March 26, 1963 R. E. FREDERICK 3,082,966

COIL WINDING MACHINE

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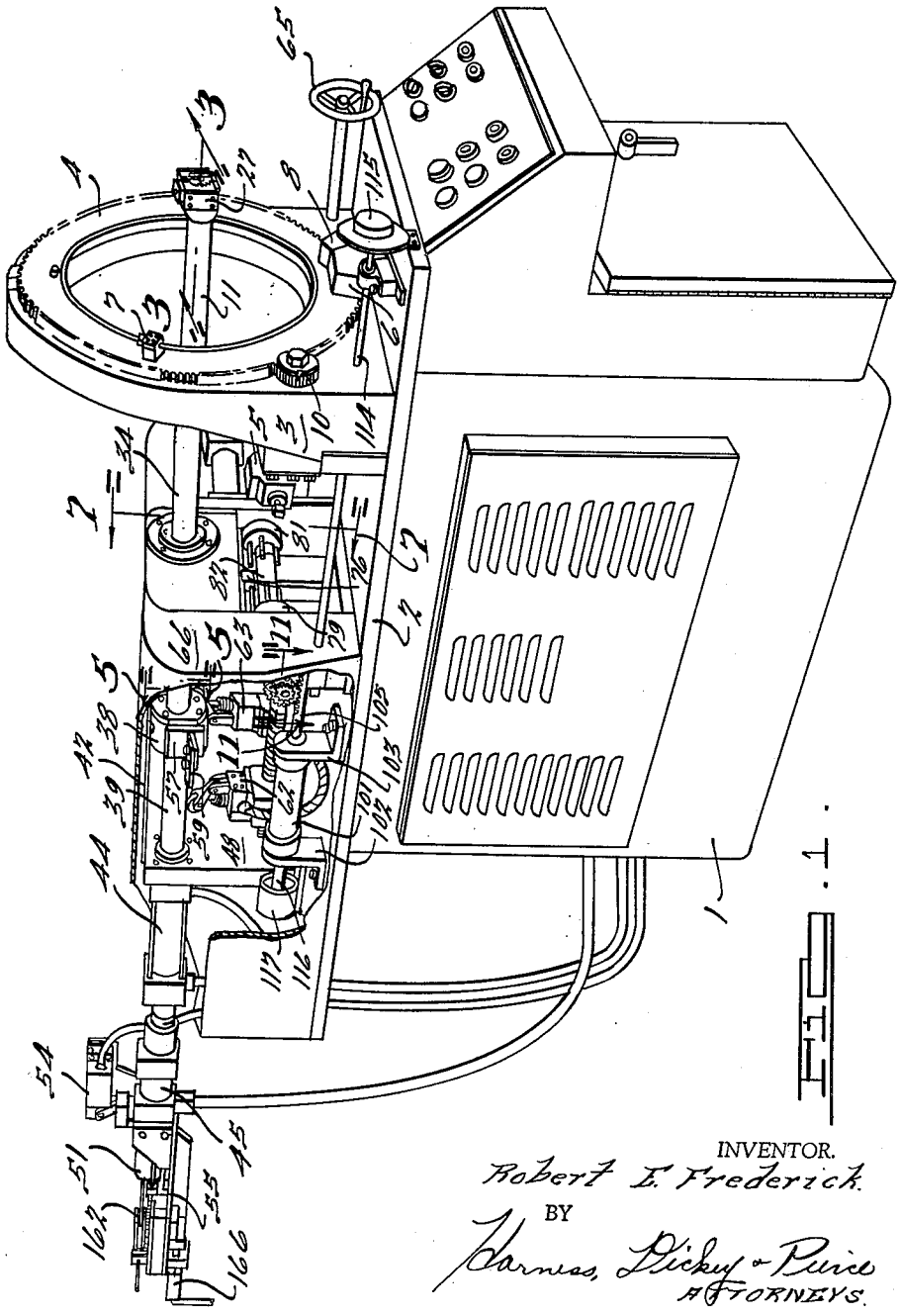


FIG. 1.

INVENTOR.
Robert E. Frederick.
BY
Harness, Dickey & Pierce
ATTORNEYS.

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COIL WINDING MACHINE

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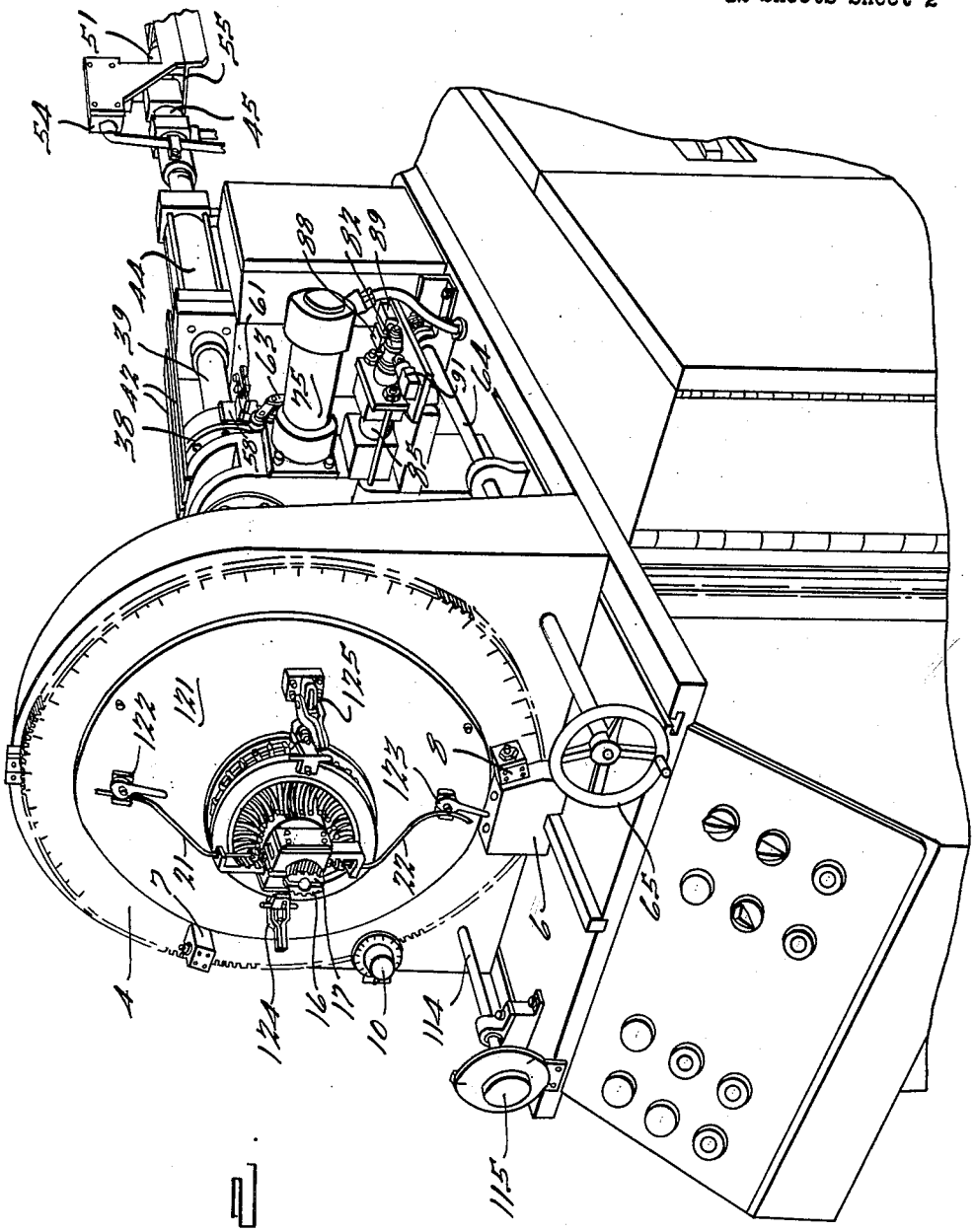


FIG. 1

INVENTOR.
Robert E. Frederick
BY
Harness, Dickey & Pierce.
ATTORNEYS.

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COIL WINDING MACHINE

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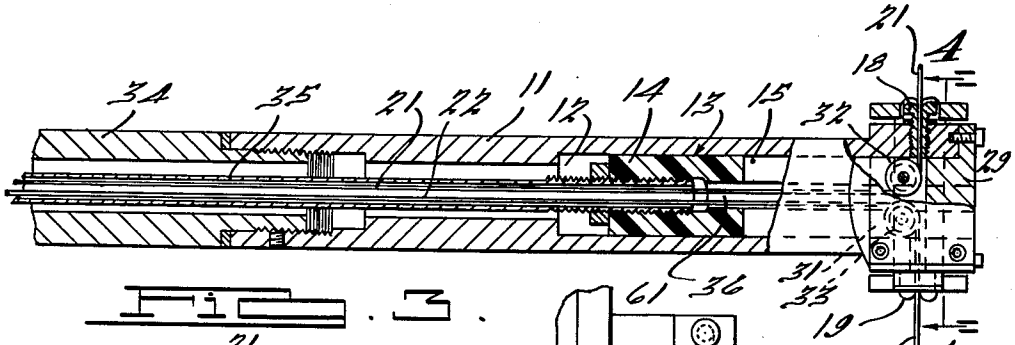


FIG. 3.

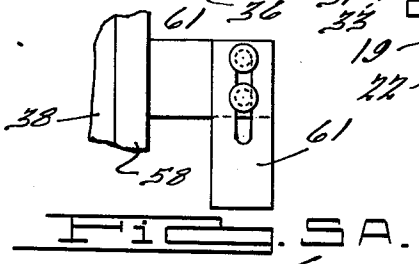


FIG. 5A.

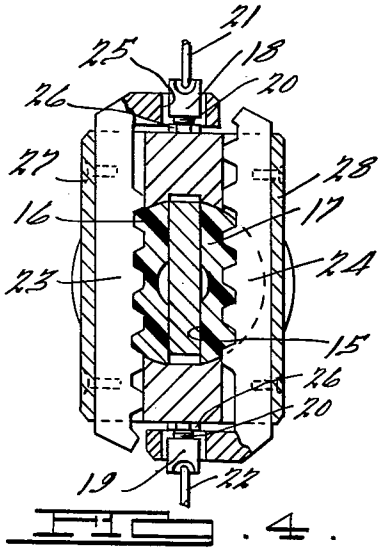


FIG. 4.

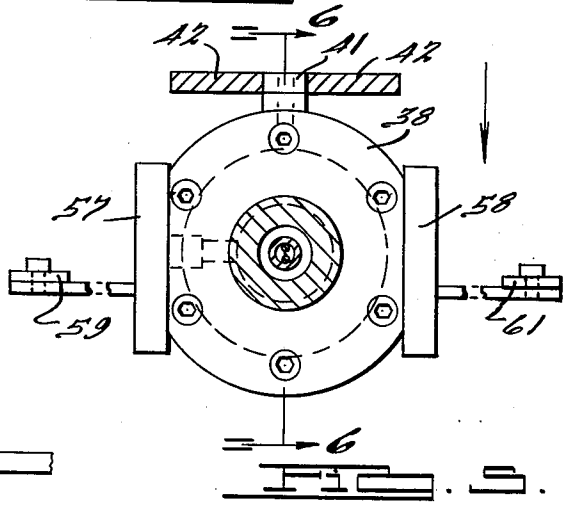


FIG. 5.

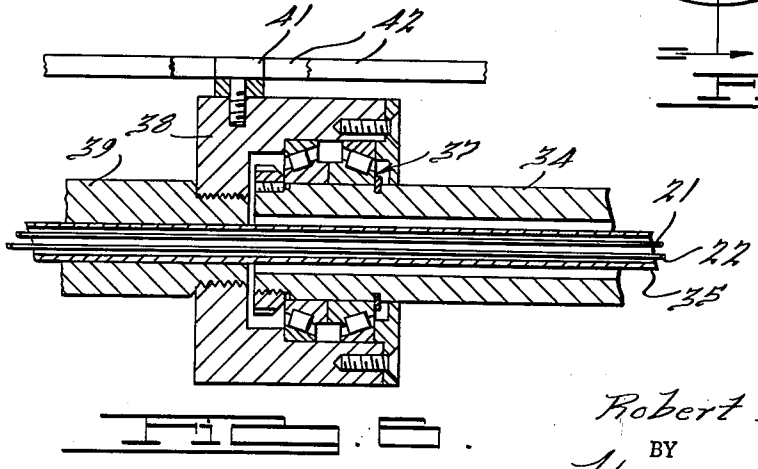


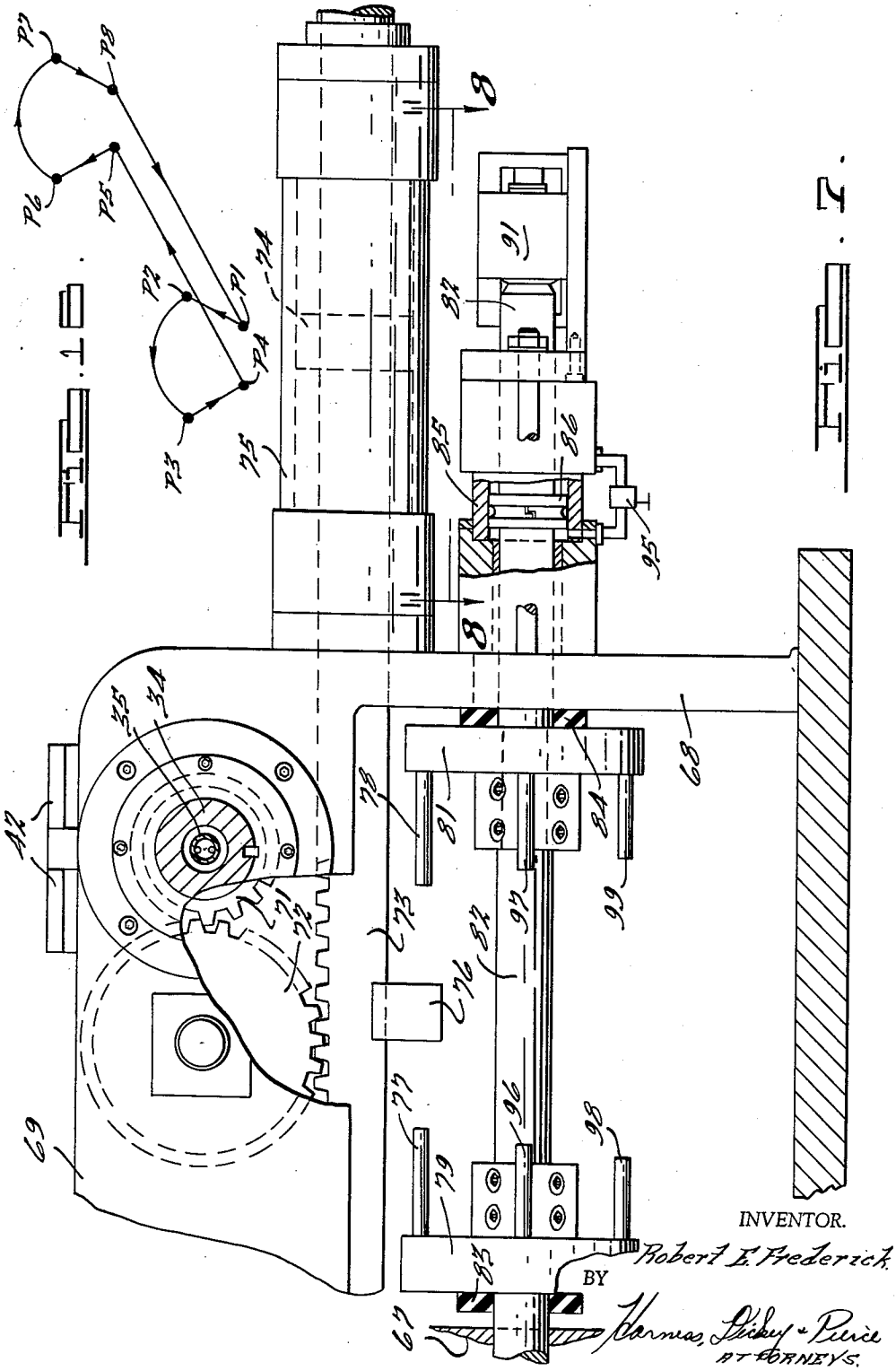
FIG. 6.

INVENTOR.
Robert E. Frederick.
BY
Harness, Dickey & Pierce.
ATTORNEYS.

March 26, 1963 R. E. FREDERICK 3,082,966

COIL WINDING MACHINE

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INVENTOR.
Robert E. Frederick
BY
Harness, Dickey & Pierce
ATTORNEYS.

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COIL WINDING MACHINE

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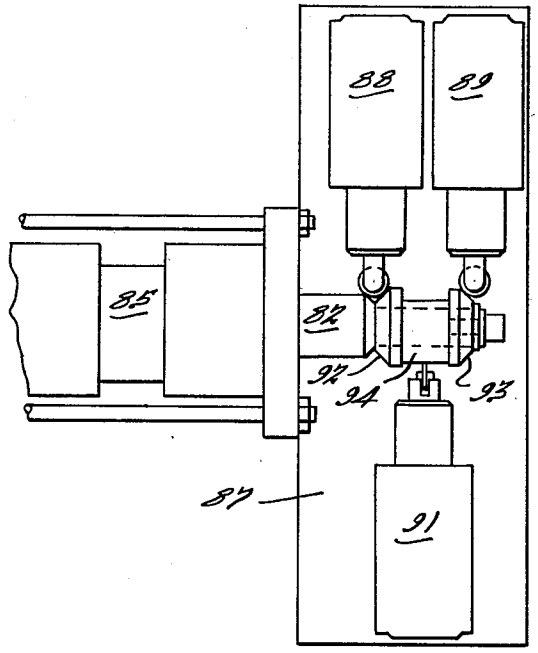


Fig. 8.

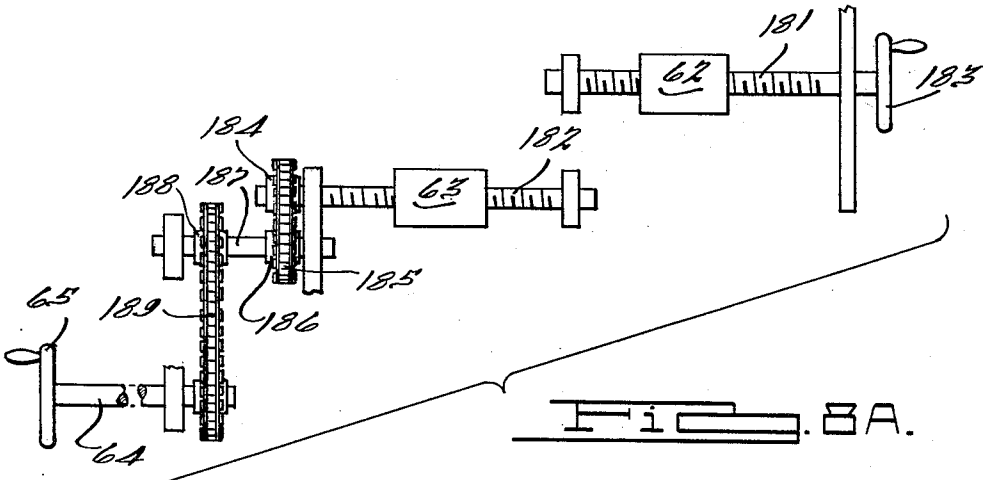


Fig. 8A.

INVENTOR.
Robert E. Frederick
BY
Harness, Dickey & Pierce,
ATTORNEYS.

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COIL WINDING MACHINE

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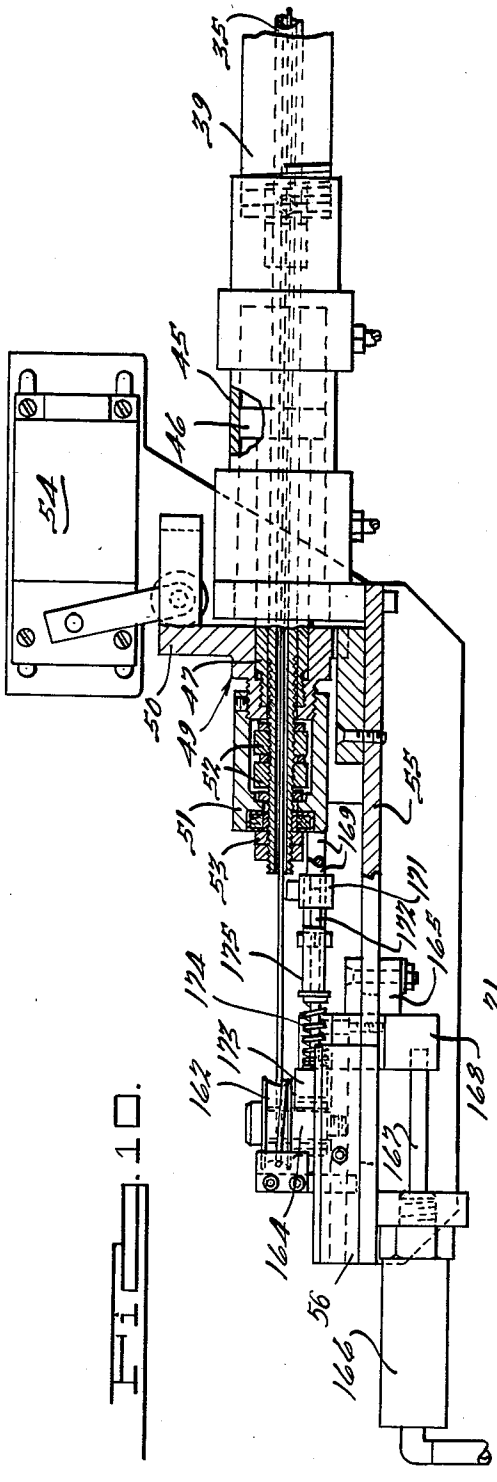


FIG. 10.

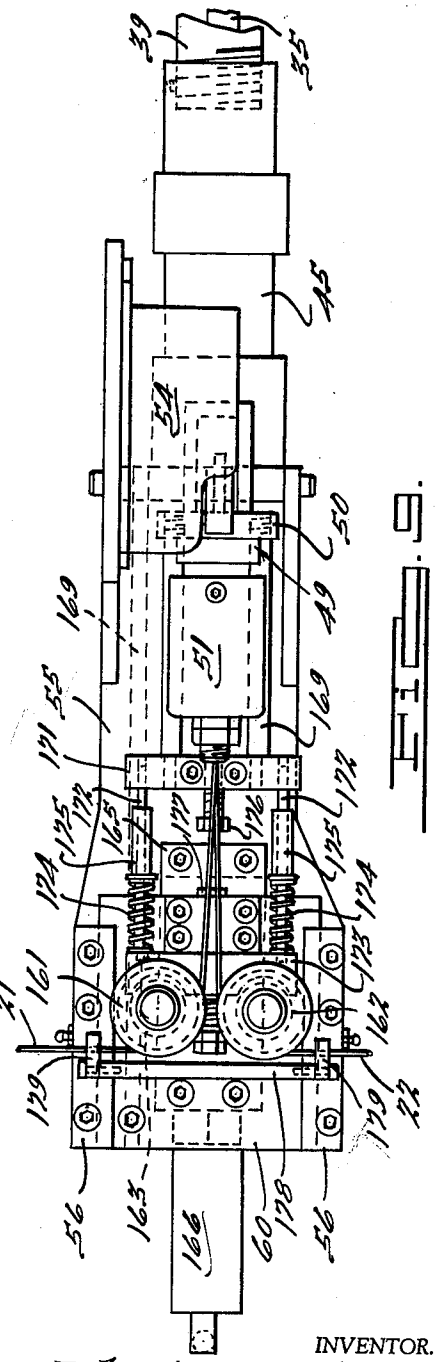


FIG. 9.

INVENTOR.
Robert E. Frederick
BY
Harness, Dickey & Pierce
ATTORNEYS.

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COIL WINDING MACHINE

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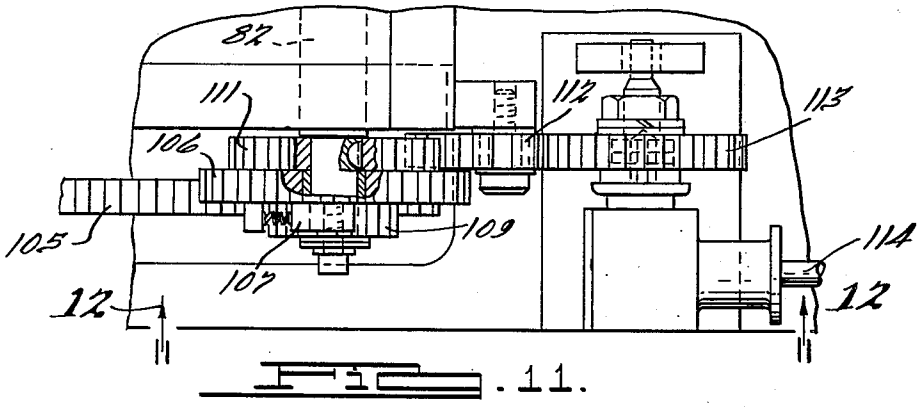


FIG. 11.

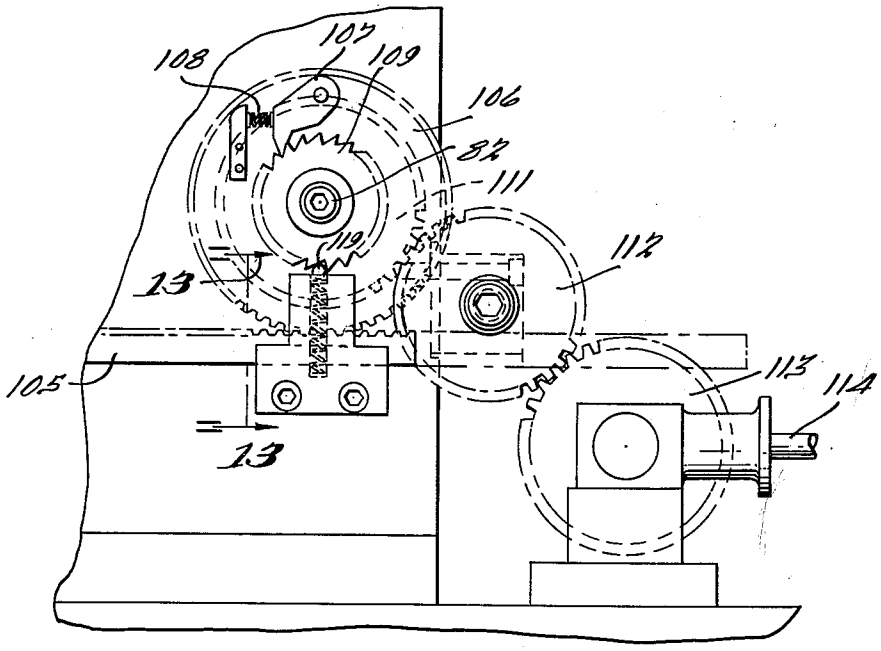


FIG. 12.

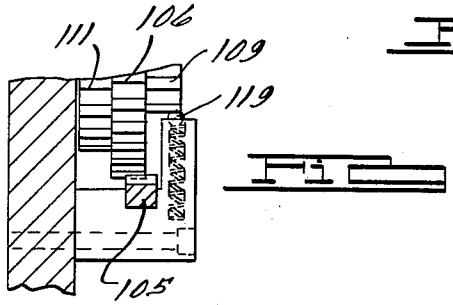


FIG. 13.

INVENTOR.
Robert E. Frederick
BY
Harness, Dickey & Pierce
ATTORNEYS.

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COIL WINDING MACHINE

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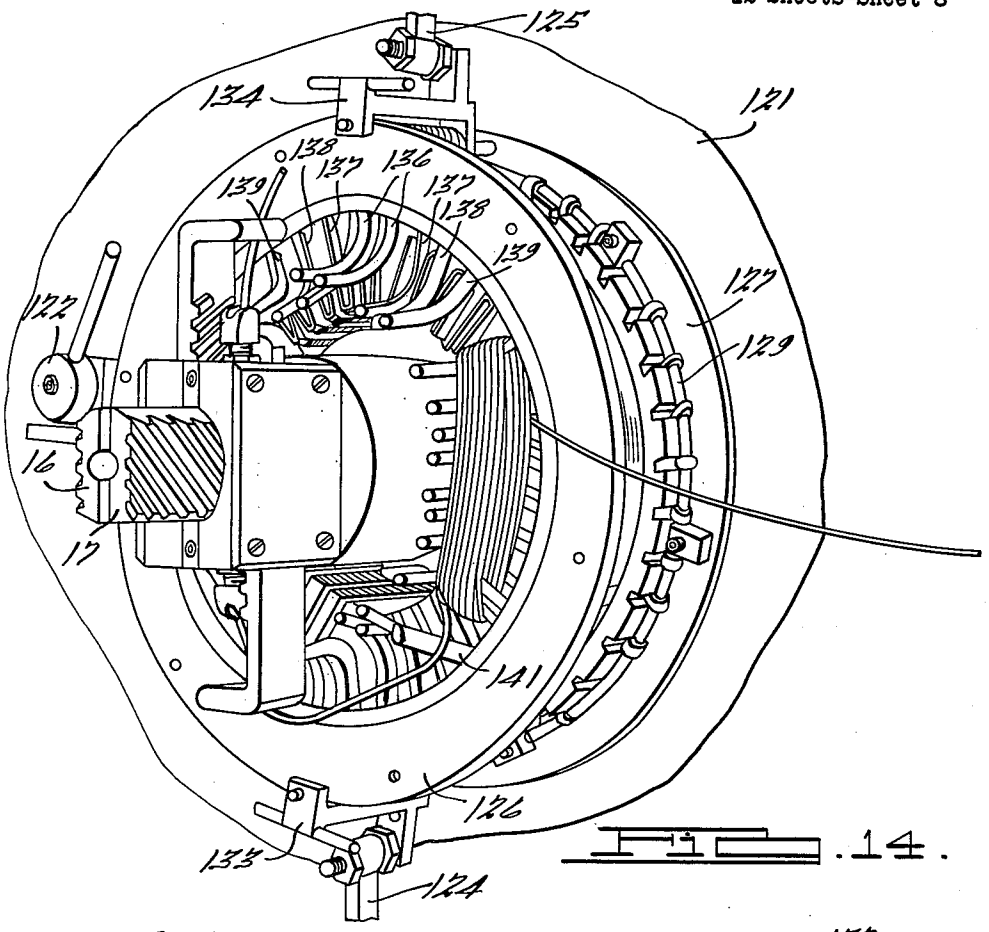


FIG. 14.

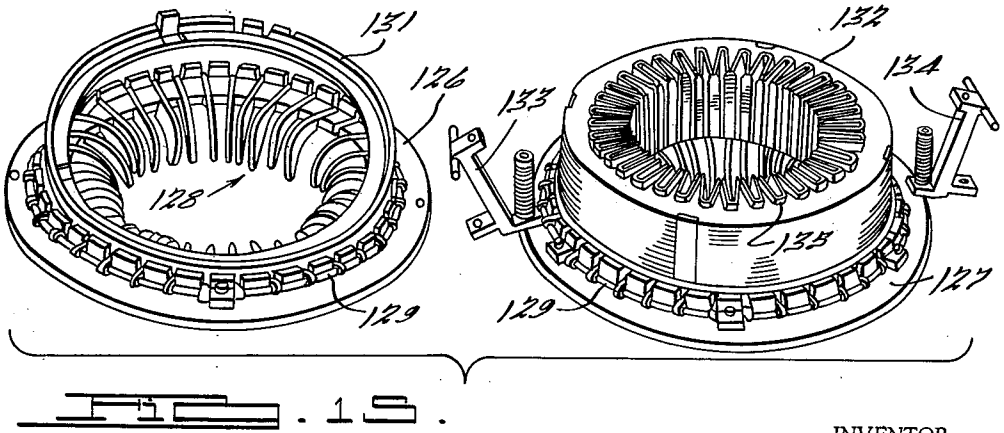


FIG. 15.

INVENTOR.
Robert E. Frederick
BY
Harness, Dickey & Pierce
ATTORNEYS.

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COIL WINDING MACHINE

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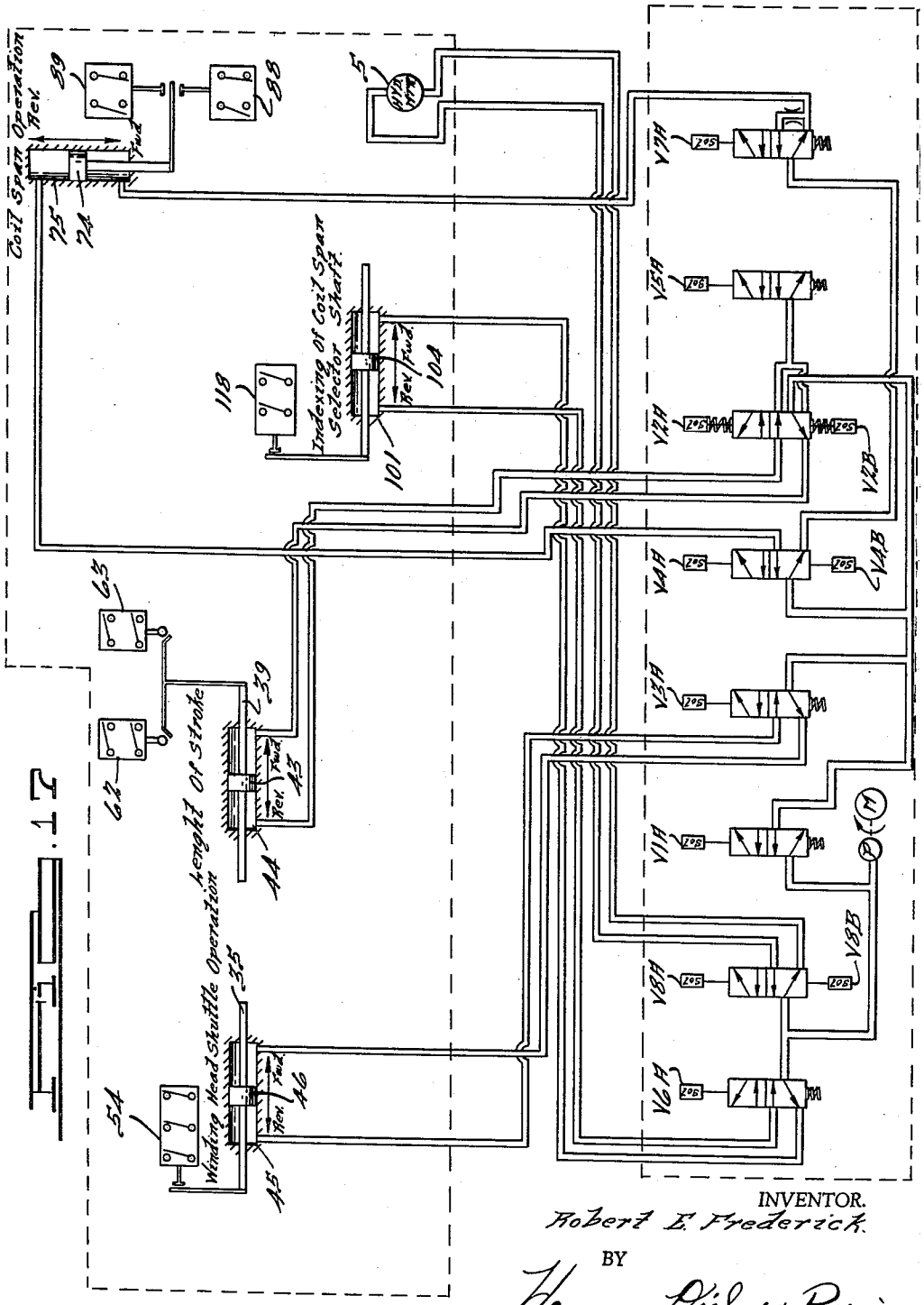


FIG. 1.

INVENTOR.
Robert E. Frederick
BY
Harness, Dickey & Pierce
ATTORNEYS

March 26, 1963 R. E. FREDERICK 3,082,966

COIL WINDING MACHINE

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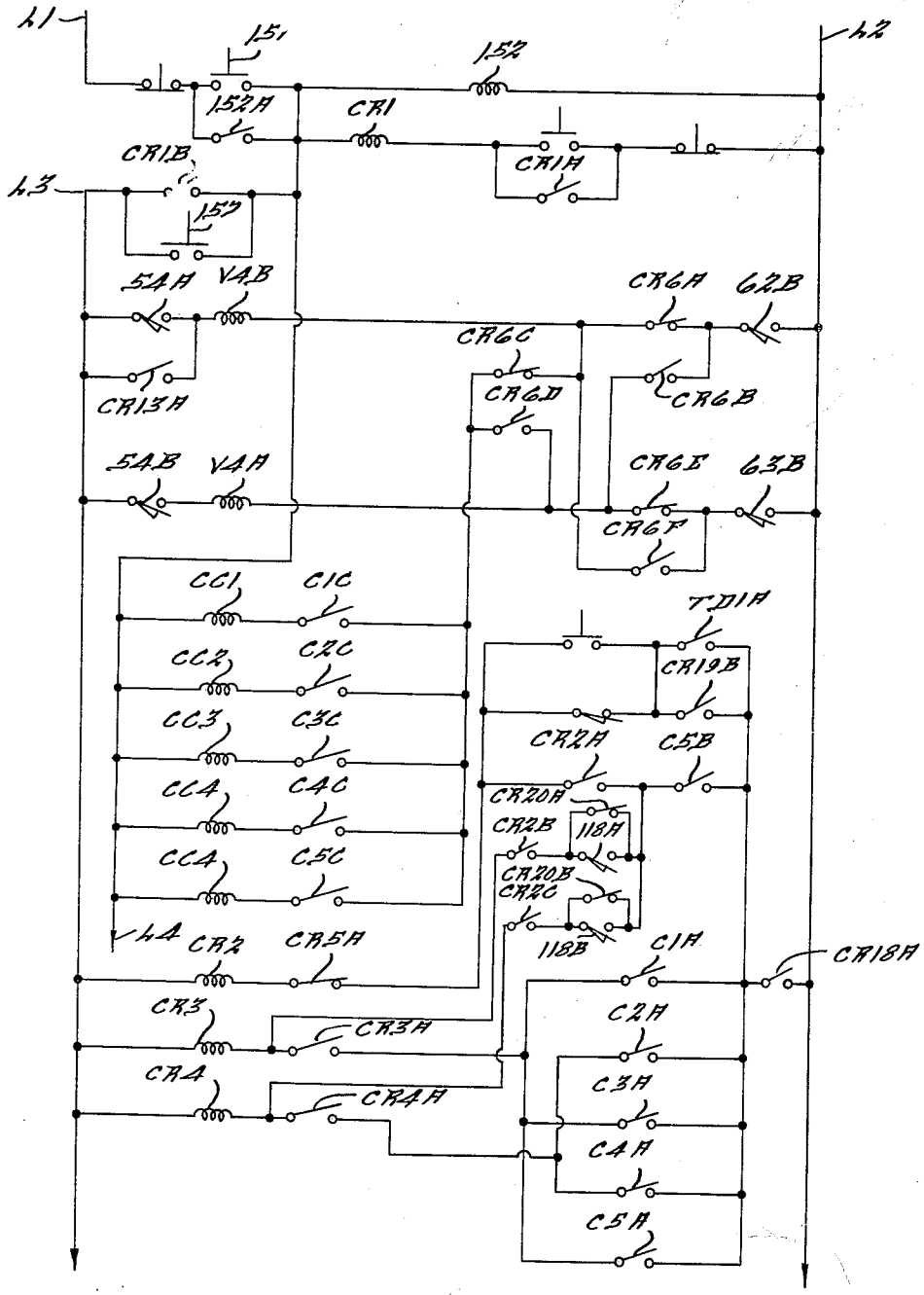


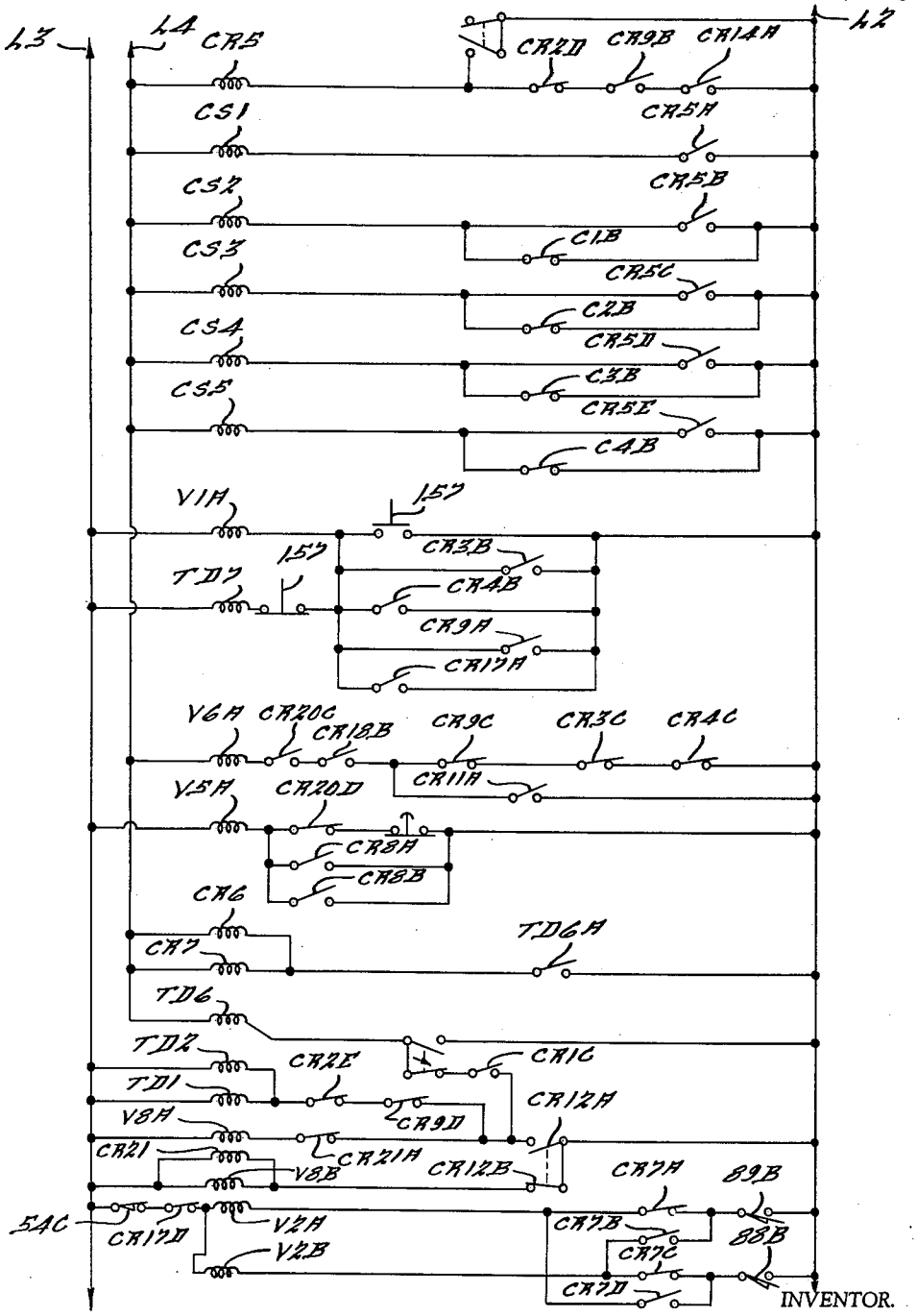
FIG. 10.

INVENTOR.
Robert E. Frederick
BY
Harness, Dickey & Pierce,
ATTORNEYS.

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COIL WINDING MACHINE

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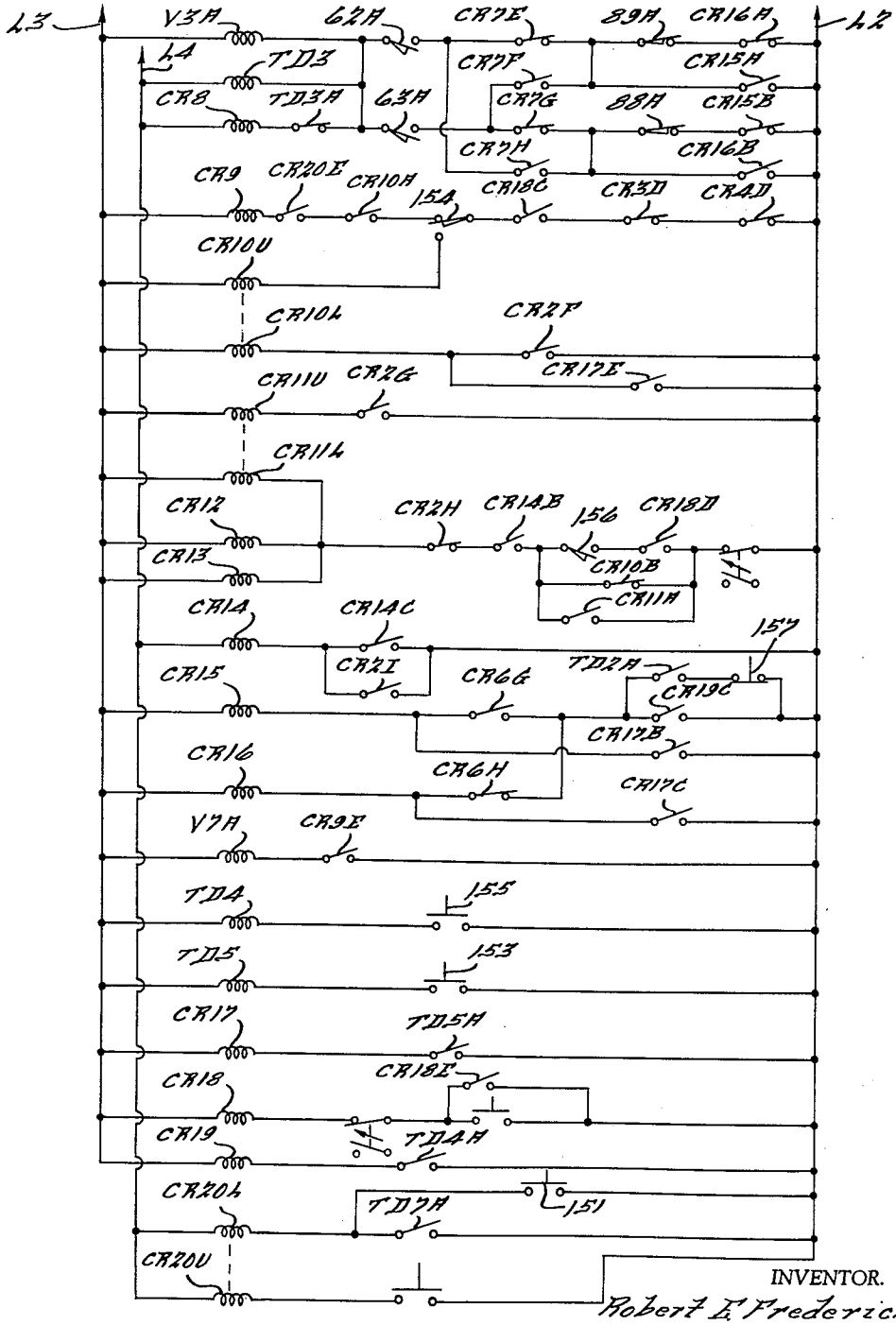
INVENTOR.
Robert E. Frederick
BY
Harness, Dickey & Pierce
ATTORNEYS.

FIG. 19.

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COIL WINDING MACHINE

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INVENTOR.
Robert E. Frederick
BY
Harness, Dickey & Pierce
ATTORNEYS.

Fig. 20.

United States Patent Office 3,082,966
Patented Mar. 26, 1963

3,082,966

COIL WINDING MACHINE

Robert E. Frederick, Detroit, Mich., assignor to Link Engineering Company, Detroit, Mich., a corporation of Michigan

Filed Jan. 15, 1958, Ser. No. 709,150
21 Claims. (Cl. 242—1.1)

This invention relates to machines for winding the electrical coils of alternating current motors and generators in place in magnetic core members.

It is an object of the invention to provide an improved machine for continuously winding multiple coils along the external or internal periphery of cylindrical or annular magnetic armature and field structures.

A specific object of the invention is to provide an improved coil winding machine for winding multiple energizing coils within the slots of the stator of an alternating current motor.

A further object of the invention is to provide an improved coil winding machine in accordance with the preceding objects which will automatically deposit within the stator slots the desired number of windings and with the proper angular displacement of the individual coils and which produces a continuous multipolar winding with the correct winding direction to provide alternate poles of different polarity.

Another object of the invention is the provision of a coil winding machine in accordance with the preceding objects in which there is provided improved means for indexing the wire feeder with respect to the magnetic core in which the wire is to be laid, both with respect to the slots of the multiple coils of individual poles and with respect to the different poles of the magnetic structure.

Another object of the invention is to provide in a coil winding machine an improved loading fixture in which the magnetic core structure is mounted and in which are hingedly mounted a plurality of wire guide fingers for forming and retaining the end loops of the coil windings, with the fingers easily removable after the winding operation is completed.

Another object of the invention is the provision of an improved coil winding machine for winding multiple coils into the slots of magnetizable cores having wire feeders for the coils provided with tension control means cyclically operated to permit free wire feed in forming the coil end loops and applying wire tension in the laying stroke to insure tightening of the coil end loops.

Other objects and features of the invention will be readily apparent to those skilled in the art from the following specification and attached drawings in which:

FIGURE 1 is a perspective view of a coil winding machine according to this invention;

FIG. 2 is a partial perspective view from the side opposite to FIG. 1 showing a stator core loaded in the machine in position to begin the coil winding operation;

FIG. 3 is a sectional view through the winding head and its drive shaft along the line 3—3 of FIG. 1;

FIG. 4 is a detail sectional view on the line 4—4 of FIG. 3;

FIG. 5 is a detail sectional view through the winding head drive shaft along the line 5—5 of FIG. 1;

FIG. 5A is a partial plan view showing a detail of FIG. 5;

FIG. 6 is a detail sectional view along the line 6—6 of FIG. 5;

FIG. 7 is a sectional view on the line 7—7 of FIG. 1 showing the mechanism for rotating the drive shaft for the winding head and indexing its extreme positions for varying coil spans;

FIG. 8 is a detail view from the line 8—8 of FIG. 7

showing control elements for the winding head rotation;

FIG. 8A is a detail representation of the stroke adjustment;

FIG. 9 is a detail plan view adjacent the end of the drive shaft opposite to the winding head;

FIG. 10 is a side elevational view of the elements of FIG. 9 with certain parts shown in section;

FIG. 11 is a detail plan view on the line 11—11 of FIG. 1 showing the coil span selecting mechanism;

FIG. 12 is a side elevational view of the mechanism of FIG. 11;

FIG. 13 is a detail sectional view on the line 13—13 of FIG. 12;

FIG. 14 is a perspective view showing the stator ring and its loading fixture in its mounted position relative to the winding head and showing the relation of one of the winding guide needles and its shuttle to the stator core after completion of the winding for one pole and the indexing of the stator into position for winding of the adjacent pole;

FIG. 15 is a perspective view showing separated parts of the loading fixture and wire guide fingers for the stator core;

FIG. 16 is a schematic representation of the path transcribed by the upper shuttle of the winding head;

FIG. 17 is a diagrammatic representation of the hydraulic circuit for the machine; and

FIGS. 18, 19 and 20 are continuing drawings showing the electrical circuit diagram for the machine.

The coil winding machine of this invention in the embodiment specifically illustrated comprises a supporting base structure 1 within which are suitably enclosed the various control elements of the machine including a source of hydraulic pressure and the various solenoid operated valves, counters and relays used to control the various machine movements in an operating cycle. Upon the supporting base 1 is mounted a table 2 carrying adjacent its forward end a stationary arbor 3 within which is rotatably mounted a ring gear 4 adapted to be rotated in opposite directions by means of a hydraulic motor 5 suitably geared to the ring 4. In front of the arbor 3 a stationary stop 6 is mounted on the table 2 and upon the front face of the ring gear 4 are mounted stops 7 and 8 adapted to engage the opposite faces of the stop 6 as the hydraulic motor 5 rotates in opposite directions so as to index the stator for the winding of alternate poles therein. As illustrated in the drawings, the stator is designed to have four electrical poles therein and, accordingly, the stops 7 and 8 are arranged to index the annular ring 4 in two positions 90° apart. An indicator 10 is geared to ring gear 4 to indicate stator position. This rotation of the stator, it is understood, occurs only after the completion of the winding of an opposite pair of poles, with the stator remaining stationary during the winding operation, the relative movement of the wire and stator during the winding of any pair of poles being effected solely by appropriate movement of the winding head and its shuttles, to be hereinafter described.

The wire winding head and its operating shaft are shown in its shuttle retracted position in FIGS. 1, 3 and 4 and with the shuttles extended in FIGS. 2 and 14. The winding head is mounted upon a hollow shaft 11 having an internal bore 12 in its free end. Within the bore 12 is disposed a reciprocable rack 13 of molded plastic formed with a cylindrical rearward portion 14 and a forward portion formed with a central slot 15 dividing a pair of oppositely facing legs 16 and 17. The exterior of the free end of the shaft 11 is formed in a generally rectangular boxlike construction and threaded into the top and bottom walls thereof are wire guide needles 18 and 19 through which extend the wires 21 and 22 to be wound into coils about the opposed electrical poles within the

stator core. The opposite side walls of the box end of the shaft 11 are provided with notches or slots in which are disposed the L-shaped shuttles 23 and 24 having interior teeth surfaces on one arm meshing with teeth in the legs 16 and 17 of the rack 13. The arms of the shuttles 23 and 24 disposed at right angles to the arms containing the teeth are provided with an aperture 25, the wall portion of which surrounding the guide needles 18 when the shuttles are retracted as clearly illustrated in FIG. 4. The threaded studs 20 of the guide needles 18 and 19 have jamb nuts 26 thereon which secure the needles in adjusted position. The shuttles 23 and 24 are maintained in place within the winding head by removable face plates 27 and 28.

On the end face of the shaft 11 and extending within the slot 15 is a T-shaped member 29 having in its inner end a slot 31 within which are rotatably mounted a pair of rollers 32 and 33 about which the wires 21 and 22 are fed. The rear end of shaft 11 is rigidly mounted on and supported by a second shaft 34 and both shafts 11 and 34 are provided with central bores through which freely extends a tube 35 rigidly connected at its forward end of the cylindrical portion 14 of the rack 13, the wires 21 and 22 extending through the tube 35 and a central bore 36 of the rack 13 to the rollers 32 and 33.

It will be understood that the cooperating teeth on the shuttles 23 and 24 and the rack legs 16 and 17 are arranged so that movement of the rack 13 forwardly from the position of FIGS. 3 and 4 into the position of FIG. 14 is accompanied by an extension of the shuttles 23 and 24 in opposite directions as shown in FIGS. 2 and 14.

The rearward end of the shaft 34 is mounted for free rotation within a bearing 37 mounted within a housing 38, rigidly connected to the end of a shaft 39. At the top of the housing 38 is disposed a roller 41 received in the slot between a pair of rigid strips 42 which prevent rotation of the shaft 39 and housing 38 while permitting free reciprocal movement thereof. Rearwardly of the housing 38 the shaft 39 is connected to a piston 43 disposed within an operating cylinder 44 rigidly mounted on a support 48 on the table 2.

Referring more particularly to FIGS. 9 and 10, shaft 39 extends through the cylinder 44 and carries on its end a hydraulic operating cylinder 45 having therein a piston 46 connected to a hollow operating shaft 47 which extends rearwardly of the cylinder 45 and has threaded thereon a bracket 49. An arm 50 extends upwardly from bracket 49 to engage the operating roller of a limit switch 54 mounted on the cylinder 45. Threaded on the bracket 49 is a housing 51, with the tube 35 extending through the cylinder 45, piston 46, shaft 47, bracket 49 and housing 51. Interiorly of the housing 51 a pair of adjusting nuts 52 and suitable spacing bearing washers shown in FIG. 10 serve to connect the tube 35 to the housing 51 and its connected parts for common reciprocating movement while permitting free rotating movement of the tube 35 relative to the housing 51. Locking nuts 53 and an oil seal complete the assembly.

Also mounted on the cylinder 45 is a shelf 55 carrying a guide 56 along which bracket 49 slides. Rearwardly of the shelf 55 and at opposite sides thereof are mounted a pair of ways 56 within which is slidably mounted a platform 60. A pair of feed rollers 161 and 162 having integral hubs 163 and 164, respectively, are rotatably mounted on platform 60 and wires 21 and 22 are fed around the rollers 161 and 162 into the open end of tube 35. Rigidly mounted on the shelf 55 are an adjustable stop 165 and a hydraulic cylinder 166 having a piston operated shaft 167 rigidly connected to a block 168 depending from the platform 60, cylinder 166 serving to normally bias the platform forwardly against the stop 165.

Rigidly mounted on the bracket 49 are a pair of rods 169 supporting a cross block 171 through which freely slide a pair of rods 172 mounted at their opposite ends in a brake block 173 adapted to press against the hubs 163 and 164 of rollers 161 and 162. About the rods 172 are disposed springs 174 and tubes 175, the tubes 175 being engaged by block 171 to apply pressure between brake block 173 and hubs 163 and 164 through the springs 174. An adjustable stud 176 on the block 171 is engageable with an abutment 177 on the platform 60. A bracket 178 carries a pair of side plates 179 having openings therein through which the wires 21 and 22 are fed to the feed rollers 161 and 162.

The apparatus just described provides for the proper tension on the wires 21 and 22 in the winding stroke with the shuttles 23 and 24 retracted and insures the pulling tight of the wire loop at the coil ends after the shuttles are retracted. It can be seen that as the piston 46 and tube 35 move rearwardly to retract the shuttles the cross block 171 will move rearwardly to engage tubes 175 and compress springs 174 to bias the braking block 173 against the hubs 163 and 164 and apply a drag against rotation of the rollers 161 and 162. At the extreme of movement of block 171 the stud 176 engages abutment 177 and moves the platform 60 against the bias of the cylinder 166. The frictional drag on the wire feed rollers ensures that the wire end loops will be pulled tight during the stroke of the wire winding head. The wire tension effected by the drag may be adjusted by a selection of the strength of springs 174, length of tubes 175, positions of stop 165 and stud 176 or a combination of them.

The housing 38 is provided with opposite side plates 57 and 58 carrying horizontal fingers on which are adjustably mounted cams 59 and 61 (FIG. 5) adapted to engage the operating rollers of a pair of limit switches 62 and 63 which are normally stationary in the operation of the machine but which may be adjustably moved toward and away from each other by the mechanism shown in detail in FIG. 2A. Here the limit switches are indicated by block diagram at 62 and 63 as adjustably mounted on lead screws 181 and 182. Lead screw 181 extends rearwardly of the machine and carries a rotatable hand wheel 183. Lead screw 182 carries a sprocket 184 engaged with a chain 185 which also engages a sprocket 186 on an idler shaft 187 which carries a second sprocket 188 connected through a chain 189 with a sprocket 191 on a shaft 64 extending to the front of the machine and there carrying a hand wheel 65. The position of limit switch 62 will determine the extreme rearward position of the wire winding head and the position of the limit switch 63 the extreme forward position of the head. These extreme positions are also influenced by the positions of the adjustable cams 59 and 61.

The spacing between the cams 59 and 61 and the limit switches 62 and 63 axially of the shafts 34 and 39 will determine the length of stroke of the wire winding head.

There will now be described the mechanism for oscillaing the winding head at the opposite ends of its stroke to effect the coil span and form the end loops of the wire turns. This is with particular reference to FIGS. 1, 2, 7 and 8. Generally centrally of the table 2 is mounted an elongated U-shaped supporting member 66 having opposite legs 67 and 68 and a hollow bight 69. Through the bight 69 extends the operating shaft 34 and the tube 35, and within the bight 69 is disposed a gear wheel 71 keyed on the shaft 34 so as to be rotatable therewith but permitting axial movement of the shaft 34 relative thereto. Meshing with the gear 71 is a pinion 72 which in turn meshes with the teeth of a horizontal rack 73 mounted in the U-shaped member 66 for reciprocating movement transversely of the axis of the shaft 34. The rack 73 is connected to a piston 74 disposed within an operating cylinder 75 rigidly mounted on the support 66. Rigidly mounted on the rack 73 and depending therefrom is a dog 76 by which the extreme positions of movement of the rack 73 are determined through engagement of the dog 76 with opposite pins 77 and 78 supported within holders 79 and 81, respectively, rigidly mounted upon a shaft 82 which extends between the legs 67 and 68 of the U-shaped member 66 so as to be both rotatable and

reciprocable relative thereto. Between the outer faces of the holders 79 and 81 and the legs 67 and 68 are disposed bumpers 83 and 84 of a shock absorbing material, such as molded nylon.

Upon the outer face of the leg 68 of the support 66 is rigidly secured a cylinder 85 through which extends the shaft 82, being connected to a piston 86 therein. Upon the free end of the cylinder structure 85 is mounted a shelf 87 carrying a plurality of limit switches 88, 89 and 91. The limit switches 88 and 89 are operated by reciprocating cam surfaces 92 and 93, respectively, adjacent to the end of shaft 82, while the limit switch 91 is operated by a rotating cam surface adjacent the end of shaft 82, such as shown at 94. The opposite ends of the cylinder 85, at opposite sides of the piston 86, are interconnected through an adjustable restricting valve 95 so that the fluid within the cylinder acts as a snubber in the oscillation of the shaft 35 and the wire winding head. It will thus be seen that as the piston 74 is moved in opposite directions by hydraulic pressure, the reciprocation of the rack 73 to effect oscillation of the shaft 34 will be limited by engagement of the dog 76 with the opposite span stop pins 77 and 78, and that in this movement the shaft 82 is given a limited axial movement until the bumpers 83 and 84 engage the opposite legs 67 and 68 of the support 66, this movement of the shaft 82 being sufficient to effect operation of the limit switches 88 and 89 to reverse the throw.

Each polar winding of the stator is formed of a plurality of coils of varying span which are disposed within the slots which extend transversely of the annular core and are spaced circumferentially about its inner surface. To secure the varying coil span, the shaft 34 is oscillated varying distances determined by the length of the coil span stop pins. In addition to the opposite pins 77 and 78, the drawings show additional pairs at 96, 97 and 98, 99. As one coil is completed the shaft 82 is rotated through a sufficient angle to present the next pair of stop pins in alignment with the dog 76 on the rack 73. The mechanism for effecting this rotation of the shaft 82 is shown more particularly in FIGS. 11, 12 and 13, considered with relation to the general showing of FIG. 1. A hydraulic operating cylinder 101 is stationarily mounted between a pair of brackets 102, 103, supported on the table 2 rearwardly of the leg 67 of the support 66. To the operating piston 104 (FIG. 17) within the cylinder 101 is connected a rack 105 meshing with a gear wheel 106 freely rotatable upon the shaft 82. Upon the face of the gear wheel 106 is pivotally mounted a pawl 107 biased by a spring 108 into engagement with the peripheral teeth of a gear wheel 109 keyed to the shaft 82. Also keyed to the shaft 82 is a gear 111 connected through a pinion 112 with a gear 113 rotatably by a shaft 114 terminating in an adjusting knob 115 at the front of the machine. The piston 104 within the cylinder 101 is connected at the end opposite the rack 105 to a shaft 116 on which is threaded a head 117 forming an adjustable stop limiting the movement of rack 105 to that which will effect the proper rotation of shaft 82 to index the succeeding pairs of stop pins with the dog 76. A limit switch 118 (FIG. 17) is operated by the piston 104 at the end of its span changing stroke.

At the beginning of a winding operation the knob 115 is rotated manually to rotate the shaft 82 into start position with the longest pair of coil span stop pins 77 and 78 indexed with the dog 76. In this respect a safety feature is provided by the limit switch 91 which must be in properly operated position with respect to the cam surface on the shaft 82 to enable the winding operation to be started. Rotation of knob 115 will rotate shaft 114 to effect rotation of gear 113 which, from FIGS. 11, 12 and 13, will effect rotation of gear wheel 111 through pinion 112 to rotate the shaft 82. The shaft 82 will be held in its adjusted position by the action of a spring pressed ball 119 in the teeth of gear wheel 109. As the shaft 82 is rotated by the gear wheel 111, gear 109, which is also keyed to shaft 82, rotates therewith and rotates relative to the gear wheel 106 which remains stationary as the teeth on gear 109 pass freely under the pawl 107. The rack 105 is at this time in its retracted position, as shown in full lines in FIG. 12, and movement of the rack 105 into extended position will rotate shaft 82 to index another pair of coil span stop pins with the dog 76 since rotation of the gear wheel 106 effects rotation of the gear 109 and shaft 82 through engagement of the pawl 107 with the peripheral teeth on the gear wheel 109. Upon reverse movement of the rack 105 in retracting direction, gear 106 rotates in reverse but the gear 109 remains stationary with the pawl 107 slipping freely past its teeth.

The mounting of the stator core upon which the machine is to operate will be described in connection with FIGS. 2, 14 and 15. Rigidly mounted on the gear ring 4 at the front of the machine is an adapter plate 121 having a central opening of a size to receive the particular stator core to be wound. Upon the front face of the plate 121 are a pair of wire clamps 122 and 123 and a pair of quick release fixture clamps 124 and 125. The fixture holding the stator core is shown partially disassembled in FIG. 15 and is comprised of front and rear annular plates 126 and 127 which carry wire guide fingers 128 pivotally mounted with respect thereto within rings 129. Upon each of the annular plates 126, 127 is mounted an adapter ring 131 and the stator core at 132 is clamped between the front and rear adapter rings 131 by means of quick release clamps 133 and 134 mounted on the rear annular plate 127 and engaging the front face of the front annular plate 126 in clamping relation. The rings 131 serve to hold the wire guide fingers 128 in their extended positions and to prevent rotation of the fingers relative to their supporting plates while the fixture is assembled. Before assembly of the stator core in the fixture, the slots therein are provided with insulating liners as at 135 into which the wire coils are wound. The wire guide fingers 128 serve to form the coil end loops at the opposite sides of the stator and are provided with a configuration to facilitate disassembly of the fixture from the stator core after the windings are completed. This can perhaps best be seen with respect to the pole shown at the top of FIG. 14. Here the pairs of fingers 136 form the end loops for the shortest span coil and will of course also receive all of the other coils of that stator pole. These fingers have the greatest axial length and are disposed at the greatest radial distance with respect to the stator. The next larger coils are formed respectively on the pairs of fingers 137 and 138 which are closer to the axis of the stator and have a lesser axial length than the fingers 136. The end loops of the outer coil are formed on the pairs of fingers 139 which are disposed at a distance from the axis of the core intermediate the fingers 136 and 137. The front annular plate 126 also carries a pair of fingers 141 about which the wires are wound in a polar shift, as shown in FIG. 14. Further with respect to FIG. 14, only the lower shuttle therein is shown as operating to effect the winding operation. This has been done for the purpose of clarity and it will be understood that in the normal operation of the machine both shuttles will be operating to effect the simultaneous winding of two opposite poles of the same polarity.

In the hydraulic circuit diagram of FIG. 17 and the electrical circuit diagrams of FIGS. 18 through 20 certain conventions of designation have been followed to facilitate an understanding of the diagrams and to relate to each other the various elements of the components of the system. Thus, the solenoid operated valves are designated by the letter V with a numeral suffix as V1, V2, etc. The solenoid operators for the valves have been given a further letter suffix as V1A, V2A, etc., and where the valve has a second operating solenoid it is designated by the suffix B as V2B, V4B, etc. The contacts of the various limit switches are designated by the limit switch number with a letter suffix as 54A, 54B, etc. Control relays and

their operating coils are designated by the letters CR with a numerical suffix as CR1, CR2, etc., and the contacts operated by the relays are designated by a further letter suffix as CR1A, CR2B, etc. Time delay relays and their operating coils are designated by the letters TD with a numeral suffix as TD1, TD2, etc., and the contacts operated thereby are designated by a further letter suffix as TD1A, TD1B. The counters used for counting the number of turns in each stator coil have a pair of coils, one a clutch coil which conditions the unit for counting and a count coil which advances the counter each time it is energized and deenergized. The clutch coils of the counters are designated by the letters CS with a numeral suffix as CS1, CS2, etc., and the counting coils are designated by the letters CC with a numeral suffix as CC1, CC2, etc. The contacts of the counter are designated by the letter C, followed by the counter numeral and a final letter suffix of A, B, etc., thus C1A. Control relays CR10, CR11 and CR20 each have a pair of latching and unlatching coils which are connected by dotted lines and are designated CR10L and CR10U, etc., to indicate their function. As the description of operation progresses, components which are referred to and are not listed above will be given numerical designations.

In operating the machine, hydraulic pressure is initiated by starting the pump motor at push button 151 to energize motor contactor coil 152. This also closes interlocking contact 152A. The following adjustments are then made for the particular stator to be wound: a proper adapter plate 121 is mounted on the ring gear 4; the number of poles and direction of movement of winding head are set; the number and length of the coil span stop pins 77, 78, and 96 through 99, are selected and mounted in the proper holders 79 and 81 with a spacing correlated with the position of the head 117 on the shaft 116 so that the successive pairs of pins will be properly indexed with the dog 76; the positions of the holders 79 and 81 on the shaft 82 are roughly located so that the needles 18 and 19 will register with the slots in the stator core in the extreme positions of oscillation of the winding head; the length of stroke of the winding head is adjusted by moving the limit switches 62 and 63 toward or away from each other as required, by rotation of the handwheel 65; and the counters are individually set to the proper number of turns per coil.

To load the assembled stator core and fixture in the machine, the winding head is moved to the rear of the machine by closing push button 153. This energizes time delay relay TD5 having an instantaneous make and time delay break of its contacts TD5A which close to energize CR17. Operation of relay CR17 performs four functions: first, contacts CR17A close to energize solenoid coil V1A of valve V1; second, contacts CR17B and CR17C close to energize relays CR15 and CR16 to allow the winding head to turn to the side; third, contacts CR17B open to open the circuit to both coils of the valve V2; fourth, contacts CR17E close to energize the latching coil CR10L of relay CR10, CR9 is now energized and CR9A closes to provide an energizing path for V1A about contacts CR17A. TD5 now times out to open TD5A and deenergize CR17, CR15 and CR16, thus permitting V3A to be deenergized whereupon valve V3 returns to the position of FIG. 17 with the cylinder 45 energized to move shaft 35 and rack 13 rearwardly to retract the shuttles 23 and 24. At this point the winding head moves to the rear and to its center position where opening of limit switch contacts 154 deenergizes CR9 and V1A to stop the cycle. With the winding head in its rearward postion the stator core 132 and its fixture may be readily mounted upon the adapter plate 21 by means of the clamps 124 and 125. The final adjustment of the positions of the coil span stop pin holders 79 and 81 may be effected by moving them to the positions to index the wire guide needles 18 and 19 with the stator slots as the winding head is jogged forwardly by operation of push button 157 having the three sets of contacts as illustrated. After the winding head is thus returned to its forward posiion, the shaft 82 is rotated to the start position of minimum coil span by rotating knob 115, the wires 21 and 22 are clamped to the adapter plate 121 by the clamps 122 and 123, the counters are reset and the automatic winding cycle started by actuating the push button 155.

Closing of push button 155 energizes TD4 which closes immediately to energize CR19. Operation of CR19 energizes either CR15 or CR16 depending on whether the machine is running in forward or reverse and also energizes CR2. Operation of CR2 energizes CR3 and CR4 and closes a holding circuit around CR19B so that CR2 remains energized after TD4 times out to open CR19. This holding circuit is in series with contacts C5B which open to deenergize CR2 at the completion of the winding cycle as counter C5 completes its count. Energization of CR3 and CR4 energizes V1A to start the winding cycle in operation. At this time it will be noted that solenoid coil V8A is energized through normally closed contacts CR12A to apply pressure to hydraulic motor 5 in a direction to rotate ring gear 4 counterclockwise to press the stop 8 against the stationary stop 6 on the table 2.

The operation of the winding head to complete one coil turn will be explained in connection with the movement of the upper shuttle only of the winding head, as has been illustrated in FIG. 16 wherein is shown the path transcribed by the upper shuttle with the directional selector switch set for forward motion. The eight salient positions of the shuttle are designated in the diagram as points P1 through P8, inclusive. The sequence opens with the winding head moving forwardly to position 1 under forward movement of piston 43 in cylinder 44; the shuttle is retracted with piston 46 in reverse position; contacts 88 are closed and when the shuttle reaches position P1 limit switch contacts 63A and 63B are closed. In position P1 valve V3 solenoid V3A is energized to move piston 46 forwardly and extend the shuttle. At position P2, contacts 54A and 54B are closed and contacts 54C opened. Solenoid coil V4A is now energized through limit switch contacts 63B and 54B, whereupon cylinder 75 is energized to move piston 74 forward and rotate the extended shuttle into the position P3 determined by engagement of the dog 76 with the coil span stop pin with which it is indexed.

In position P3, limit switch contacts 88A are opened and 88B are closed. Opening of contacts 88A deenergizes V3A and valve 3 moves under its spring return to effect movement of the piston 46 in reverse to retract the shuttle to position P4. This closes limit switch contacts 54C and through these and contacts 88B the solenoid valve coil V2B is energized to effect movement of the stroke piston 43 in the reverse direction, thus moving the retracted shuttle into position P5 where limit switch contacts 62A and 62B are closed, whereupon solenoid valve coil V3A is energized through limit switch contacts 62A and 89A which were closed at position P3.

The valve V3 is then operated to move piston 46 forwardly to extend the shuttle to position P6 where limit switch contacts 54A and 54B are closed. Solenoid valve coil V4B is thus energized through limit switch contacts 54A and 62B and piston 74 moves in reverse to rotate the extended shuttle to position P7 where limit switch contacts 89A are opened and 89B closed. Opening of contacts 89A deenergizes solenoid valve coil V3A and piston 46 now moves in reverse to retract the shuttle to position P8 wherein limit switch contacts 54C close, whereupon solenoid valve coil V2A is energized through limit switch contacts 54C and 89B and the stroke piston 43 moves forward to move the winding head shuttle from the position P8 toward the position P1, thus completing one complete turn in the coil being wound.

The sequence of operation taking place as the machine indexes automatically from coil to coil in the winding cycle will now be described. The count out on any

counter takes place when the winding head moves to the rear of its stroke closing the contacts on limit switch contacts 62B and energizing the counter coil for the last time. However, the counter contacts do not open until the winding head oscillates from one side to the other and moves forward, opening limit switch contacts 62B. When the counter counts out its A contacts open, deenergizing relay CR3 in the case of counters C1, C3 and C5 and relay CR4 in the case of counters C2 and C4. The opening of CR3 and CR4 opens the circuit which was energizing solenoid valve coil V1A but this remains energized by the circuit including contacts CR9A which are closed with the energization of relay CR9 through the normally closed contacts of relays CR3 and CR4. The winding head thus continues to move to its forward position and oscillates to its center position where it opens limit switch contacts 154 to deenergize CR9 and valve solenoid V1A to close valve V1. Solenoid valve coil V6A is energized through the normally closed contacts of relays CR3, CR4 and CR9. This energizes coil span selector cylinder 101 to move piston 104 forwardly whereby shaft 82 is rotated through the rack and gear wheel arrangements shown in FIGS. 11 through 13 to index the next set of soil span stop pins with the dog 76. When the piston 104 has moved all the way forwardly, it will operate limit switch 118 to close its normally open contacts 118A and 118B, whereupon control relays CR3 and CR4 are again energized and in turn energize solenoid valve coil V1A to operate valve V1 and again start the winding cycle. This action also deenergizes solenoid valve coil V6A, whereupon piston 104 reverses to reset itself for the next forward index, this action opening limit switch contacts 118A and 118B but with the winding cycle continuing in view of the holding circuit about either CR3 or CR4.

The above indexing action is the same for all counters except counter C5. This counter opens its C5B contacts as it counts out and thus deenergizes relay CR2. With CR2 deenergized the indexing from coil to coil will be the same as described above except that the automatic restart is not effective when the coil span indexing cylinder closes limit switch 118. If the machine is set for a two-pole winding operation it must now be manually unloaded, loaded and restarted. If the machine is set for a four-pole winding operation it will automatically index and wind in the second pair of poles. When CR2 is deenergized as counter C5 counts out, its normally closed contacts complete a circuit so that CR12 is energized when the winding head oscillates to its center forward position, closing limit switch contacts 156. Energization of CR12 relay opens contacts CR12B which were energizing solenoid valve coil V8B, and closes contacts CR12A which energizes solenoid valve coil V8A. Operation of valve V8 reverses the flow of oil to the hydraulic motor 5 and rotates the ring gear 4 in a clockwise direction through 90° until the stop 7 on the ring gear engages the stationary stop 6 on the table 2. This new position of the stator core and fixture is that illustrated in FIG. 14. At the same time coil V8A is energized TD1 and TD2 are also energized. TD1 is time delay make and instantaneous break in operation and its function is to restart the automatic winding cycle for the second set of poles after the winding fixture head has completed its index to the 90° position. In order to do this, the time delay setting is sufficiently long so that indexing is complete before TD1 times out and energizes CR2. TD2 which is instantaneous make and time delay break, functions to energize CR15 to prevent the winding head moving to the rear until TD2 times out.

After the machine completes its winding of the second pair of poles, CR12 is deenergized to open valve coil V8A and close valve coil V8B which again reverses the flow of oil to hydraulic motor 5 and returns the fixture head to its initial position. At this point the machine is ready for manual unloading, loading and restarting.

In winding the second pair of poles in a four-pole winding operation, the direction of movement of the winding head shuttles is reversed so that the coils are wound the opposite direction in order to produce adjacent poles of opposite electrical polarity, the opening of contacts CR12A as deenergizing time delay relay TD6 which was previously energized through contacts CR1C and CR12A to close contacts TD6A and energize relays CR6 and CR7. With control relay CR6 energized solenoid valve coils V4A and V4B are controlled for energization through its normally open contacts. With CR7 energized solenoid valve coils V2A and V2B are controlled through the normally open contacts of relay CR7. With contacts TD6A opening to deenergize control relays CR6 and CR7 solenoid valve coils V4A and V4B controlling the stroke of the winding head have their energization interchanged, now being effected through the normally closed contacts of relay CR6, and thus the direction of motion of the winding head stroke is reversed. Similarly, with control relay CR7 deenergized, the energization of solenoid valve coils V2A and V2B is now interchanged with the energization effected through the normally closed contacts of relay CR7 and with the oscillating movement of the winding head reversed. This reversal of motion of the stroke and oscillation of the winding head thus results in the second set of poles being wound in reverse to produce the opposite electrical polarity.

What is claimed is:

1. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding head, means for reciprocating said head axially of said core between the front and back faces thereof in a wire laying stroke, means for rotating the head in opposite directions while the head is in its opposite extreme positions to form the coil end loops, stop means for limiting the extreme positions of rotation of the head to determine the coil span, said stop means having limited movements in opposite directions as it performs its stop function, limit switches operated by said limited movements of the stop means, and reversing circuits set up by said limit switches for reversing the direction of rotation of the head.

2. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding head, means for reciprocating said head axially of said core between the front and back faces thereof in a wire laying stroke, means for rotating the head in opposite directions while the head is in its opposite extreme positions to form the coil end loops, a plurality of stop means of varying span for limiting the extreme positions of rotation of the head to produce a plurality of coils of different spans, means for counting the number of turns wound in the coils, means for positioning a different span stop means in limiting position to wind a new coil as each preceding coil counts out, means for rotating said core supporting means to index a second electrical pole to be wound with said wire feeding head, means for energizing said core support rotating means upon counting out of the counting means for the last coil to be wound on the preceding pole, means also actuated when said last coil counting means counts out for reversing the direction of coil winding so that adjacent poles will be of different electromagnetic polarity, said last mentioned means including reversing circuits for both of said head reciprocating means and head rotating means to reverse their cycle of movement and reverse the direction in which the coil is wound.

3. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding

head, means for reciprocating said head axially of said core between the front and back faces thereof in a wire laying stroke, means for rotating the head in opposite directions while the head is in its opposite extreme positions to form the coil end loops, a plurality of pairs of stop means for limiting the extreme positions of rotations of the head, the spacing between each pair of stop means determining a coil span and the spacing between the different pairs determining different coil sizes, said stop means having limited movement in opposite directions as they perform their stop functions, means operated by said limited movement of the stop means for setting up a reversal of the direction of rotation of the head in its opposite extreme positions, means for counting the number of turns wound in a coil, and means for positioning a different pair of coil stop means in limiting position when the turn counting means counts out.

4. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding head, means for reciprocating said head axially of said core between the front and back faces thereof in a wire laying stroke, means for rotating the head in opposite directions while the head is in its opposite extreme positions to form the coil end loops, a dog movable with the rotation of the head, a plurality of pairs of stops circumferentially arranged about a rotatable axis with the stops in each pair spaced axially of said rotatable axis a distance determined by the span of a coil to be wound, means for counting the number of turns wound in a coil, and means for rotating said stops about said axis to index a succeeding pair of stops with said dog as the turns of a coil are counted out.

5. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding head, means for reciprocating said head axially of said core between the front and back faces thereof in a wire laying stroke, means for rotating the head in opposite directions while the head is in its opposite extreme positions to form the coil end loops, a dog movable with the rotation of the head, a plurality of pairs of stops circumferentially arranged about a rotatable axis with the stops in each pair spaced axially of said rotatable axis a distance determined by the span of a coil to be wound, means for counting the number of turns wound in a coil, means for rotating said stops about said axis to index a succeeding pair of stops with said dog as the turns of a coil are counted out, and means for automatically terminating the winding operation when the turns on the last coil to be wound are counted out.

6. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding head, means for reciprocating said head axially of said core between the front and back faces thereof in a wire laying stroke, means for rotating the head in opposite directions while the head is in its opposite extreme positions to form the coil end loops, a dog movable with the rotation of the head, a plurality of pairs of stops circumferentially arranged about a rotatable axis with the stops in each pair spaced axially of said rotatable axis a distance determined by the span of a coil to be wound, means for counting the number of turns wound in a coil, means for rotating said stops about said axis to index a succeeding pair of stops with said dog as the turns of a coil are counted out, said stops having limited axial movements in opposite directions as they perform their limiting function, and means operated by said stop axial movement for setting up a reversal of the direction of rotation of the head in its opposite extreme positions.

7. The coil winding machine defined in claim 6 in which said stops are constituted by pairs of opposed pins of varying length and in which the pins are mounted in spaced holders adjustably mounted on a rotatably and axially movable shaft.

8. The coil winding machine recited in claim 6 in which said pairs of stops are mounted around a rotatably and axially movable shaft, with the shaft provided with a pair of spaced cam surfaces engaged with stationary limit switches to effect the setting up of reversal circuits controlling the direction of head rotation.

9. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding head, means for reciprocating said head axially of said core between the front and back faces thereof in a wire laying stroke, means for rotating the head in opposite directions while the head is in its opposite extreme positions to form the coil end loops, means for counting the number of turns wound in a coil, means for rotating said core supporting means as the turn counter counts out to index another core pole with the wire feeding head and means for reversing the directions of movement of the wire feeding head to wind a pole of different polarity including a pair of reversing circuits for the reciprocating means and the rotating means for the wire head, and means for actuating the reversing circuits as the counter counts out.

10. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising a rotatable support, means for indexing said support in a plurality of circumferentially spaced positions, means for mounting a core to be wound upon said support, a wire feeding head, means for reciprocating said head axially of said core between the front and back thereof in a wire laying stroke, a wire guide shuttle on said head, means for extending and retracting said shuttle while the head is in its opposite extreme positions, means for rotating the head in opposite directions while the shuttle is extended at the front and back of the core to form the coil end loops, means for cyclically moving the wire feeding head and shuttle to effect the coil winding operation for the core pole with which the wire feeding head is indexed, means for rotating the core supporting means to a second polar indexed position upon the completion of the winding for the preceding pole, and a pair of reversing circuits for the reciprocating means and the rotating means of the wire feeding head actuated when a polar winding is finished to effect a reversal of the movements of the wire feeding head in the winding cycle so that adjacent core poles will be wound with opposite electromagnetic polarity.

11. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising rotatable supporting means, means for indexing said supporting means in a plurality of circumferentially spaced positions, means for mounting a core to be wound upon said supporting means, a wire feeding head, means for reciprocating said head axially of said core between the front and back thereof in a wire laying stroke, a wire guide shuttle on said head, means for extending and retracting said shuttle while the head is in its opposite extreme positions, means for rotating the head while the shuttle is extended to form the coil end loops, stop means for limiting the extreme positions of rotation of the head to determine the coil span, means for counting the number of turns wound in a coil, means for adjusting said stop means to the span of a succeding coil as the turns of a preceding coil are counted out, means for adjusting said stop means to the initial coil span when the last coil of a core pole is counted out, means for indexing said core supporting means to a second polar position as said last polar coil is counted out, and means for reversing the actuating circuits controlling the reciprocating and rotating movements of the wire feeding head when said last polar coil is counted out whereby the machine is set for winding the coils of an adjacent core pole in opposite electromagnetic polarity.

12. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising rotatable supporting means, means for indexing said supporting means in a plurality of circumferentially spaced positions, means for mounting a core to be wound upon said supporting means, a wire feeding head, means for reciprocating said head axially of said core between the front and back thereof in a wire laying stroke, a wire guide shuttle on said head, means for extending and retracting said shuttle while the head is in its opposite extreme positions, means for rotating the head while the shuttle is extended to form the coil end loops, stop means for limiting the extreme positions of rotation of the head to determine the coil span, said stop means having limited movements in opposite directions as it performs its limiting functions, means operated by movement of said stop means to set up a reversal of the direction of rotation of the head in its opposite extreme positions, means for counting the number of turns wound in a coil, means for adjusting said stop means to the span of a succeeding coil as the turns of a preceding coil are counted out, means for adjusting said stop means to its initial span position when the coil turns for the last coil in a pole are counted out, means for rotating said core supporting means to a second indexed polar position when the last polar coil is counted out, and means for reversing the direction of reciprocation and rotation of said wire feeding head when said last polar coil is counted out whereby the machine is set up to effect the winding of the coils of an adjacent pole in opposite electromagnetic polarity.

13. A machine for winding wire coils into the slots in magnetizable cores of electrical machine comprising rotatable supporting means, means for indexing said supporting means in a plurality of circumferentially spaced positions, means for mounting a core to be wound upon said supporting means, a wire feeding head, means for reciprocating said head axially of said core between the front and back thereof in a wire laying stroke, a wire guide shuttle on said head, means for extending and retracting said shuttle while the head is in its opposite extreme positions, means for rotating the head while the shuttle is extended to form the coil end loops, stop means for limiting the extreme positions of rotation of the head to determine the coil span, said stop means having limited movements in opposite directions as it performs its limiting functions, means operated by movement of said stop means to set up a reversal of the direction of rotation of the head in its opposite extreme positions, means for counting the number of turns wound in a coil, and means for adjusting said stop means to the span of a succeeding coil as the turns of a preceding coil are counted out.

14. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding head, means for reciprocating said head axially of said core between the front and back thereof in a wire laying stroke, a pair of oppositely directed wire feeding needles on said head, a wire guide shuttle about each of said wire feed needles, means for extending said wire guide shuttles in opposite directions away from said head and for retracting said shuttles toward the head, means for operating said last mentioned means while the head is in its opposite extreme positions, means for rotating the head while the shuttles are extended to form the coil end loops, stop means for limiting the extreme positions of rotation of the head to determine the coil spans, said stop means having limiting movements in opposite directions as it performs its limiting function, and means operated by the movement of said stop means for setting up the reversal in the direction of rotation of the head in its opposite extreme positions.

15. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding

head, means for reciprocating said head axially of said core between the front and back thereof in a wire laying stroke, a pair of oppositely directed wire feeding needles on said head, a wire guide shuttle about each of said wire feed needles, means for extending said wire guide shuttles in opposite directions away from said head and for retracting said shuttles toward the head, means for operating said last mentioned means while the head is in its opposite extreme positions, means for rotating said head while the shuttles are extended to form the coil end loops, stop means for limiting the extreme positions of rotation of the head to determine the coil spans, said stop means having limited movements in opposite directions as it performs its limiting function, means operated by said movements of said stop means for setting up the reversal in the direction of rotation of the head in its opposite extreme positions, means for counting the number of turns wound in a coil, and means for adjusting the stop means to the span for a succeeding coil as the turns in the preceding coil are counted out.

16. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding head, means for reciprocating said head axially of said core between the front and back thereof in a wire laying stroke, a pair of oppositely directed wire feeding needles on said head, a wire guide shuttle about each of said wire feed needles, means for extending said wire guide shuttles in opposite directions away from said head and for retracting said shuttles toward the head, means for operating said last mentioned means while the head is in its opposite extreme positions, means for rotating the head while the shuttles are extended to form the coil end loops, stop means for limiting the extreme positions of rotation of the head to determine the coil spans, said stop means having limited movements in opposite directions as it performs its limiting function, means operated by said movements of said stop means for setting up the reversal in the direction of rotation of the head in its opposite extreme position, means for counting the number of turns wound in a coil, means for adjusting the stop means to the span for a succeeding coil as the turns in the preceding coil are counted out, means for adjusting said stop means to initial coil span position, means for rotating said core supporting means to a position indexing another core pole with the wire feeding head, and means reversing the direction of movement of the wire feeding head, said last three means operating when the turns on the last coil of a core pole are counted out.

17. A coil winding machine as defined in claim 16 in which the reciprocating means for the wire feeding head and the rotating means for the head each includes a hydraulic cylinder and piston whose direction of movement is controlled by a pair of valve operating coils and in which the reversal of movement of the head is effected by reversing circuits for the pairs of coils which are actuated to reverse the order in which the coils in each pair are energized to effect wire feeding movements of the head.

18. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding head, means for reciprocating said head axially of said core between the front and back thereof in a wire laying stroke, a wire guide shuttle on said head, means for extending and retracting said shuttle while the head is in its opposite extreme positions, means for rotating the head in opposite directions while the shuttle is extended at the front and back of the core to form the coil end loops, stop means for limiting the extreme positions of rotation of the head to determine the coil span, means mounted to reciprocate with the head for feeding the wire thereto, means for applying a frictional drag to said wire feeding means, and means operated by the shuttle operating

means for setting said frictional drag when the shuttle is in retracted position and releasing the drag as the shuttle moves to extended position.

19. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding head, means for reciprocating said head axially of said core between the front and back thereof in a wire laying stroke, a wire guide shuttle on said head, means for extending and retracting said shuttle while the head is in its opposite extreme positions, means for rotating the head in opposite directions while the shuttle is extended at the front and back of the core to form the coil end loops, stop means for limiting the extreme positions of rotation of the head to determine the coil span, means mounted to reciprocate with the head for feeding the wire thereto, and means operated with the shuttle operating means for applying a drag to said wire feeding means and operating to release the drag with the shuttle extended to provide free wire feeding as the head is rotated to form the coil end loops and to set the drag as the shuttle is retracted to apply tension to the wire in the wire laying stroke and insure tightening of the end loops.

20. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding head, means for reciprocating said head axially of said core between the front and back thereof in a wire laying stroke, a pair of oppositely directed wire feeding needles on said head, a wire guide shuttle about each of said wire feed needles, means for extending said wire guide shuttles in opposite directions away from said head and for retracting said shuttles toward the head, means for operating said last mentioned means while the head is in its opposite extreme positions, means for rotating the head while the shuttles are extended to form the coil end loops, means for feeding the wire to said needles, means for applying a drag to said wire feeding means, and means controlled with the shuttle operating means for releasing the drag as the shuttles are extended to provide for free wire feed as the head rotates and for setting the drag as the shuttles are retracted to place tension on the wires as the head reciprocates in its wire laying stroke.

21. A machine for winding wire coils into the slots in magnetizable cores of electrical machines comprising supporting means for a core to be wound, a wire feeding head, means for reciprocating said head axially of said core between the front and back thereof in a wire laying stroke, a pair of oppositely directed wire feeding needles on said head, a wire guide shuttle about each of said wire feed needles, means for extending said wire guide shuttles in opposite directions away from said head and for retracting said shuttles toward the head, means for operating said last mentioned means while the head is in its opposite extreme positions, means for rotating the head while the shuttles are extended to form the coil end loops, means mounted to reciprocate with the head for feeding the wires to the needles, and means operated with the shuttle operating means for applying a drag to said wire feeding means and operating to release the drag as the shuttles are extended to provide free wire feeding as the head is rotated to form the coil end loops and to set the drag as the shuttles are retracted to apply tension to the wires in the wire laying stroke of the head and insure tightening of the coil end loops.

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