

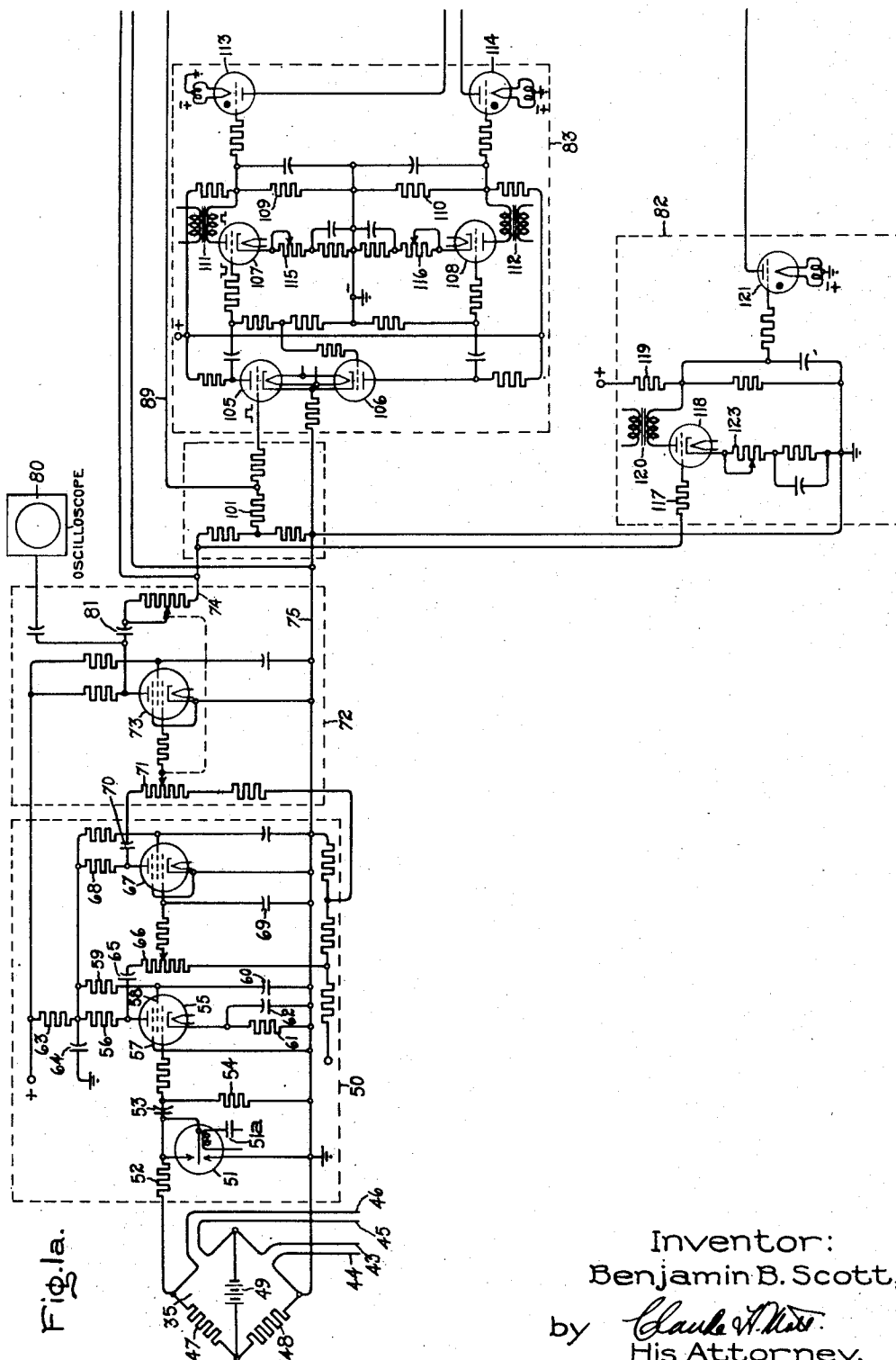
Sept. 29, 1953

B. B. SCOTT
WINDING MACHINE

2,653,772

Filed July 22, 1949

2 Sheets-Sheet 1



Inventor:
Benjamin B. Scott,
by *Charles A. Scott*
His Attorney.

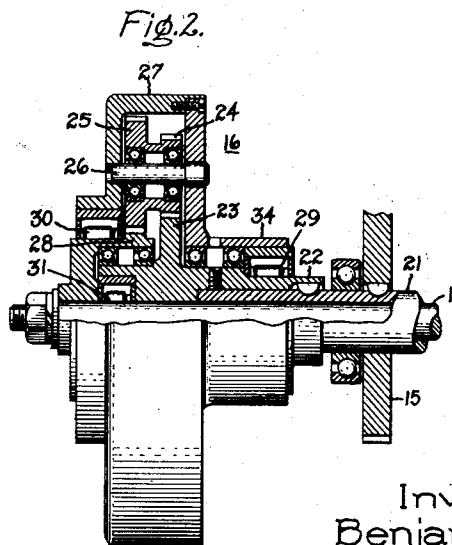
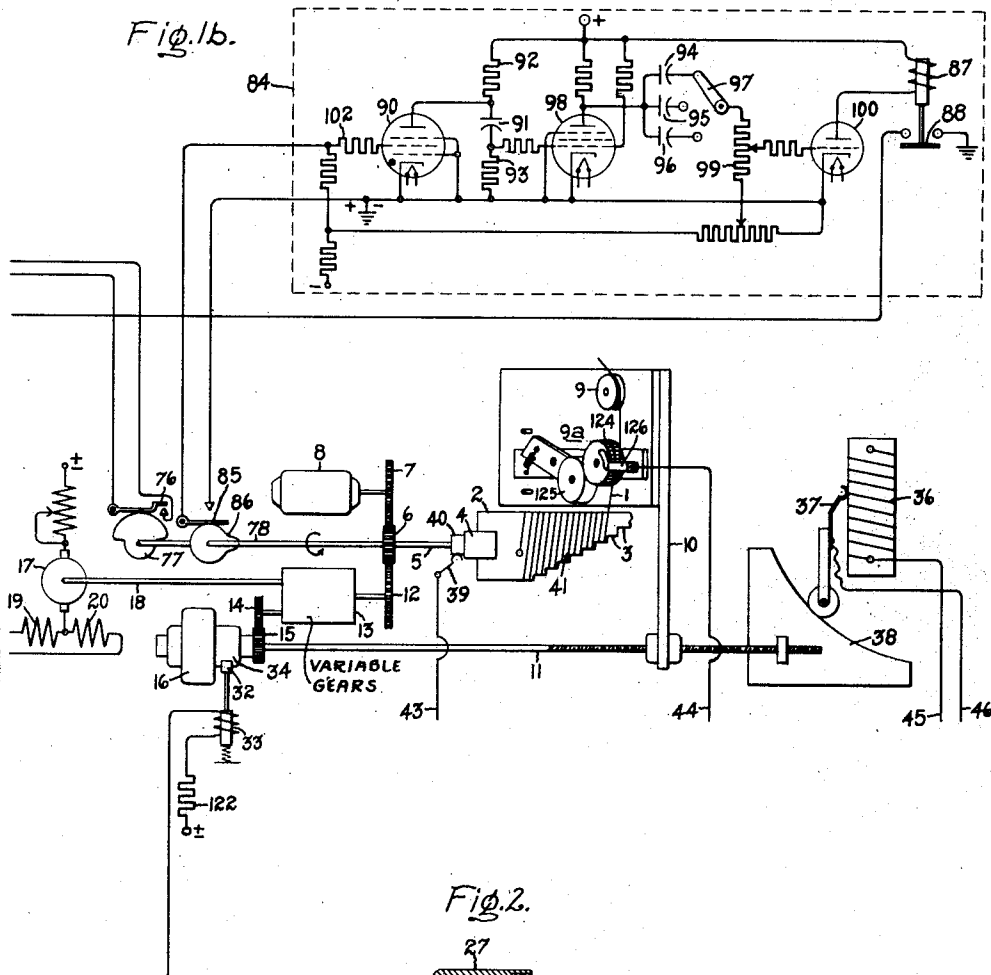
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2 Sheets-Sheet 2



Inventor:
Benjamin B. Scott,
by *Charles T. Mott*
His Attorney.

UNITED STATES PATENT OFFICE

2,653,772

WINDING MACHINE

Benjamin B. Scott, Schenectady, N. Y., assignor
to General Electric Company, a corporation of
New York

Application July 22, 1949, Serial No. 106,295

12 Claims. (Cl. 242-9)

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My 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, my invention relates to apparatus for winding resistance wire into precision variable resistance units having either linear or non-linear resistance characteristics, the variation in resistance as an electric contact is moved over bared portions of the turns being in accordance with a desired mathematical function of the movement of the contact. Such apparatus is described and claimed in a copending application of John W. Moore, S. N. 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 a master resistance is immediately corrected by an incremental change in the spacing of the turn being wound. In other words, if the wound resistance is found to be too high, the turn spacing is increased, whereas if it is found to be too low, the turn spacing is decreased. This variation in turn spacing is made necessary because of manufacturing variations in the unit resistance of the wire, variations in the size of the resistance support and inaccuracies in the turn spacing itself, etc.

In carrying out this invention in one form, two correction means are provided for adjustment of the turn spacing, both corrections being applied to a lead screw which progressively moves a winding head feeding the wire to the resistance support. One correction is applied in response to small deviations from correct resistance values during the winding process to apply additional incremental rotation of the lead screw for substantially instantaneous turn spacing correction of the individual turn being wound. The other correction is applied in response to greater deviations from correct resistance values during the winding process and effects a change in the speed of rotation of the lead screw and therefore winding rate by means of a variable gear in the driving connections between the winding head stock spindle and the lead screw. Preferably the uncorrected winding rate may be selected to

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produce a minimum desired turn spacing. This combination of corrections provides the advantages of the great accuracy of substantially instantaneous incremental turn position adjustment for small corrections, together with accurate continuous adjustment of the winding-rate to approximately instantaneous theoretical values based on actual wire unit-resistance and resistance support dimensions. It should be noted that a change in winding-rate alone requires the winding of several turns of resistance wire for the introduction of the desired correcting resistance-increment, whereas the incremental turn adjustment is substantially instantaneous in producing this effect. With the combination of the two corrections, the high accuracy of incremental turn adjustment for small corrections is supplemented by winding-rate adjustment for greater corrections when required.

For a more complete understanding of the invention, reference should be had to the accompanying drawing, Figs. 1a and 1b of which show a diagrammatic representation of a winding machine embodying this invention, while Fig. 2 is an enlarged view, partly in section, of the incremental lead screw adjusting means.

Referring to the drawing, I have shown this invention as applied to a winding machine for winding a resistance wire 1 supplied under suitable tension from a reel (not shown), connected with suitable wire tension means such as a torque motor (not shown), to a support 2 made of electrically insulating material, this support being shown as a strip or card having a plurality of steps 3 on one edge, approximating roughly the output function of the unit. The support 2 is secured at one end to a clamp 4 mounted on a winding spindle 5 driven through gears 6 and 7 from a suitable electric driving motor 8. It will be understood that the opposite end of the card 2 is likewise supported by a suitable clamp (not shown) mounted on a shaft in alignment with the shaft 5, although to prevent bending of non-rigid cards a rotary slot type support may be used for the card, such as disclosed in the aforesaid Moore application.

For the purpose of guiding the wire in its desired turn spaced position on the card 2, the wire passes over a guide pulley 9 and a roller contact device 9a mounted on a winding head 10 which is suitably mounted for slidable movement in a direction substantially parallel with the axis of the spindle 5 and moved to feed the wire in a desired spaced turn relation by a lead screw 11. The lead screw 11 is driven from the

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spindle 5 through gears 6, 12, a suitable infinitely variable speed transmission or gearing 13, gear 14, gear 15, and a differential device 16 connected to the lead screw 11.

Corrections are introduced in the rate of movement of the winding head 10 by varying the ratio of the gearing 13 which is effected by a servomotor 17 connected to the gearing 13 by a shaft 18. The motor is controlled automatically, in response to wound resistance variation, for rotation in each direction by energization of one or the other of its field windings 19 and 20 so as to increase or decrease the gear ratio of the gearing 13. Preferably the motor 17 is a high speed, low inertia, split field, gear motor.

The differential device 16 for introducing an incremental turn correction constitutes a portion of the material described and claimed in a copending application, S. N. 103,388, filed by Benjamin B. Scott, George F. Greene and Frank E. Valentine on July 7, 1949, for Winding Machine, assigned to the same assignee as this application.

A system employing the variable speed transmission for gearing 13 and the associated apparatus constitutes a portion of the material described and claimed in a copending patent application, Ser. No. 108,342 now Patent 2,618,440 filed August 3, 1949 by the present inventor, Benjamin B. Scott, together with co-inventors George F. Greene and Frank E. Valentine for a Winding Machine, and assigned to the same assignee as this application.

Referring to Fig. 2 the differential device 16 comprises a sleeve 21 to which the gear 15 is secured, this sleeve being rotatably mounted on the lead screw shaft 11. Rigidly secured to the sleeve 21 is a second sleeve 22 provided with a gear 23 which meshes with a gear 24 rigidly secured coaxially to a larger gear 25. The gears 24 and 25 constitute planetary gears and are mounted for rotation on a common supporting pin 26 carried by an outer housing 27 enclosing the differential gear. Preferably, three sets of planetary gears 24, 25 (only one set 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 lead screw 11. Each gear 25 engages a gear 28 which is rigidly secured to the lead screw 11.

For the purpose of preventing undesired relative movement in a clockwise direction between the parts, as viewed from the lefthand end of Fig. 2, three roller type free-wheeling clutches 29, 30 and 31 are provided. The clutch 29 is between the sleeve 22 and the housing 27, the clutch 30 between the housing and the gear 28, and the clutch 31 between the gear 23 and the lead screw 11. These clutches allow relative movement of the inner members 22, 28 and 11 in a clockwise direction with respect to their outer members.

Under normal operating conditions, the housing 27 and the planetary gears turn with the sleeve 22 and positively lock the sleeve 22 to the lead screw shaft 11 through clutch 31 and gear 28 so that the lead screw is driven directly by the gear 15. In order to introduce a correction, a brake 32 is applied by energization of a coil 33 to the braking hub 34 of the housing 27 so as to hold the housing and the planetary gears against rotation. In this case, the lead screw is driven through the planetary gear at a driving ratio greater than 1:1, since the gear 23 is larger than the gear 28, whereby an increased rotation is applied to the lead screw shaft. This addi-

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tional incremental rotation of the lead screw is preferably in a direction to increase the spacing of the turn being wound with relation to the preceding turn. Back-lash in gears 23, 24, 25 and 28 is overcome by means of clutch 30. It is contemplated that the adjustment of the variable gear 13 will be such as to drive the lead screw at a speed slightly lower than the speed required for the desired turn spacing. Consequently, the brake 32 will be applied intermittently to correct the spacing by increasing it as the winding of the resistance on the card 2 proceeds.

The servomotor 17 and the coil 33 are energized selectively from a Wheatstone bridge 35 which compares the amount of resistance wound on the card with the desired resistance to that point as contained in a master resistance 36. The corresponding amount of the master resistance is determined by a sliding contact 37 moved over bared-edge portions of the resistance winding 36 by a suitable cam 38 which, in turn, is moved by the lead screw 11 in a direction parallel with the axis of the spindle 5. It will be understood that the resistance 36 is a precision wound linear resistance, while the cam 38 is shaped to give the desired amount of this master resistance 36 included in the Wheatstone bridge circuit.

By means of a brush 39 bearing on a contact ring 40 on the spindle 5 electrically connected to the starting end of the wound portion 41 of the resistance, and the roller contact device 9a on the winding head 10 engaging the resistance wire being wound on the unit, and conductors 43 and 44 leading respectively from the contacting brushes 39 and the other contact device 9a, the wound portion 41 is connected in one arm of the Wheatstone bridge. Similarly, the included portion of the master resistance 36 is connected as a corresponding arm of the bridge by means of a conductor 45 connected to its lower end and a conductor 46 connected to the brush 37. Also connected in the bridge are adjustable fixed resistances 47 and 48. The bridge is energized by a suitable supply source, such as a battery 49.

When the bridge is unbalanced upon the occurrence of a difference between the ratio of the resistance 36 to the resistance 41 and the fixed ratio of the resistance 47 to the resistance 48, the positive or negative bridge unbalanced signal voltage is applied to an electronic converter and amplifier unit 50 comprising a mechanical interrupter 51 which serves to convert the direct current signal voltage from the bridge to a pulsating voltage having a frequency of 60 pulsations per second. The interrupter 51 operates to intermittently short the signal voltage through a current-limiting resistor 52 to produce a 60-cycle voltage of approximately square wave form across the condenser 53 in series with the resistor 54. The resistor 54 provides a leak for current from the grid of the tube 55 and the condenser 53 blocks this current path from the interrupter 51. By varying a capacitor 51a in circuit with the interrupter 51 the pulsating voltage can be shifted in phase as desired.

The tube 55 operates as an amplifier with plate voltage supplied through the load resistor 56 and with the grid 57 at ground potential, screen grid voltage supplied at 58 and filtered through a resistor 59 and a capacitor 60, and bias voltage is supplied through a cathode resistor 61 and filtered by a capacitor 62. A resistor 63 and capacitor 64 provide voltage supply decoupling between the amplifier and the following stages,

The signal voltage from the tube 55 is applied through a blocking capacitor 65 to a potentiometer resistor 66 from which resistor grid voltage is supplied to the tube 67 whose plate voltage is supplied through a resistor 68. The capacitor 69 prevents oscillations in the tube 67. The signal voltage from the tube 67 is supplied through a blocking capacitor 70 to a potentiometer resistor 71 in a signal-limiting unit 72 of the type described and claimed in a copending application, S. N. 81,852, filed on March 17, 1949, by Dorothy L. Cabaniss for Signal Limiter Circuit, assigned to the same assignee as this application. The tube 73 of this unit operates to saturation so as to limit the amplified voltage pulsations to a predetermined amplification voltage ratio, such as 5000 to 1. The purpose of this signal limiter is to prevent excessive output signal control voltages and erratic operation of the control in the event of high contact resistance, open circuits, etc. in the winding bridge 35.

The signal voltage from the signal limiter unit 72, which voltage appears between the conductor 74 and the grounded wire 75, is short-circuited to disable the control over 180-degree periods of winding spindle 5 rotation by means of a biased-open switch 76 periodically closed through 180-degrees rotation by a cam 77 secured to a shaft 78 driven in a 1:1 ratio with the spindle 5. As indicated in the drawing, the shaft 78 is a continuation of the spindle 5. This 180-degree rotation period during which the switch 76 is open to provide for operation of the control is the period of 90-degree card rotation before and after the straight or brushing edge of the card is lowermost with the wire extending upward parallel with the card. This has the advantage in the half-way position, i. e., the position with the straight edge lowermost, of a predetermined length of feed wire between the contact device 9a and the straight edge of the card, which wire length is included in the bridge circuit, thereby to provide an accurate comparison of the resistances for the desired completion of the incremental turn correction at this point. This cam operated switch 76 forms a portion of the material described and claimed in the above-mentioned Moore application.

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 by suitable tension means (not shown), during one-half of each revolution. Obviously the bridge, under such conditions of wire reversal, is erratic. Furthermore, while the exact placement of the turn is of primary importance on the straight or brushing edge of the card, it has been found in practice that little error is produced by reliance upon turn-positioning adjustment on the stepped or rear card edge. In a typical machine the incremental correction was usually completed during the first 90 degrees of this 180-degree rotation period so that the turn-corrective positioning adjustment actually occurred on the rear card edge. The adjustment of the variable speed gearing 13 by the servomotor also is effected during this 180-degree period.

A suitable oscilloscope 80 connected to the output signal from the unit 72 between a capacitor 81 and the tube 73, so that it is not affected by the short-circuit operation of the switch 76, gives a visual indication of bridge 35 balance condi-

tion as a function of signal magnitude from the unit 72.

During the period that the switch 76 is open, the signal is applied to two units 82, and 83 for the control respectively of the brake coil 33 and the field windings 19 and 20 of the servomotor.

The unit 82 is responsive only to a positive signal bridge voltage which is reproduced by a too close wire turn spacing, i. e., the resistance of the wire so far wound is too high. When this positive voltage reaches a predetermined error value the coil 33 is sufficiently energized to apply the brake 32 for additional rotation of the lead screw and increased spacing of the next turn. It will be understood that this additional rotation of the lead screw does not change perceptibly the amount of the resistance 41 in the bridge circuit but does, by movement of the cam 38, change the amount of the resistance 35 in the bridge circuit so as substantially to balance the bridge, whereupon the coil 33 is de-energized and the brake 32 released.

The unit 83 is an electronic inverter and amplifier and provides amplified positive or negative power increments to the servomotor 17 in accordance with positive or negative unbalance signals from winding-bridge 35.

The unit 83 controls the servomotor 17 upon the occurrence of a greater signal voltage than required for application of the brake 32. It is responsive both to positive signal voltages and to negative voltages resulting from too great spacing of the turns, i. e., the resistance so far wound is too low, and controls the servomotor 17 adjustment of the ratio in the gearing 13 to change the speed of the lead screw up or down so as not only to effect increased turn spacing but, also, decrease the turn spacing in case it becomes too great.

Moreover, the operation of the unit 83 is under the control of a timer unit 84 which is synchronized by a normally open switch 85 closed for a short interval once each revolution of the spindle 5 by a cam 86 mounted on the shaft 78, the switch 85 being closed simultaneously with the opening of the switch 76, or immediately after the opening of the switch 76. This timer 84 normally energizes a coil 87 to maintain a ground switch 88 closed, whereby the input signal to the unit 83 is grounded through a conductor 89 and the unit 83 disabled. When the switch 85 is closed, however, the switch 88 opens and the unit 83 energizes one or the other of the motor fields, if the signal voltage is great enough, for adjustment of the variable speed gearing 13.

When the switch 85 is open, the bias on the grid of thyratron tube 90 prevents it from firing so that a voltage builds up on capacitor 91 through the resistors 92 and 93. At this time, one of the capacitors 94, 95 or 96 of different values selected by the switch 97, as shown the capacitor 94, is charged to the voltage across the tube 98 which is conducting at saturation. The capacitor 94 is in series with the resistor 99 and the bias thereby placed on the grid of the tube 100 causes this tube to pass current and energize the relay coil 87 to hold its contacts 88 closed whereby the signal voltage through the resistor 101 is grounded.

When the switch 85 is closed momentarily each revolution, the grid of the tube 90 is connected through the resistor 102 and the switch 85 to ground, whereby its bias is removed and the tube 90 becomes conducting and allows the

capacitor 91 to discharge through it and the resistor 93. This discharge produces a short duration negative voltage pulse, whose duration is independent of the time of closure of the switch 85, across the resistor 93. This negative pulse is applied to the grid of the tube 98 to cause it to become nonconducting, whereupon the voltage on the capacitor 94 builds up to a greater value and produces a short duration positive voltage pulse across the resistor 99. This positive pulse is applied to the grid of the tube 100 but has no effect on its operation.

The positive voltage pulse across the resistor 99 is followed, when the negative pulse on the grid of the tube 98 decays and the tube 98 becomes conducting, by a negative pulse resulting from the discharge of the capacitor 94 through the tube 98 and the resistor 99, which negative pulse causes the tube 100 to become nonconducting for de-energization of the coil 87, whereupon the switch 88 opens. The input signal voltage is thus applied to the servomotor control unit 83 for a period of time determined by the duration of the negative pulse, which is selected by the capacitor 94, 95 or 96.

The input signal voltage is amplified and inverted in phase by the tube 105 and amplified and inverted again by the tube 106. This produces a signal voltage on the grid of tube 107 which is 180 degrees out of phase with the input signal, and an equal signal voltage on the grid of tube 108 which is in phase with the input signal.

The tubes 107 and 108 operate as discriminators. Direct plate voltage is supplied to these tubes from across the resistors 109 and 110, respectively, while a suitable 60 cycle alternating voltage is superimposed on the direct plate voltages by transformers 111 and 112, the connections being such that the alternating voltages applied to the plates are in phase with each other.

A suitable alternating voltage is applied to the plates of the thyatron tubes 113 and 114 through the resistor 20, the armature of the servomotor 17, and the field windings 19 and 20, respectively, these plate voltages being out of phase with the alternating plate voltages of the tubes 107 and 108. The opposite side of this alternating supply source is grounded, as are the cathodes of the tubes 113 and 114.

With zero signal voltage, each of the tubes 107 and 108 conducts slightly on positive plate voltage half cycles to produce 60-cycle sawtooth voltages on the grids of the thyatron tubes 113 and 114, which sawtooth voltages are out of phase with the plate voltages of thyratrons 113 and 114 and are adjusted by potentiometers 115 and 116 to give the desired sensitivity to the signal voltage. This produces a slight conduction of the thyratrons 113 and 114 under these conditions but not enough to effect operation of the servomotor.

A positive 60 cycle signal voltage at the tube 105 is in phase with the alternating plate voltages of the tubes 107 and 108 and produces an out-of-phase voltage on the grid of the tube 107, thereby decreasing the current through tube 107 and decreasing the sawtooth voltage on the grid of the thyatron 113. This increases the conduction of the thyatron 113 and, if great enough, effects operation of the servomotor in a direction to increase the lead screw speed, i. e., decrease the ratio of the gear 13, and thereby increase the turn spacing. At this time, the voltage on the

grid of tube 108 is in phase with its plate voltage, whereby the sawtooth voltage on the grid of the thyatron 114 is increased to prevent it from firing.

A negative signal voltage is out of phase with the alternating plate voltages of the tubes 107 and 108, and causes the thyatron 114 to conduct current for operation of the motor in the reverse direction, if the signal is great enough, to increase the ratio of the gear 13 and hence decrease the lead-screw speed and the turn spacing.

Referring again to the unit 82, the signal voltage is supplied, when the switch 76 is open, through the resistor 117 to the tube 118 which operates as a discriminator. It is supplied with direct plate voltage through resistor 119 and with alternating plate voltage from a transformer 120. The thyatron 121 is supplied with alternating plate voltage 180 degrees out of phase with the alternating component of the plate voltage on the tube 118 through a resistor 122 and the coil 33. With zero input signal voltage, the tube 118 conducts slightly on positive half-cycles of its alternating plate voltage and is cut off on negative half-cycles producing a 60-cycle sawtooth voltage on the grid of the thyatron 121 which is out of phase with the plate voltage of the thyatron. This sawtooth voltage is adjusted by the resistor 123 for the desired sensitivity to the signal voltage with resulting slight conduction of the thyatron.

A negative input signal voltage is in phase with the alternating plate voltage on the tube 118 and causes the tube 118 to conduct more current thereby increasing the negative sawtooth voltage on the thyatron 121 and preventing it from firing. A positive input signal voltage is 180 degrees out of phase with the alternating plate voltage of the tube 118 and decreases the current through the tube 118, whereby the sawtooth voltage on the thyatron 121 is reduced and the thyatron caused to fire over portions of the positive half-cycle, depending on the signal magnitude, to energize the coil 33 and apply the brake for an incremental turn correction.

The roller contact device 9a, which is described and claimed in my copending application Serial No. 68,818, filed January 3, 1948 for Electrical Contact Device, comprises an electrical conducting contact wheel 124 provided with sharp teeth on its periphery around which wheel the wire 1 is passed in one complete turn. The sharp teeth on the wheel pierce the enamel or other insulation on the wire and make a reliable electrical contact with the wire. A spring-biased pressure wheel 125 presses the wire against the teeth and assures penetration of the insulation on the wire. The wire 44 leads to an electric contact 126 which bears on the wheel 125.

In the operation of the machine it is contemplated that the potentiometers 115 and 116 will be adjusted so that the servomotor will maintain the winding rate too high, such as five turns per inch too high, and, as a result, turns spaced too closely together. The incremental correction will then operate to increase the turn-spacing for exact placement of the wire. In a typical machine, for example, when the correct winding rate was 200 turns per inch, the variable speed gear 13 was automatically adjusted to wind 205 turns per inch. When the wire unit resistance increased because of manufacturing variations to such an extent that 195 turns per inch was correct, the variable speed gear was adjusted in re-

sponse to a positive signal voltage of predetermined value to reduce the winding rate to 200 turns per inch. Similarly when the winding rate became correct, it was automatically increased five turns per inch. This adjustment of the variable speed gear 13 occurred for other variations affecting the winding rate to give either a positive or a negative signal voltage, such as variations in the card size and variations to meet resistance design requirements as reflected by the variations in the amount of the master resistance 36 included in the bridge circuit.

It should further be noted that in a typical machine the signal voltage may be negative enough to cause readjustment of the variable gear 13 at the start of the 180-degree correction period, i. e., when the switch 76 is closed by the cam 77, the servomotor operating to increase the ratio of the gear 13 for decreased turn spacing. However, the increased length of wire between the contact device 9a and the card, resulting from the card rotation through the next 90 degrees to the point where the straight edge of the card is lowermost, generally introduced sufficient resistance in the bridge circuit to give a positive signal voltage and produce an incremental correction during this 90 degree period.

A typical machine provided with control means embodying my present invention has been operated to wind enameled nickel-chromium-iron alloy wire having a diameter of .00225 in. at speeds up to 330 R. P. M. Wire having a diameter of .001 in. has been wound at a speed of 150 R. P. M. The diameter referred to is the diameter of the bare wire. As an example of the accuracy of the wire placement by the incremental adjustment, corrections in the positioning of the wire as small as .0001 in. are made in winding wire having a diameter of .0015 in.

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

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

1. A resistance winding machine comprising driving means for turning a resistance support, means for feeding a wire to said support, a driving connection including a variable speed gear between said driving means and said feeding means for moving said feeding means at predetermined adjustable speeds to feed the wire to said support in a predetermined spaced turn relation, an incremental turn-spacing adjustment device included in said driving connection for effecting an additional turn spacing movement of said feeding means, means responsive to a predetermined difference between the resistance wound on the support and a desired resistance up to that point for operating said incremental adjustment device for immediate turn spacing adjustment, and means responsive to a predetermined greater difference between said resistances for operating said variable speed gear to vary the speed of said wire feeding means for turn spacing adjustment.

2. 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 driving means including a variable speed gear and a member normally rotating with said driving

means but arranged to be stopped to provide incremental turn corrective movement of said feeding means, braking means for stopping said member, means for comparing the resistance of the wire wound on the support at predetermined points with a desired resistance at said points, means responsive to a predetermined difference between said resistances for operating said braking means to stop said member thereby to vary the movement of said feeding means for wire turn adjustment, and means responsive to a predetermined greater difference between said resistance for adjusting said variable speed gear to vary the speed of said feeding means for winding rate adjustment.

3. The combination in a winding machine for winding resistance wire on a support, of means responsive to a predetermined difference between the resistance of the wire on the support and the desired resistance up to that point for increasing or decreasing the winding rate so as to maintain the winding rate slightly higher than necessary for correct turn spacing, and incremental turn corrective means responsive to a resistance difference smaller than said predetermined difference for increasing the spacing of each turn as it is wound.

4. The combination in a winding machine for winding resistance wire on a support, of means responsive to a predetermined difference between the resistance of the wire on the support and the desired resistance up to that point for increasing or decreasing the winding rate so as to maintain the winding rate slightly higher than necessary for correct turn spacing, timing means for disabling said winding rate adjusting means, means driven with the resistance support for controlling said timing means to render said winding rate adjusting means effective for a predetermined interval of time each revolution of the support, and incremental turn corrective means responsive to a predetermined smaller difference between said resistances for increasing the spacing of each turn as it is wound so as to give the desired resistance gradient.

5. A resistance winding machine comprising driving means for turning a support, means for feeding a wire to said support, a driving connection including a variable speed gear between said driving means and said feeding means for moving said feeding means at predetermined adjustable speeds to feed the wire to said support in a predetermined spaced turn relation, an incremental turn spacing adjustment device included in said driving connection for effecting an additional turn-spacing movement of said feeding means, means responsive to a predetermined difference between the resistance wound on the support and a desired resistance up to that point for adjusting said variable speed gear to increase or decrease the winding rate so as to maintain the winding rate slightly higher than necessary for correct turn spacing, and means responsive to a resistance difference smaller than said predetermined difference for operating said incremental adjustment device to increase the spacing of each turn as it is wound so as to give the desired resistance gradient.

6. A resistance winding machine comprising driving means for turning a resistance support, means for feeding a wire to said support, a driving connection including speed varying means between said driving means and said feeding means for moving said feeding means at a predetermined adjustable speed to feed the wire to

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said support in a predetermined spaced turn relation, an incremental turn spacing adjustment device included in said driving connection for effecting an additional turn spacing movement of said feeding means, a motor for operating said speed varying means, means for producing a pulsating voltage varying in phase and value with the difference between the resistance of the wire wound on the support and a desired resistance up to that point, means responsive to the phase and value of said voltage for energizing said motor for forward or reverse rotation for adjustment of said speed varying means to increase or decrease the speed of said wire feeding means for wire turn spacing adjustment, means responsive to rotation of the support for limiting the operation of said motor to a predetermined period of time during each revolution of the support, and additional means responsive to the phase and value of said voltage for energizing said incremental adjustment device to increase the spacing of each turn as it is wound so as to give the desired resistance gradient.

7. A resistance winding machine comprising driving means for turning a resistance support, means for feeding a wire to the support, a driving connection including a turn spacing adjustment device between said driving means and said feeding means for moving said feeding means at a predetermined adjustable speed to feed the wire to said support in a predetermined spaced-turn relation, means for producing a pulsating voltage varying in phase and value with the difference between the resistance of the wire wound on the support and a desired resistance up to that point, a biased-open switch connected to disable said voltage-producing means, timing means for normally maintaining said switch closed, a cam switch, a cam driven with said resistance support for operating said cam switch momentarily to another position, means responsive to the momentary operation of said cam switch for causing said timing means to open said disabling switch and maintain it open for a predetermined period of time, and means responsive to the phase and value of said voltage when said disabling switch is open for operating said turn spacing adjustment device.

8. A resistance winding machine comprising driving means for turning a resistance support, means for feeding a wire to the support, a driving connection including a variable speed gear between said driving means and said feeding means for moving said feeding means at a predetermined adjustable speed to feed the wire to said support in a predetermined spaced-turn relation, a motor for operating said variable speed gear, means for producing a pulsating voltage varying in phase and value with the difference between the resistance of the wire wound on the support and a desired resistance up to that point, a biased-open switch connected to disable said voltage-producing means, timing means for normally maintaining said switch closed, a cam switch, a cam driven with said resistance support for operating said cam switch momentarily to another position once each revolution of said support, means responsive to the momentary operation of said cam switch for causing said timing means to open said disabling switch and maintain it open for a predetermined period of time, and means responsive to the phase and value of said voltage when said disabling switch is open for energizing said motor for adjustment of said variable-speed gear.

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9. A resistance winding machine comprising driving means for turning a resistance support, means for feeding a wire to the support, a driving connection including a variable speed gear between said driving means and said feeding means for moving said feeding means at a predetermined adjustable speed to feed the wire to said support in a predetermined spaced-turn relation, a motor for operating said variable speed gear, means for producing a pulsating voltage varying in phase and value with the difference between the resistance of the wire wound on the support and a desired resistance up to that point, a biased-open disabling switch connected to short circuit said voltage-producing means, timing means for normally maintaining said switch closed, a cam switch, a cam driven with said resistance support for operating said cam switch momentarily to another position once each revolution of said support, means responsive to the momentary operation of said cam switch for causing said timing means to open said disabling switch and maintain it open for a predetermined period of time, and means responsive to the phase and value of said voltage when said disabling switch is open for energizing said motor for forward or reverse rotation in dependence upon the phase of said voltage for adjustment of said variable-speed gear to increase or decrease the speed of said wire-feeding means for wire-turn spacing adjustment.

10. A resistance winding machine comprising driving means for turning a resistance support, means for feeding a wire to said support, a driving connection including a variable speed gear between said driving means and said feeding means for moving said feeding means at a predetermined adjustable speed to feed the wire to said support in a predetermined spaced-turn relation, a motor for operating said variable speed gear, means for producing a pulsating voltage varying in phase and value with the difference between the resistance of the wire wound on the support and a desired resistance up to that point, a biased-open disabling switch connected to short circuit said voltage-producing means, timing means for normally maintaining said switch closed, a biased-open cam switch, a cam driven with said resistance support for closing said cam switch momentarily once each revolution of said support, means responsive to the momentary closing of said cam switch for causing said timing means to open said disabling switch and maintain it open for a predetermined period of time, and means responsive to the phase and value of said voltage when said disabling switch is open for energizing said motor during said predetermined period of time for forward or reverse rotation in dependence upon the phase of said voltage for adjustment of said variable speed gear to increase or decrease the speed of said wire-feeding means for wire-turn spacing adjustment.

11. A resistance winding machine comprising driving means for turning a resistance support, means for feeding a wire to said support, a driving connection including a variable speed gear between said driving means and said feeding means for moving said feeding means at a predetermined adjustable speed to feed the wire to said support in a predetermined spaced turn relation, a motor for operating said variable speed gear, means for producing a pulsating voltage varying in phase and value with the difference between the resistance of the wire wound on the support

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and a desired resistance up to that point, means for amplifying said voltage, means for limiting said amplified voltage to a predetermined maximum value, a biased open disabling switch connected to short circuit said voltage-limiting means, a coil for closing said switch, electronic timing means for normally energizing said coil to maintain said switch closed, a biased open cam switch, a cam driven with said resistance support for closing said cam switch momentarily once each revolution of said support, means responsive to the momentary closing of said cam switch for causing said timing means to deenergize said coil for a predetermined period of time thereby to open said disabling switch and maintain it open for a predetermined period of time, and means responsive to the phase and value of said voltage when said disabling switch is open for energizing said motor for forward or reverse rotation in dependence upon the phase of said voltage and at a speed depending upon the value of said voltage for adjustment of said variable speed gear to increase or decrease the speed of said wire-feeding means for wire turn spacing adjustment.

12. A resistance winding machine comprising driving means for turning a resistance support, means for feeding a wire to the support, a driving connection including a variable-speed gear between said driving means and said feeding means for moving said feeding means at a predetermined adjustable speed to feed the wire to said support in a predetermined spaced turn relation, an incremental turn spacing adjustment device included in said driving connection for momentarily increasing the speed of said feeding means so as to increase the spacing of the wire turn being wound, means for producing a pulsating voltage varying in phase and value with the difference between the resistance wound on the support and a desired resistance up to that point, a first biased open disabling switch connected to short circuit said voltage producing means, a cam driven with said support for closing said

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disabling switch during a predetermined period of each revolution of said support, means responsive to a predetermined polarity of said voltage when said disabling switch is open for operating said turn spacing adjustment device to increase the spacing of each turn as it is wound, a second biased-open disabling switch connected to short circuit said voltage producing means, a coil for closing said second disabling switch, electronic timing means for normally energizing said coil to maintain said switch closed, a biased open cam switch, a cam driven with said resistance support for closing said cam switch momentarily once each revolution of said support substantially simultaneously with the opening of said first disabling switch, means responsive to the momentary closing of said cam switch for causing said timing means to deenergize said coil for a predetermined period of time thereby to open said second disabling switch and maintain it open for a predetermined period of time, and means responsive to the phase and a predetermined minimum value of said voltage when said disabling switch is open for energizing said motor during said predetermined period of time for forward or reverse rotation in dependence upon the phase of said voltage and at a speed depending upon the value of said voltage for adjustment of said variable speed gear to increase or decrease the speed of said wire feeding means thereby to maintain the winding rate too high.

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