

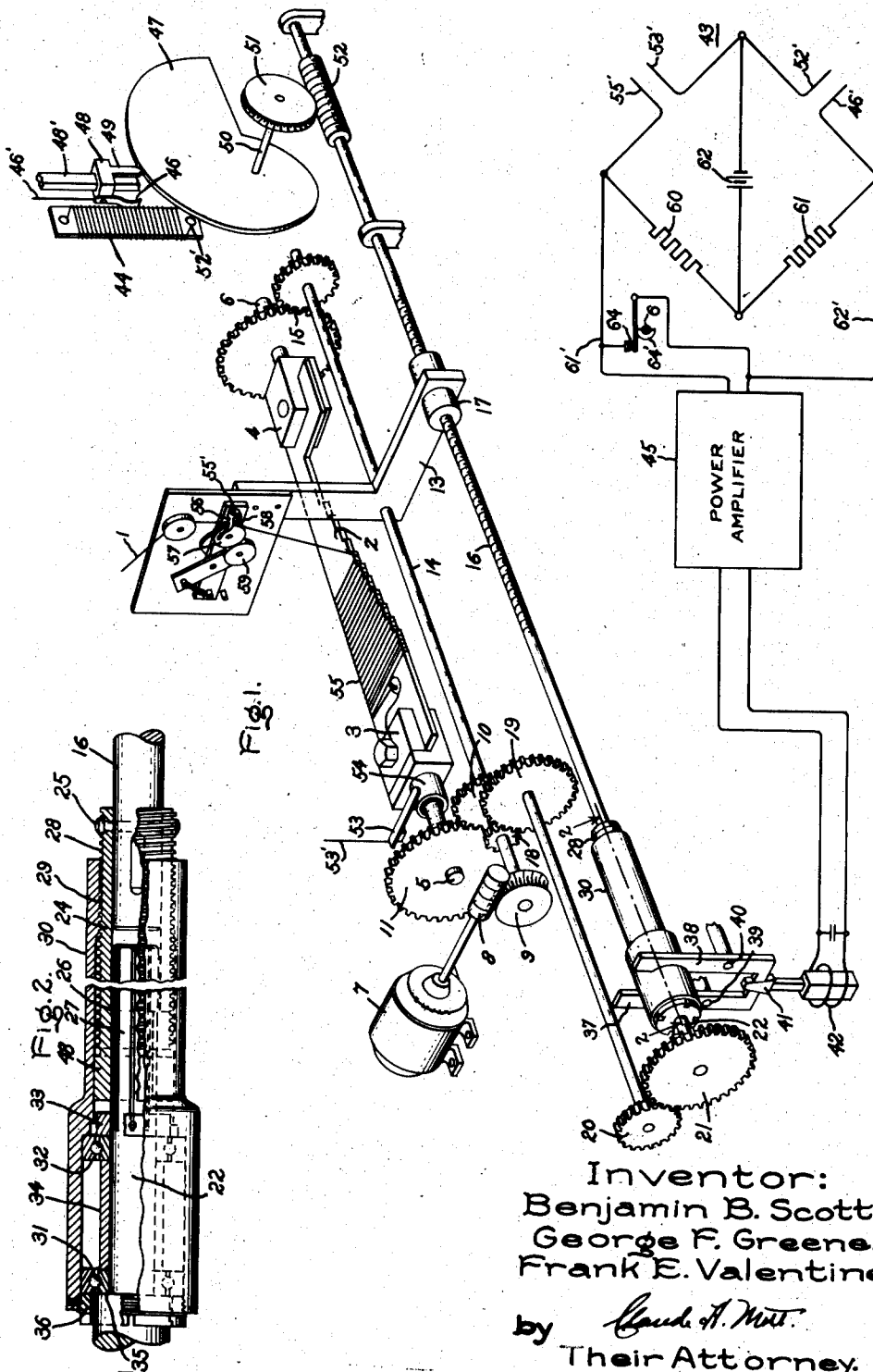
July 14, 1953

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WINDING MACHINE

2,645,429

Filed July 7, 1949

2 Sheets-Sheet 1



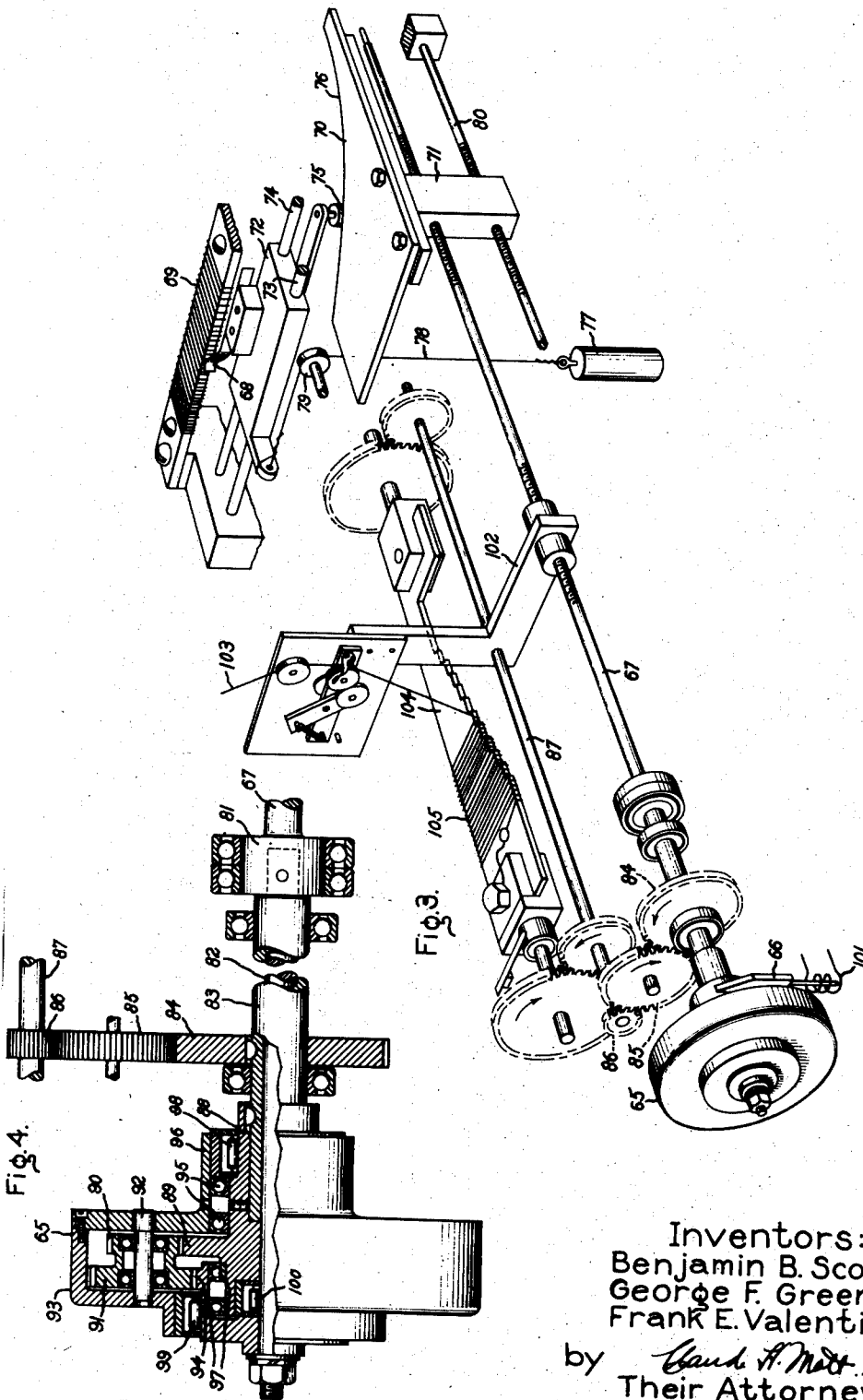
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UNITED STATES PATENT OFFICE

2,645,429

WINDING MACHINE

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Application July 7, 1949, Serial No. 103,388

9 Claims. (Cl. 242—9)

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This invention relates to winding machines, more particularly to machines for winding precision variable resistance units, and has for its object simple, reliable, and accurate means for introducing corrections during the winding operation in the positioning of the turns as they are wound.

More specifically, this invention relates to apparatus for winding resistance wire into precision variable resistance units having either linear and non-linear resistance characteristics such that their variation in resistance, as a sliding contact is moved over bared portions of the turns, is in accordance with a desired mathematical function, such as described and claimed in a copending application of John R. Moore, Serial No. 664,471, filed April 24, 1946, for Resistor Winding Apparatus, which application is assigned to the same assignee as this application.

In the winding of such resistances the total resistance wire that has been wound is compared continuously with a desired resistance up to that point, and deviation from a predetermined ratio, such as 1:1, between the wound resistance and the corresponding portion of the master resistance is corrected by immediate incremental positional adjustment of the turn being wound. In other words, if the resistance that is wound is found to be higher than the required resistance up to that point then the spacing of the wire being wound is increased so as to give the correct resistance at the brushing edge engaged by the sliding contact. This variation in the turn spacing is made necessary by manufacturing tolerances in the diameter of the wire, size of the resistance support, slight inaccuracies in the turn spacing itself, and requirements of the basic process leading to turn positioning in accordance with the theoretical output curve of the resistance unit.

In carrying out this invention corrective means is provided for introducing an incremental corrective movement in the resistance wire feeding means so as to increase the turn spacing when required, which corrective means is characterized by low inertia of the moving parts, negligible backlash and low spring-backlash of the parts, independence from the effect of variable friction between the parts, and substantially instantaneous response whereby great accuracy in the introduction of the corrective movements is achieved.

In accordance with the invention, a lead screw drive for the winding head is driven normally at a speed slightly lower than the required speed

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and a corrective driving connection is provided for the lead screw. This corrective connection normally rotates with the lead screw but is arranged, when stopped by the application of suitable braking means, to apply an additional incremental corrective movement to the lead screw, either axial movement or rotative movement depending upon the method used as will be explained in the following. The corrective driving connection in one form comprises a splined connection in the lead screw providing for axial movement of a section to elongate the lead screw for increased turn spacing as the winding proceeds, together with an outer sleeve on the splined connection in screw-threaded relation with the movable portion of the lead screw whereby when the sleeve is stopped by braking means the lead screw is moved axially as well as rotatively. This corrective axial movement of the lead screw likewise advances a contact on a master resistance, whereby, when the required corrective movement is made, a portion of a master resistance included in a resistance measuring device is made substantially equal to a predetermined ratio of the wound resistance.

In another form of the invention, a speed-increasing differential gear is interposed in the lead screw so as normally to constitute a direct drive, but provided with planetary change-speed gearing mounted on an outer sleeve, which sleeve can be stopped by suitable braking means to effect an additional rotative movement of the lead screw for turn corrective purposes.

For a more complete understanding of this invention, reference should be had to the accompanying drawings, Fig. 1 of which is a fragmentary diagrammatic view of a winding machine embodying the invention, Fig. 2 is an enlarged view partly in section of the lead screw adjusting means, while Figs. 3 and 4 are views similar to Figs. 1 and 2, respectively, showing a modified form of the invention.

Referring to the drawing, as shown, this invention is applied to a winding machine for winding a resistance wire 1 supplied under suitable tension from a reel (not shown) to a support 2 made of electrically insulating material, this support being shown as a strip or card having a straight edge, which is the brushing or contact edge, and a plurality of steps on its other edge to assist in providing desired resistance variations. The ends of the card are secured between clamps 3 and 4 mounted on aligned shafts 5 and 6. By means of an electric motor 7 connected to the shaft 5 through worm gearing 8, 9 and gears 10 and 11,

the card 2 is rotated in a clockwise direction, as seen in the drawing, to wind the wire on the card. To prevent axial twist and bending of cards which are not extremely stiff, and consequent irregularities in turn spacing, a rotary slot type of card holder may be used, such as disclosed in a co-pending application of John R. Moore, Serial No. 664,471, filed April 24, 1946, for Resistor Winding Apparatus, which application is assigned to the same assignee as this application.

For the purpose of guiding the wire in its desired turn spaced position on the card, the wire passes over a guide pulley 12 mounted on a winding head 13 which is slidably mounted on a guide or countershaft 14 on which the gears 9 and 10 are mounted. The end of the shaft 14 opposite the gear 10 is connected by gearing 15 to drive the shaft 6 at the same speed as the shaft 5.

The winding head 13 is advanced along the shaft 14, which is parallel with the shafts 5 and 6, by means of a lead screw 16 cooperating with a nut 17 carried by the winding head. By means of the gears 18, 19, 20 and 21, the lead screw 16 is connected to be driven at a predetermined speed relation with the shafts 5 and 6 and the card, which speed relation is selected to be slightly lower than the speed of the lead screw required to give the desired turn spacing. In other words, the winding head 13 if driven normally by the lead screw would space the turns too closely together.

For the purpose of introducing an additional corrective movement to the winding head 13, corrective means is provided for moving the lead screw axially to advance the winding head. For this purpose the lead screw is provided with an aligned short section 22 which is connected to form a part of the lead screw by a splined connection comprising a sleeve 24 secured by a rivet 25 to the end of the lead screw 16, and provided with internal splines 26 which cooperate with external splines 27 on the righthand end of the section 22. It will be understood that the gear 21 is secured to the lefthand end of the section 22 and that the section 22 is secured against axial movement by suitable bearings (not shown). The sleeve 24 is provided also with external screw threads 28 which are engaged by an internal screw threaded portion 29 on the end of an outer sleeve 30 enclosing the splined connection and having its lefthand end, as seen in Fig. 2, mounted on the lead screw section 22 by means of ball bearings 31 and 32 which are pre-loaded to prevent end-play. By means of a collar 33 secured to the lead screw section 22, the bearing 32 is held against the end of a sleeve 34 on the section 22, which sleeve in turn holds the bearing 31 against a shoulder 35 on the section 22 whereby the bearings 31 and 32 are secured to the section 22. The outer sleeve 30 is in turn secured to the two bearings 31 and 32 so as to be held against axial movement relative to the section 22 by means of a screw 36 in the end of the sleeve acting to preload the bearings 31 and 32.

For the purpose of securing the outer sleeve 30 against rotation intermittently to effect axial turn corrective movement of the lead screw section 23 toward the right hand, as seen in the drawing, braking means is provided for engaging the sleeve consisting of two arms 37 and 38 mounted on pivots 39 and 40 in position to engage and clamp between them the sleeve 30. The arms 37 and 38 are applied to the sleeve by means of a cam or wedge 41 movable upward by a magnet coil 42 between the lower ends of the arms so as to force

the upper ends of the arms against the sleeve and hold it against rotation.

The coil 42 is energized, when the resistance of the wound portion of the resistance unit varies a predetermined amount from the desired value up to that point, under the control of a Wheatstone bridge 43 which continuously compares the amount of resistance actually wound with the correct value of master resistance 44 at any point as included between the terminal connection 52' and the brush connection 46'. The voltage unbalance of the bridge is amplified by an electronic power amplifier 45 for energization of the coil 42.

As shown, the master resistance 44 is a precision wound linear resistance. It is provided with a sliding electric contact 46 which is moved over one edge into engagement with each successive turn, by means of a rotatable cam 47 having a shape such as to give the desired resistance variation. The contact 46 is carried by a slider 48 mounted on a guide 48', the slider 48 being provided with a projection 49 held in engagement with the periphery of the cam 46 by means of a spring bias (not shown). The cam 47 is mounted on a shaft 50 which is connected to a worm gear 51 meshing with a worm 52 secured to the lead screw 16 whereby the cam is driven in a predetermined speed relation with the lead screw. It will be observed that when the lead screw is adjusted axially, the worm 52 acts as a rack to turn the cam 47 a corresponding amount.

The master resistance 44 is connected electrically in one arm of the bridge 43 by means of a conductor 45' connected to the brush 46 and a conductor 52' connected to the lower end of the master resistance.

The resistance unit being wound is connected at its starting end in another arm of the Wheatstone bridge by a conductor 53' connected to a brush 53 which bears on a contact ring 54 electrically connected to the starting end of the resistance 55 being wound on the card 2. The other end of the resistance 55 is connected to the bridge by a conductor 55' leading to an electric contact 56 mounted on the winding head 13. This contact 56 engages an electrically conducting contact wheel 57 provided with sharp teeth 58 on its periphery, around which wheel the wire 1 is passed in one complete turn. The sharp teeth 58 pierce the enamel or other insulation on the wire and make a reliable electric contact with the wire. A spring biased pressure wheel 59 is provided to press the wire against the teeth and assure penetration of the insulation on the wire. This wire contact means is described and claimed in co-pending application Serial No. 68,818, now Patent 2,568,465, filed January 3, 1949, by the present co-inventor Benjamin B. Scott for Electrical Contact Device.

Two additional adjustable fixed resistances 60 and 61 form the other two arms of the bridge which is energized by a suitable source shown as a battery 62. The resistances 60 and 61 are adjusted to have predetermined ratio with respect to each other, such as 1:1 and when the ratio of the resistance 55 to the master resistance 44 has this same value, the bridge is balanced. Any variation from this predetermined value in the ratio of the resistance 55 to the master resistance 44 resulting from incorrect value of the resistance 55 results in a bridge unbalance which is applied to the power amplifier 45 by the conductors 61' and 62'.

In the operation of the machine, before the winding of a resistance unit is started, the mo-

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tor 7 is energized by a suitable control switch (not shown) to operate in a reverse direction to turn the cam 47 counterclockwise to a starting position while, at the same time, the brake arms 37 and 38 are applied manually by pushing the wedge 41 upward to secure the outer sleeve 30 against rotation whereby the lead screw 16 is moved toward the left to a starting position closely adjacent the end of the section 22. After the wire 1 has been connected to the card, the motor 7 is started in a winding direction. As previously stated, it is contemplated that the lead screw 16 will be driven too slowly and, consequently, the coil 42 in a typical machine is energized to apply the brake and adjust the lead screw axially toward the right intermittently whenever the bridge voltage is sufficient to produce the required energization of the coil 42.

It will be noted that rotation of the cam counterclockwise by axial corrective lead screw adjustments, not only adjusts the winding head 13 for increased spacing of wire but, at the same time, moves the contact 46 upward to insert more of the master resistance 44 in the bridge and give a bridge voltage balance, at which time the coil 42 is deenergized for withdrawal of the brake arms 37 and 38 and release of the sleeve 30. In a typical machine a wound resistance error of .01 per cent to .02 per cent of the total resistance to be wound produced a turn corrective axial movement of the lead screw. The corrective movement was continued until the bridge was substantially balanced.

It is contemplated that the brake may be applied manually by the operator by pushing the wedge 41 upward when the wound resistance deviates from the desired value as indicated by a suitable galvanometer (not shown) connected to indicate the voltage unbalance of the bridge. In such case, the automatic bridge brake applying means including the coil 42 would not be used.

Preferably, the axial lead-screw turn-spacing correction is made only during the 180 degree period of card rotation in which the wire is wound across the rear card edge opposite to the straight brushing edge of the card, i. e., the period of 90 degrees rotation before and after the straight edge of the card is lowermost with the wire in the plane of the card. This has the advantage in the half-way position, i. e., position with the straight edge lowermost, of a predetermined length of feed wire 1 between the contact wheel 57 and the straight edge, which length is included in the bridge, thereby to give a desired accurate comparison of the resistances for the completion of the incremental correction at this point. It will be noted that when winding a card portion lying wholly on one side of the axis of rotation, such as the right-hand portion of the card 2, the wire actually reverses its movement, i. e., is retrieved, during one half of each revolution. Obviously the bridge, under such conditions of wire reversal, is very erratic. Moreover, while the exact placement of the turns is of primary importance on the brushing edge, it has been found in practice that little error is produced by reliance on turn corrective positioning adjustment on the rear card edge. The limitation of the corrective movement to this 180 degree period is effected by means of a normally open switch 64 connected across the bridge terminals, which switch is operated by a 180 degree cam 64' connected to the shaft 6 so as to be closed during the remaining period of revolution

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of the card and thereby disable the Wheatstone bridge. The cam 64' effects the opening of the switch 64 for operation of the Wheatstone bridge control during the 180 correction degree period referred to. A system including a switch such as the cam operated switch 64 for disabling the Wheatstone bridge during a portion of each revolution forms a portion of the subject matter described and claimed in the above-mentioned application Ser. No. 664,471 of John R. Moore.

It will be understood that the movement of the wire feeding head by the lead screw is synchronized with the movement of the brush 46 over the master resistance by the lead screw in such manner that when the bridge is balanced, the turn across the straight brush edge of the card is in the desired position. In a typical machine, the turn correction was effected during the first 90 degrees of the correction period, at which time the wire is in the plane of the card ready to bend over the rear edge of the card in its corrected position, the straight edge of the card then being lowermost.

In the modified form of this invention shown in Figs. 3 and 4, a differential 65 operated by a brake 66 is provided for introducing turn corrective movement to the lead screw 67 of a winding machine of the type shown in Fig. 1, this movement being a turning movement of the lead screw instead of a combination of rotational and axial movement as disclosed in Figs. 1 and 2. In this form, the sliding brush 68 on the linear master resistance 69 is operated by a cam 70 provided with a driving nut member 71 cooperating with the threads on the lead screw 67 so that the cam is driven by rotational movement of the lead screw. As shown, the brush 68 is carried on a support 72 slidably mounted on guide rods 73 and 74 and provided with a roller 75 held in engagement with the cam surface or edge 76 of the cam by suitable means, such as a biasing weight 77 connected to the carriage 72 by means of a wire 78 passing over a guide pulley 79. An additional guide rod 80 is provided for the nut member 70 extending parallel with the lead screw 67 for securing the cam 70 for linear movement in a predetermined plane which may be horizontal as shown.

Referring to Fig. 4, for convenience in construction the lead screw is provided near its left-hand end with an enlarged hub or coupling portion 81 having an axial recess into which extends the righthand end of a short shaft 82, the end of the shaft 82 being secured to the hub 81 so that the shaft 82 constitutes a continuation of and is part of the lead screw 67. Rotatably mounted on the shaft 82 is a sleeve 83 to which is secured a driving gear 84 connected through an idler gear 85 with a gear 86 on the countershaft 87 which corresponds with the countershaft 14 of Fig. 1. Rigidly secured to the sleeve 83 is a second sleeve 88 provided with a gear 89 which meshes with a gear 90 rigidly secured coaxially to a gear 91. The gears 90 and 91 constitute planetary gears and are mounted for rotation on a common supporting pin 92 carried by an outer housing 93 enclosing the differential gear. Preferably, three sets of planetary gears 90, 91 (only one being shown) are provided in the housing, these three sets being mounted in the housing at equally spaced 120 degree intervals in concentric relation with the axis of the shaft section 82 and each gear 90 engaging the gear 89. Each gear 91 engages a gear 94 which is rigidly secured to the lead screw section 82.

Ball bearings 95 are provided between a braking hub 96 of the casing 93 and the sleeve 88 and ball bearings 97 are provided between the lefthand end of the sleeve 88 and the gear 94. In addition, we have provided three roller type free-wheeling clutches 98, 99 and 100 for preventing reverse backlash movement between various parts of the differential gear. The clutch 98 is between the housing 93 and the sleeve 88, the clutch 99 between the housing 93 and the gear 94, and the clutch 100 between the gear 89 and the lead screw section 82. As viewed from the lefthand end of Fig. 4, these free wheeling clutches allow relative movement of the inner members 88, 94 and 82 with respect to the outer members in each case in a counterclockwise direction but positively prevent relative movement in the opposite direction.

Under normal operating conditions it will be understood that the housing 93 and the planetary gears 90, 91 turn with the sleeve 83 and the lead screw section 82 and positively lock them together so that the screw section 82 is driven directly by the gear 84 from a suitable motor, such as the motor 7 shown in Fig. 1. In order to introduce a correction by rotative movement of the lead screw 67, the brake 66 is applied by energization of the coil 101 to the braking hub 96 of the casing 93 so as to hold the casing and the planetary gears against rotation about the axis of the screw 67. In this case the drive for the screw section 82 is through the planetary gearing and, since the gear 89 is larger than the gear 90 and the gear 91 is larger than the gear 94, a driving ratio greater than 1:1 is introduced between the gear 84 and the screw section 82. Therefore, as long as the casing 93 is secured by the brake, the screw section 82 is driven at a higher speed than for direct drive and an additional rotative movement is thus applied to the lead screw for additional linear movement of the winding head 102 and the cam 70. This movement, as in the form shown in Figs. 1 and 2, is preferably in a direction to increase the spacing of the turn being wound with relation to the preceding turn. As in the form shown in Figs. 1 and 2, the lead screw 67 is preferably geared to the driving motor so as to be driven when the brake is not applied at a speed slightly lower than the speed required for the desired turn spacing. Consequently, the brake 66 will be applied intermittently to provide for additional rotative movement of the lead screw as the winding of the resistance wire 103 on the card 104 proceeds.

It will be understood that the resistance wire 105 wound on the card and the amount of the master resistance 69 included by the contact 68 are connected in a Wheatstone bridge circuit, as disclosed in connection with Fig. 1, so that a predetermined variation in the ratio of their resistances produces a bridge voltage which is utilized through a suitable power amplifier to energize the brake coil 101 when the bridge voltage reaches a predetermined value. Adjustment of the winding head and cam reduces the bridge unbalance voltage and when it reaches a predetermined minimum value, the coil 101 is deenergized and the brake 66 is released.

While we have shown a particular embodiment of our invention, it will be understood, of course, that we do not wish to be limited thereto since many modifications may be made and we therefore contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of our invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A winding machine comprising driving means for turning a support, means for feeding a wire to the support, a driving connection between said feeding means and said driving means including a member normally rotating with said driving means but arranged to be held to provide turn corrective movement of said feeding means, braking means for said member, means for comparing the resistance of the wire wound on the support at predetermined points with a desired resistance at said points, and means responsive to a predetermined difference between said resistances for operating said braking means to hold said member thereby to vary the movement of said feeding means for wire turn adjustment.

2. A resistance winding machine comprising driving means for turning a card about a predetermined axis, means for feeding a wire to the card, a lead screw for moving said feeding means, a driving connection between said lead screw and said driving means including a member normally rotating with said lead screw but arranged to be stopped to provide additional turn corrective movement of said lead screw, braking means for said member, a coil for operating said braking means, a master resistance, a sliding contact on said master resistance, a cam for moving said contact over said master resistance, a driving connection between said cam and said lead screw for moving said cam in a predetermined desired relation with said lead screw, a second contact mounted on said feeding means for engaging the wire being wound on said card, means including said contacts for comparing the resistance wound on the card and the resistance of a corresponding portion of said master resistance, and means responsive to a predetermined difference between said resistances for operating said braking means to stop said member thereby to effect an additional movement of said lead screw for turn and master resistance adjustment.

3. A winding machine comprising driving means for turning a support, means for feeding a wire to the support, a driving connection between said feeding means and said driving means including a lead screw and a splined connection providing for independent axial movement of said lead screw, a member mounted for rotation with said splined connection, a screw threaded connection between said member and one portion of said splined connection, and braking means for holding said member to effect an axial movement of said lead screw for wire turn adjustment.

4. A winding machine comprising driving means for turning a support, means for feeding a wire to the support, a driving connection between said feeding means and said driving means including a lead screw and a splined connection providing for independent axial turn corrective movement of said lead screw, external screw threads on one portion of said splined connection, a sleeve surrounding said splined connection rotatably mounted on the other portion of said splined connection and provided with an internal screw threaded portion cooperating with said external threads, braking means for holding said sleeve, and means for operating said braking means to stop said sleeve thereby to effect an axial movement of said lead screw for wire turn adjustment.

5. A resistance winding machine comprising driving means for turning a support, means for feeding a wire to the support, a driving connection between said feeding means and said driv-

ing means including a lead screw and a splined connection providing for independent axial movement of said lead screw, external screw threads on one portion of said splined connection, a sleeve surrounding said splined connection rotatably secured to the other portion of said splined connection and provided with an internal screw threaded portion cooperating with said external threads, braking means for stopping said sleeve to provide for axial movement of said lead screw, a coil for operating said braking means, means for comparing the resistance of the wire wound on the support at predetermined points with a desired resistance at said points, and means responsive to a predetermined difference between said resistances for operating said braking means to stop said sleeve thereby to effect an axial movement of said lead screw for wire turn adjustment.

6. A resistance winding machine comprising driving means for turning a card about a predetermined axis, means for feeding a wire to the card, a lead screw for moving said feeding means, a driving connection between said lead screw and said driving means including a splined connection providing for independent axial movement of said lead screw, external screw threads on one portion of said splined connection, a sleeve surrounding said splined connection rotatably secured to the other portion of said splined connection and provided with an internal screw threaded portion cooperating with said external threads, braking means for stopping said sleeve to provide for axial movement of said lead screw, a coil for operating said braking means, a master resistance, a sliding contact on said master resistance, a cam for moving said contact over said master resistance, a worm wheel connected to said cam, a worm on said lead screw meshing with said worm wheel thereby to drive said cam in a predetermined desired relation with said lead screw, a second contact mounted on said feeding means for engaging the wire being wound on said card, means including said contacts for comparing the resistance wound on the card with the resistance of a corresponding portion of said master resistance, and means responsive to a predetermined difference between said resistances for operating said braking means to stop said sleeve thereby to effect an axial movement of said lead screw for turn master resistance adjustment.

7. A resistance winding machine comprising driving means for turning a support about a predetermined axis, means for feeding a wire to the support, a lead screw for moving said feeding means, a driving connection between said lead screw and said driving means including a speed change differential gear normally rotating with said lead screw but arranged to be held to provide a different speed of said lead screw, braking means for stopping said differential gear, a coil for operating said braking means, means for comparing the resistance of the wire wound on the support at predetermined points with a de-

sired resistance at said points, and means responsive to a predetermined difference between said resistances for energizing said coil to apply said braking means to stop said differential gear thereby to vary the speed of said lead screw for wire turn adjustment.

8. A resistance winding machine comprising driving means for turning a card about a predetermined axis, means for feeding a wire to the card, a lead screw for moving said feeding means, a driving connection between said lead screw and said driving means including a speed-increasing differential gear provided with planetary gears, a housing surrounding said gear, means mounting said planetary gears on said housing, said housing being normally free to rotate with said lead screw whereby said differential gear forms a rigid driving connection for said lead screw, braking means for stopping said housing to provide higher speed rotation of said lead screw, a coil for operating said braking means, a master resistance, a sliding contact on said master resistance, a cam for moving said contact over said master resistance, a driving connection between said cam and said lead screw for moving said cam in a predetermined desired relation with said lead screw, a second contact mounted on said feeding means for engaging the wire being wound on said card, means including said contacts for comparing the resistance wound on the card with the resistance of a corresponding portion of said master resistance, and means responsive to a predetermined difference between said resistances for operating said braking means to stop said housing thereby to increase the speed of said lead screw for turn and master resistance adjustment.

9. The combination with a rotatably mounted driven device, of a worm gear connected to drive said device, a worm meshing with said worm gear, driving means for turning said worm, a driving connection between said driving means and said worm including a splined connection providing for independent axial movement of said worm, a member mounted for rotation with said splined connection, a screw-threaded connection between said member and one portion of said splined connection, and braking means for stopping said member to effect an axial movement of said worm thereby to modify the movement of said driven device.

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