction coil 47 has a secondary winding 49, the terminals of which are connected by conductors 50 and 51 to the mercury in the cups 32 and 31 respectively, suitable binding posts 43 and 52 serving to connect these conductors to the mercury, thus forming, with the loop of resistance wire that passes over the pulley 57, a circuit which is conductive excepting for the insulation about those portions of the resistance wire that are submerged in the mercury. When the switch 53 is closed, the high voltage set up in the above described circuit of the secondary winding 49 of the induction coil 47 breaks down the insulation of those portions of the wire that are submerged in the mercury, thus conductively connecting the resistance wire, through the mercury in the cup 32 and binding post 43 to the conductor 42, and thus completing the circuit in which the ohmmeter 38 and the battery 41 are included.

The circuit thus completed extends from one terminal of the battery 41, conductor 42, binding post 43, the mercury in the cup 32, the resistance wire thus far wound onto the form 1, the other end of which is grounded to the chuck 12, then by way of the conductor 39, through the ohm-meter 38, then back by way of the conductor 40 to the battery 41.

In order to prevent low voltage and heavy current from fusing the loop of resistance wire that is included in the high voltage circuit of the induction coil, I provide a spark gap 54 in one of the secondary conductors which prevents the passage of current until the potential reaches a value high enough to break down the insulation yet unaccompanied by high current flow. As sparking over from the globule of mercury in one of the containers to that in another would be accompanied by spattering and vaporization of the mercury, and might have other detrimental effects, I provide a spark gap 55 shunted between the secondary conductors 50 and 51 in order to limit the electro-motive force and prevent such sparking over. Such sparking over is particularly apt to occur if the high tension circuit is made effective in the absence of the loop of wire the insulation of which is to be broken down.

Between the container 31 and the container 32 the resistance wire passes around a pulley 57. As during the winding of the form 1, the winding is continually started and stopped, and as the spool 25 has considerable inertia, the pulley 57 is mounted to provide a cushion in order to prevent breaking of the resistance wire. As shown, the pulley 57 is journalled in a block 58 which is slidable in a vertical slot 59 provided in the bracket 33, and springs 60 and 61 hold the block 58 and pulley 57 in a central position.

From the container 32, the wire being wound passes to the form 1, onto which it may be wound, but preferably it passes first through a guiding and feeding device which is generally indicated by the numeral 62. Referring now to Figure 10, as well as to the upper part of Figure 9, this guiding and feeding device 62 preferably comprises a pair of cylindrical rollers 63 and 64, one of which, for example the roller 64, is mounted in stationary journals 65, and the other of which is rotatably mounted on journals 66 provided by arms 67 pivoted at 68. A spring 69 urges the roller 63 towards the roller 64.

The length of the cylindrical rollers 63 and 64 is substantially equal to that of a form 1 to be wound, and in order to guide the wire into the proper groove, guide rods 70, 70 and 70*a*, 70*a* are provided, being fastened to a bar 71, which is slidable parallel to the axis of the form 1. These guide rods serve to guide the wire being wound into the proper groove, and the operator may shift them back and forth as occasion demands.

It has been noted that the chuck 12 is revolved by a constant torque device. The wire is preferably drawn from the spool 25, however, by positive rotation of one of the rollers, for example the roller 64. As indicated in Figure 9, the roller 64 is connected to a motor 72 which drives it. A switch 73 for the motor 72 may be associated with the reversing switch 10 for the main driving motor 9, so that a single lever may operate both, but the roller 64 is rotated in one direction only. A rheostat 74 is provided to govern the speed of the motor 72.

In order that I may fill each groove 3 with substantially the same amount of wire, and in order that the operator may have a ready means of determining when the form has been wound with enough wire to give it the desired resistance, subject to careful check by the resistance-measuring apparatus already described, a counter 75 is provided, which is preferably associated with the wire guiding and drawing device 62. The counter 75 may be rotated directly from the roller 64.

In order to wind the form 1, a suitable length of wire is drawn from the spool 25, passed through the slots 35 and 36, around the pulley 57, and between the rollers 63 and 64, the guide rods 70, 70 and 70*a*, 70*a* having first been adjusted so as to guide the wire into the first groove 3. The form 1 is placed upon the arbor 20 and clamped by the chuck 12, and the resistance wire passed through an end slot 5. The end of the wire is first cleaned, and inserted in a clamp 12*a* provided on the chuck 12, in order to provide a complete circuit for the current through the ohm-meter 38, in the subsequent testing operation.

The form 1 is first made smooth as by applying and then baking upon it a light coat of bakelite varnish. In winding, one of the grooves is taken as a starting point, and is filled, whereupon another groove is similarly filled, until the whole form is wound. In this way the voltage drop between succeeding turns is maintained at a low figure without the use of layer separators, or layer winding. This gives the device low distributed capacity.

In a preferred form of the invention, the form 1 is rotated by the constant torque device 13, and the wire is fed at a constant rate by the rollers 63 and 64. This permits the wire to be wound upon the form with an even tension, which is a very desirable feature. For reasons which will hereinafter appear, the wire is preferably wound upon the form 1 with a rather light tension.

In a preferred form of the invention, the form is first rotated in a given direction and, the guide rods 70, 70 and 70*a*, 70*a* having been adjusted, the wire is guided by them into one end groove 3. The operator watches the counter 75 and fills this groove with approximately the desired length of wire. He then stops the motors 9 and 72, and closes the switch 53 provided

in the primary circuit of the coil 46, thereby energizing this coil. A high electro-motive force, having a high frequency, is thereby set up in the secondary, and this electro-motive force is powerful enough to break down the insulation of the wire at the mercury in the containers 31 and 32, and to jump the spark gap 54. The ohm-meter 38 thereupon registers the resistance of the circuit including the battery 41, conductors 39, 40 and 42, and the length of resistance wire from the container 32 to the clamp 12*a*. The scale of the ohm-meter may, of course, be calibrated to read directly the resistance of the wire actually wound, as the remainder of the circuit is of constant resistance.

After the resistance of the wire wound into the first groove is checked, as above described, and after winding more wire into this groove, or unwinding some wire from it, to obtain the desired resistance length, the wire is led along a slot 5 to the next adjacent groove. The switch 10 is then shifted to cause the motor 9 to reverse and thus to rotate the form 1 in the reverse direction, and the second groove is filled with the desired length of wire, which length may be checked in the manner just described. These operations are repeated until all of the grooves are filled, the wire being wound in opposite directions in adjacent grooves for non-inductive impedances, and with all in one direction for reactive impedance, and some in one direction and others in the opposite direction to secure different types of reactive impedances. When winding of the form 1 has been completed, it is removed from the chuck 12 and arbor 20. Both ends of the wire are then passed through the holes 7 into the bore 6, and out of said bore. When using the resistance testing apparatus, the wire is preferably not passed through either hole 7 until it has been wound. If the wire were passed through the hole 7 and bore 6 to start with, a fairly long end would have to be left to connect it to the clamp 12*a*, and the effective length would be changed when this was cut off. However, this part of the method might be varied in many ways.

The wire that projects from the ends of the form 1 is cut so as to leave but a short end projecting from each end of the form. The windings are next impregnated with bakelite varnish and the whole unit baked. Both projecting ends of the wire are then scraped clean.

The article of the invention may be incorporated in resistance units having a wide range of resistances, and consequently the tensile strength of the wire used may vary greatly. The constant torque device to rotate the form 1 is particularly adapted for winding wire of low tensile strength, and the constant torque device with the constant rate feeding device is particularly adapted for loose winding of the wire. These devices may be dispensed with when winding certain grades of wire.

In some cases it may be necessary to use the resistance testing apparatus only when the winding is practically completed. One reason why it is sometimes desirable to test the resistance separately during the winding of each groove is that commercial enameled wire is sometimes unreliable, and needs careful checking.

By winding the form 1 loosely and then impregnating it with bakelie varnish, imperfections in the enamel insulation originally existing or caused by the disruptive discharge at the mercury cups 31 and 32, or both, are covered up and the wire completely insulated.

The article is now in the condition illustrated in Figure 6, with a short end of wire projecting from each end of the form 1, which ends have been scraped to remove the enamel, and with successive grooves 3 wound with wire in different directions. The magnetic flux changes set up in the article induce opposite electromotive forces in the wire by reason of this fact, and for that reason the self inductance of the complete device is low.

Referring now to Figures 3 and 4, I preferably provide a pair of washers 76, the chief function of which is to protect the article from breakage, as will hereinafter be more fully set forth. These washers may be made of any suitable durable or non-brittle insulating substance, such as bakelite, fiber, rubber, or the like. The washers 76 have a large central hole 77 which is substantially of the same diameter as that of the portions 2, 2 so that they will fit thereon. A plurality of recesses 78 extend outwardly from the hole 77 for a purpose which will hereinafter appear.

Referring to Figure 5, binding posts 80 are provided, having shank portions 81 adapted to fit with a loose fit in the bore 6 of the form 1, and having enlarged portions 82 and threaded portions 83. The enlarged portions 82 leave shoulders 84 which abut the ends of the form 1. They also preferably are provided with depressions or grooves 85 for a purpose which will hereinafter appear. Nuts 86 are provided to fit on the threaded portions 83 of the binding posts 80 to facilitate the connection of the resistance in circuit with any apparatus desired.

The form 1 having been wound with wire as already set forth, the shanks 81 of the binding posts 80 are inserted in the ends of the bore 6 and pushed in as far as the shoulders 84 will allow. At the same time the washers 76 are placed over the reduced portions 2 abutting the end portions 4. The loose ends of the wire which have been scraped, as already stated, are preferably left exposed outside of the article as thus far assembled, being conveniently given positions such as are illustarted in Figure 8. The device is then related to any suitable mold, and any suitable metal, such as type metal, is then cast onto the ends of the article, forming integral portions 88, 88, as shown in Figures 7 and 8. These portions 88 grip firmly the reduced end portions 2, 2 of the ceramic form 1, and the metal flows into the recesses 78 of the washers 76, forming key portions 89 (Figure 8) which prevent the washers from turning. A perfect electrical union is made between the ends of the wire and the metal 88, and between said metal and the binding posts 80, the latter being gripped firmly in position by metal which flows into the groove 85 and/or beyond the enlarged portion 82. The metal flows into the space between the shank portions 81 of the binding posts 80 and the wall of the bore 6 of the ceramic form 1, further assuring a perfect electrical union between the wire and the binding posts 80, and forming in effect a bushing in the bore 6 for the shanks 81. Owing to the large area of this space as compared with its width, the metal solidifies before it reaches the unobstructed part of the bore 6 and, in most cases, before it fully fills the space between the shanks 81 and the surrounding ceramic form, and this solidifying arrests the further flow of the metal

and insures a firm integral casting 88, making the entire device a rigid unit mechanically and a perfect electrical union between the binding posts 80 by way of the continuous windings.

An advantageous feature of the electrical union between the binding posts 80 and the wire just described consists in the fact that the cross section of the wire is nowhere reduced (as is the case where spot welding is resorted to), the contact is "noiseless", the binding posts 80 and metal 88 being an integral part of the winding; the union is quickly and cheaply made, and at the same time serves as a mechanical element of the article, uniting the several parts thereof firmly. The ceramic material preferably used for the form 1 makes the device electrically sound, and said material strongly adheres to the metal 88. In the complete device both inductance and capacity are low, the inductance being low if the winding is reversed as set forth in the particular preferred form described, heat dissipation is good, giving high power rating, and shorted turns under load are largely eliminated. The ceramic form is protected from breakage by the washers 76, but these washers may be omitted if desired.

The winding can be very accurately controlled by means of the reversing switches 10 and 73, and the rhostats 11 and 74, together with the counter 75. Other means for measuring off a length of wire might be substituted; in particular I might count the revolutions of the spool 25. The final winding of he device is under complete control by reason of the rheostats and the resistance measuring apparatus. In some cases it may be possible to measure the resistance without stopping the feed, in which case the winding would be stopped when the pointer of the ohm-meter registered the desired resistance.

It will be seen that there is provided a construction of an essentially practical nature in which the several objects of this invention are attained. It will be seen also that the invention includes several features, which may be used separately or together. As various possible embodiments might be made of the mechanical features of the above invention, and as the art herein described might be varied in various parts, all without departing from the scope of the invention, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. In a wire wound resistor, the combination with a ceramic form having a bore, a series of radial walls leaving grooves, the walls being broken away to leave slots therein connecting the grooves, and resistance windings in the several grooves connected along the slots, of a spindle terminal in one end of the bore, there being a transverse hole from the exterior of the form to the bore, a winding lead passing through said hole into said bore alongside said spindle, and metal cast in position around said spindle and the end of said form uniting them mechanically and electrically connecting the lead to the spindle terminal.

2. The combination with a wire wound resistor having the elements and features claimed in claim 1, of an insulating washer on said form located between the windings and the cast metal on the outside of the form.

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