United States Patent

[11] 3,575,219

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Continuation-in-part of application Ser. No. 717,819, Apr. 1, 1968.

[54] **COIL WINDING APPARATUS AND METHOD**
37 Claims, 26 Drawing Figs.

[52] **U.S. Cl.** **140/92.1,** 29/605
[51] **Int. Cl.** **B21f 3/04**
[50] **Field of Search** 140/1, 92.1, 92.2; 29/605

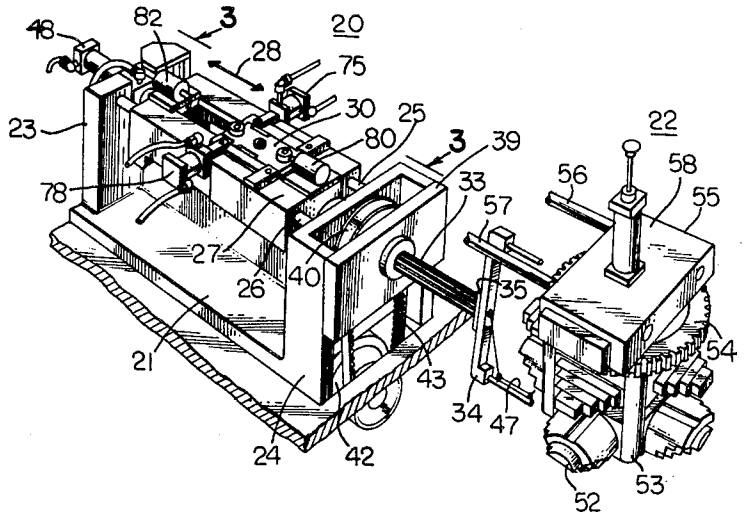
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Primary Examiner—Lowell A. Larson
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ABSTRACT: Apparatus for winding coils on a coil form having a plurality of steps of progressively smaller size. A flyer is provided mounted on a shaft for winding an elongated strand on the steps to form the coils. A first support is provided for rotatably supporting the shaft and a drive is coupled to the shaft for rotating the same thereby to rotate the flyer. A second support is provided for supporting the first support for longitudinal movement parallel with the axis of the shaft. A first actuator is provided on the second support operably connected to the first support for longitudinally moving the first support and the shaft so as to position the flyer in winding relationship with the coil form steps. A second actuator is provided operably connected to the second support for moving the same longitudinally thereby to move the first support and the shaft so as to traverse the flyer with respect to the coil form.



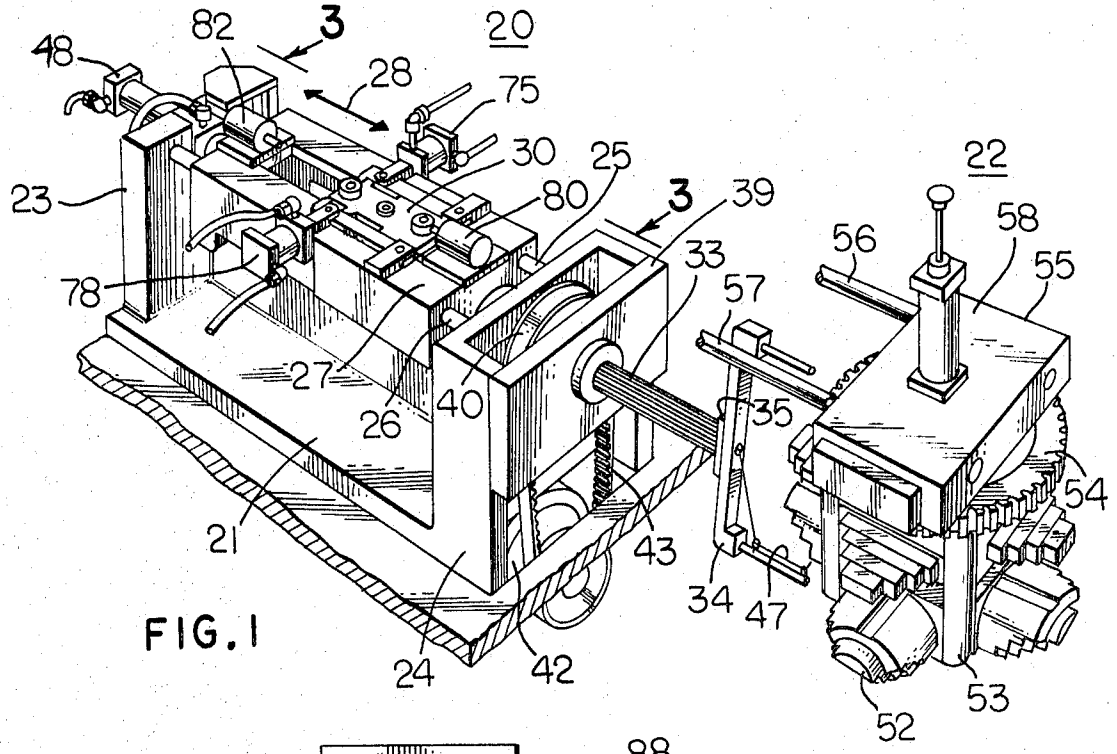


FIG. 1

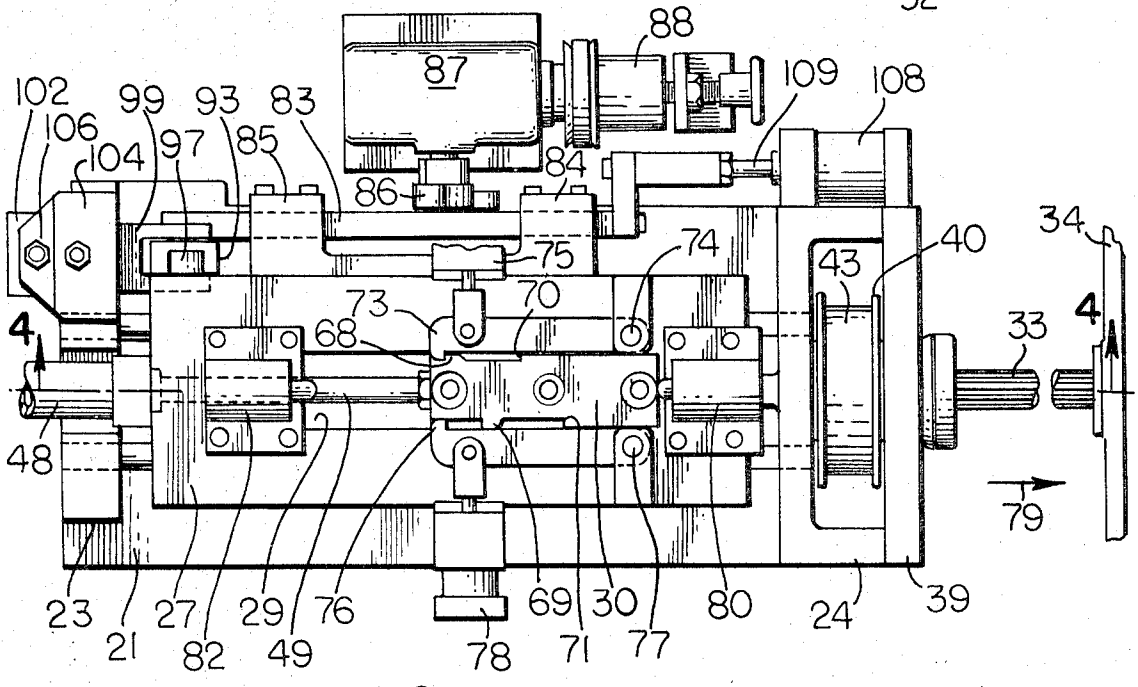


FIG. 2

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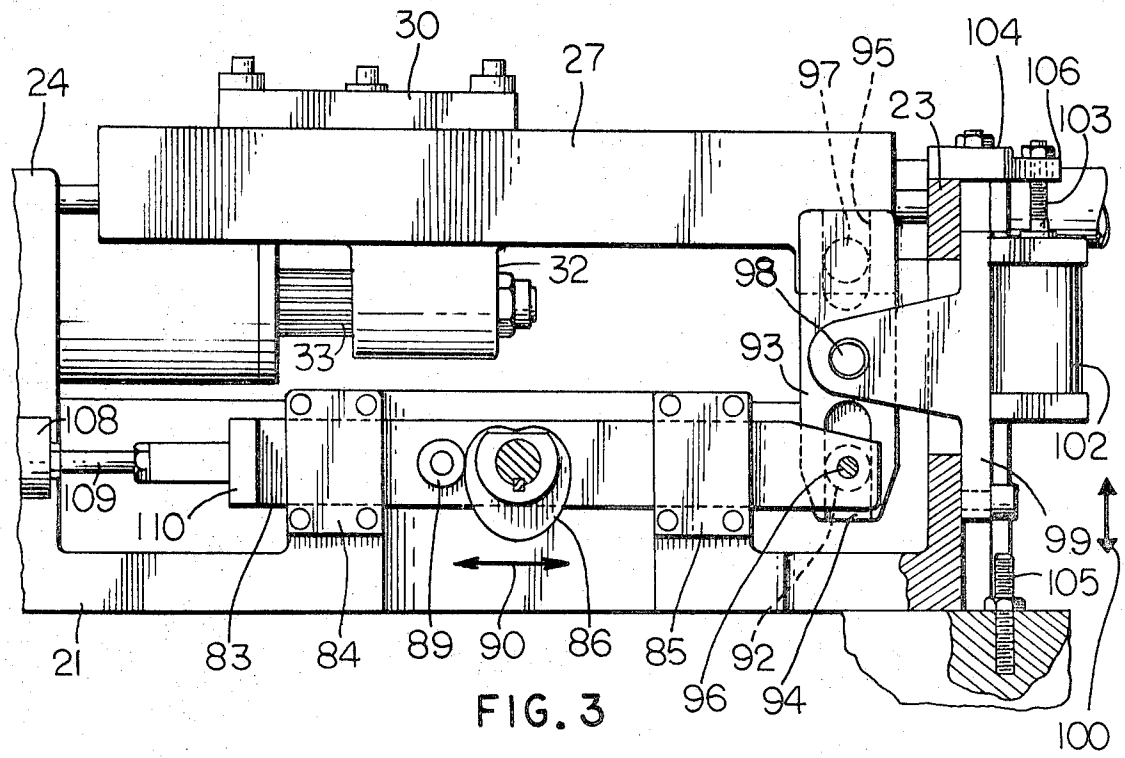


FIG. 3

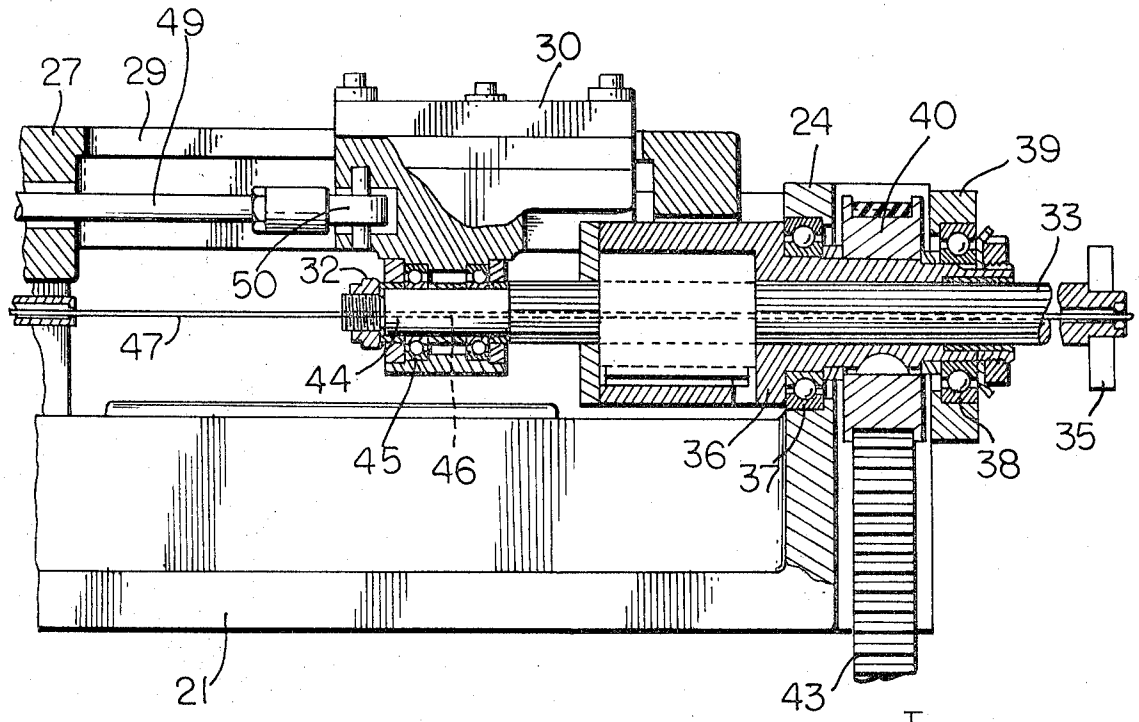


FIG. 4

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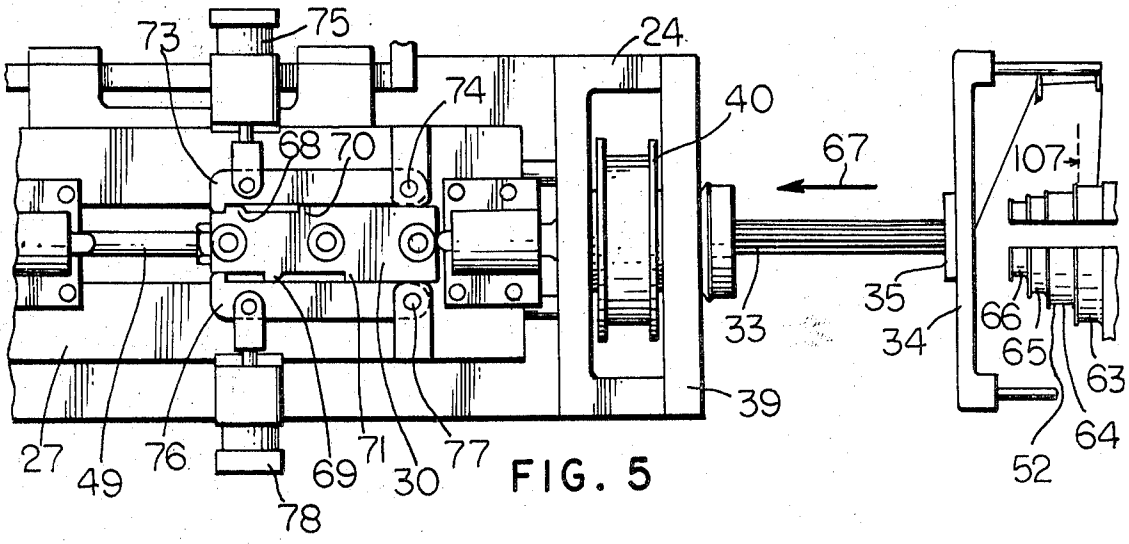


FIG. 5

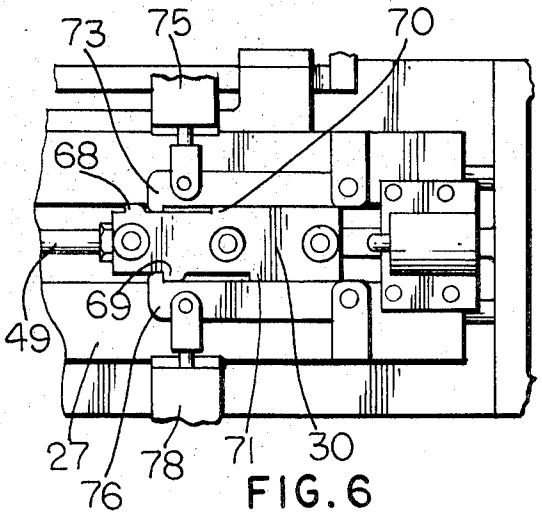


FIG. 6

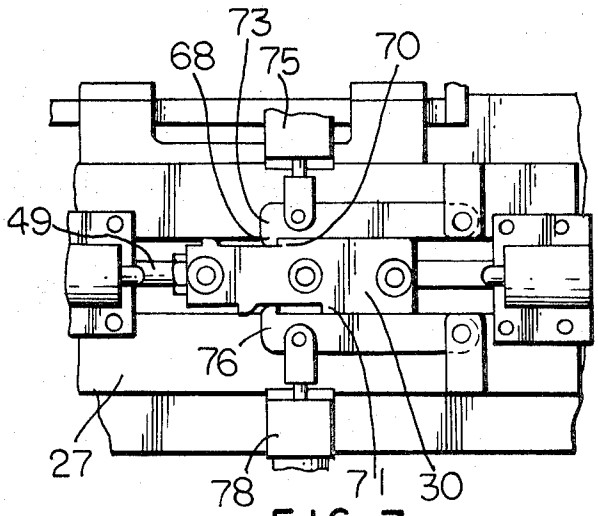


FIG. 7

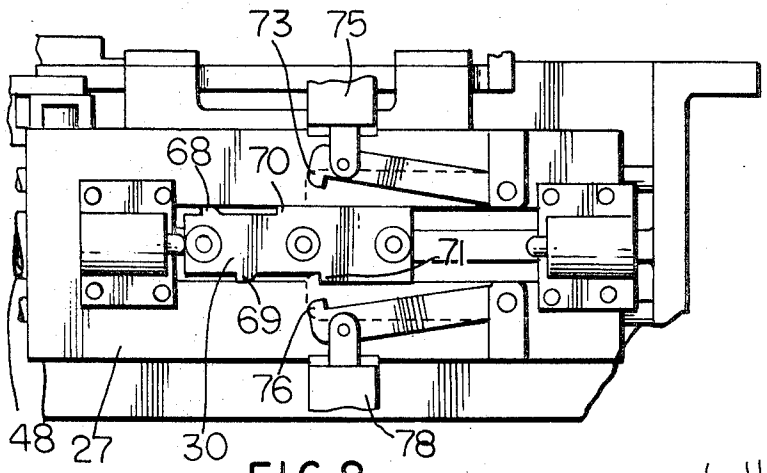


FIG. 8

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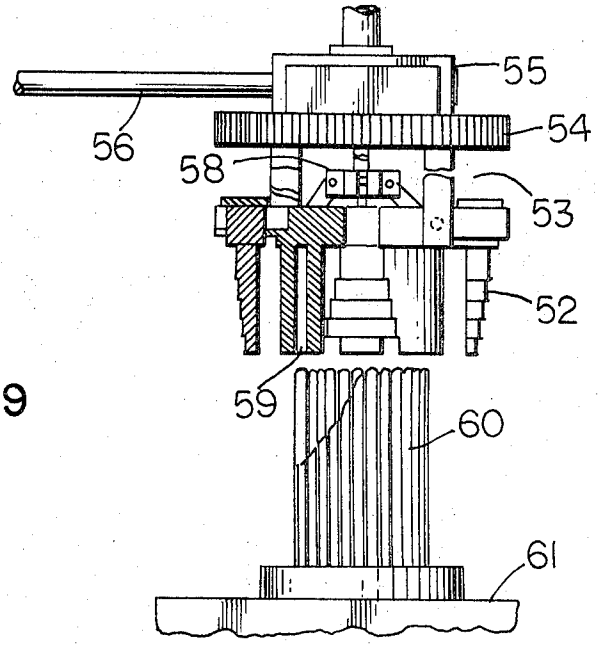


FIG. 9

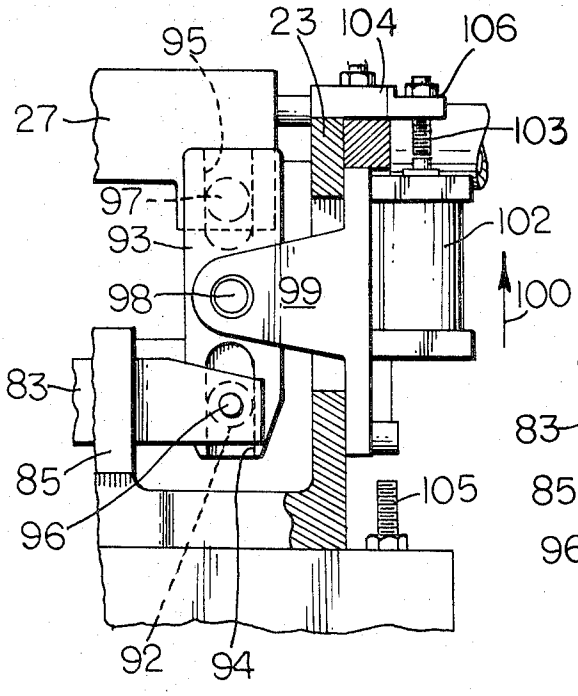


FIG. 10

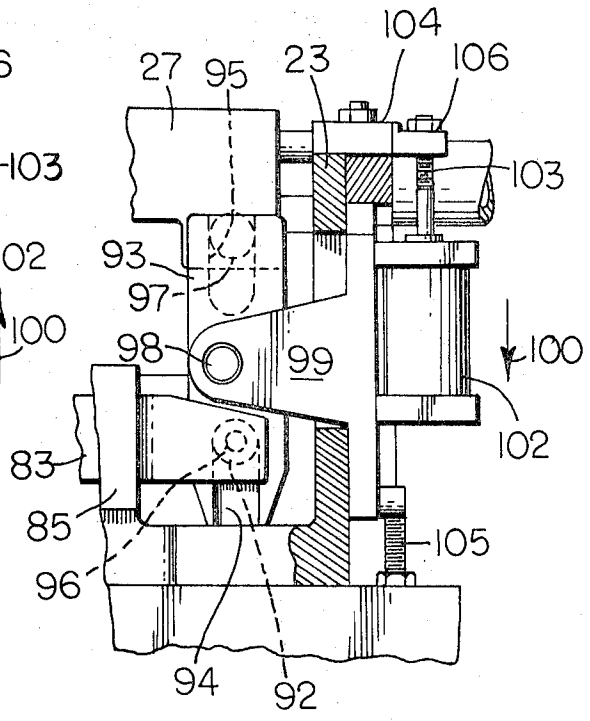


FIG. 11

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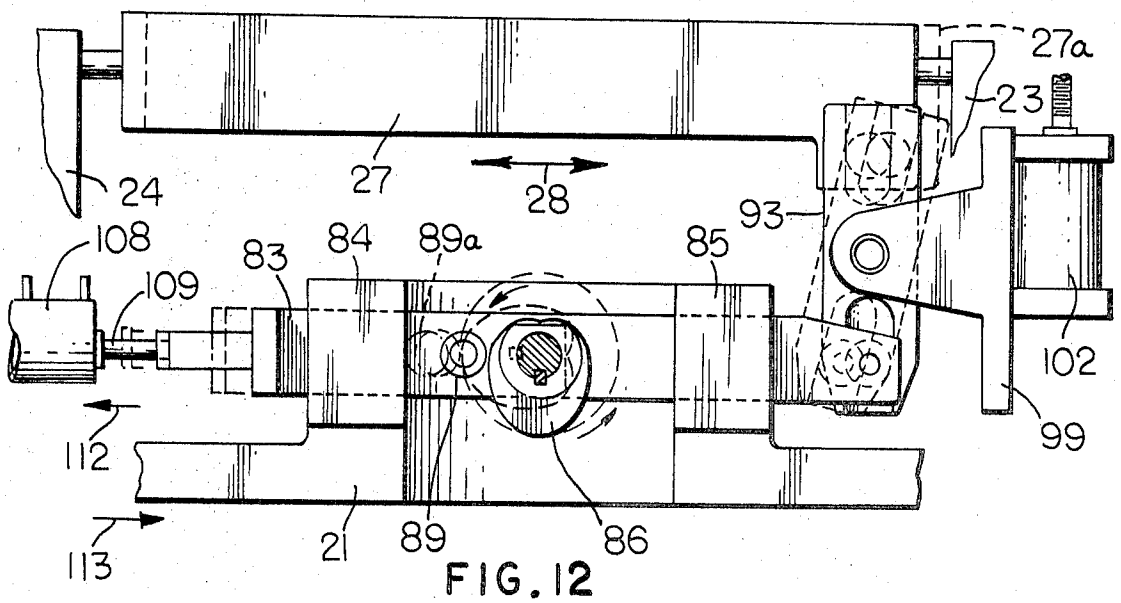


FIG. 12

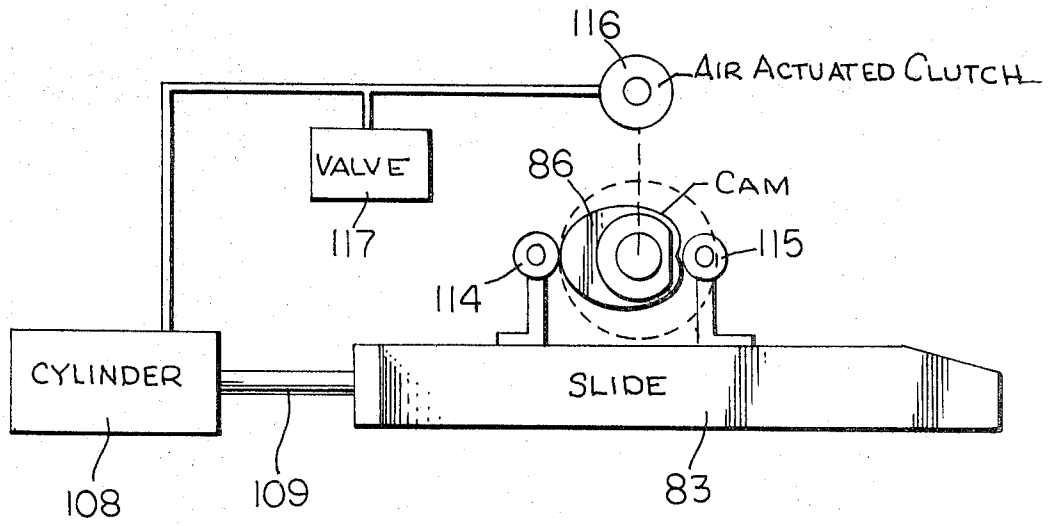
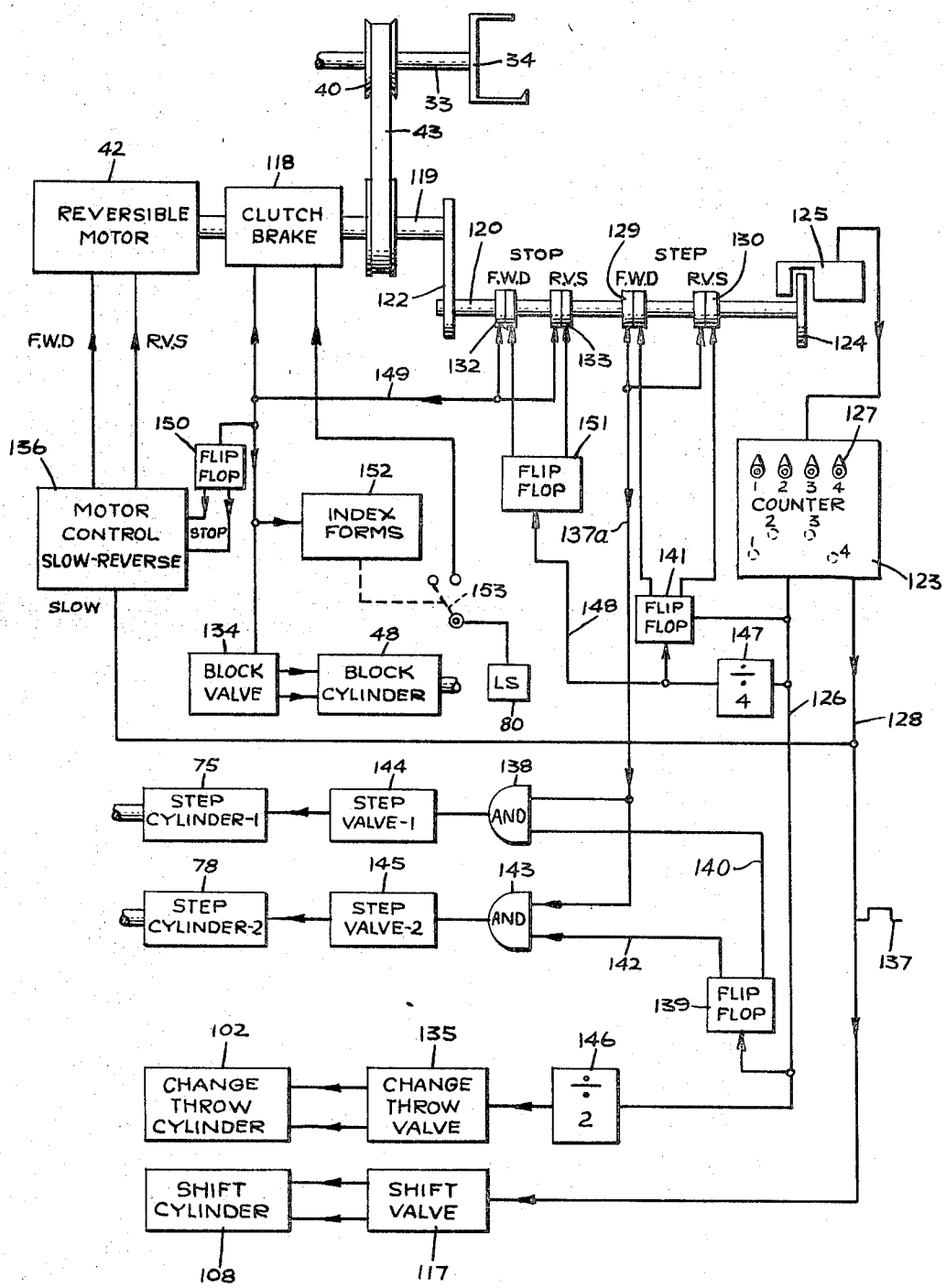


FIG. 13

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FIG. 14



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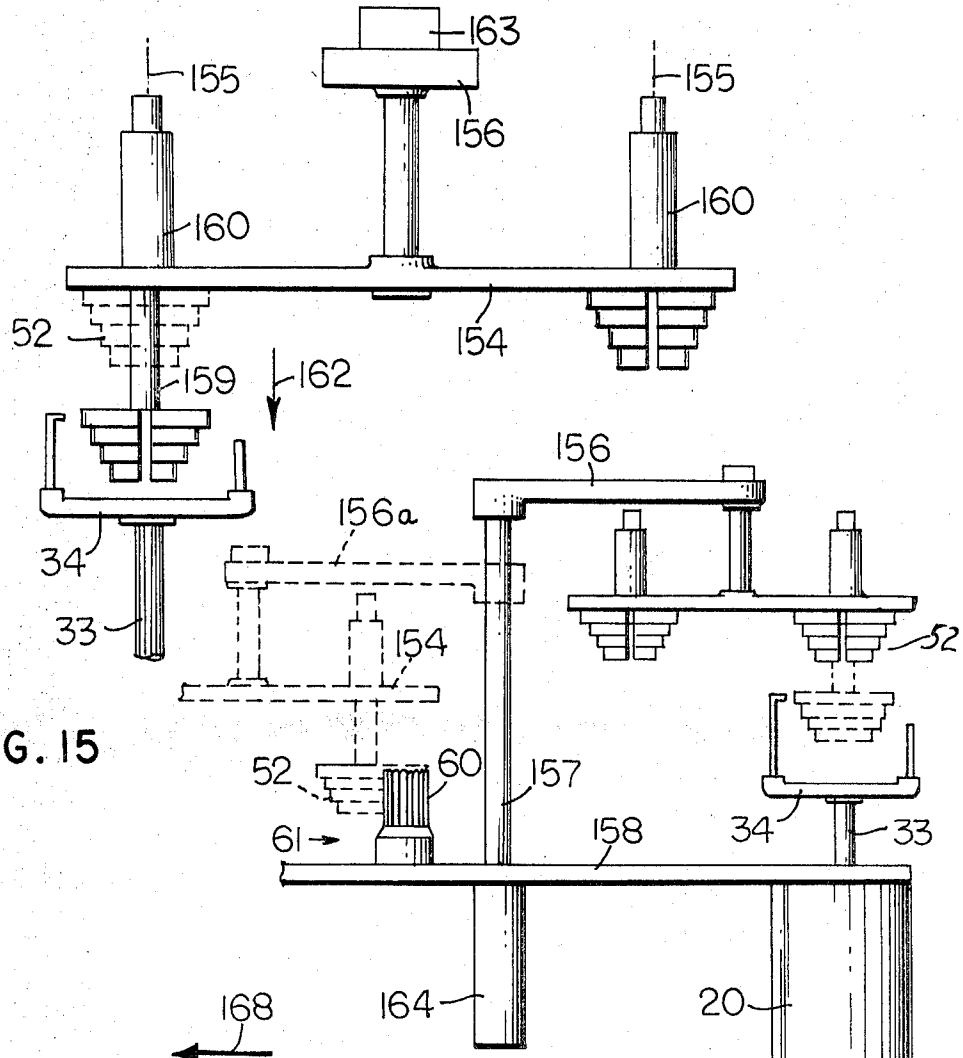


FIG. 15

FIG. 16

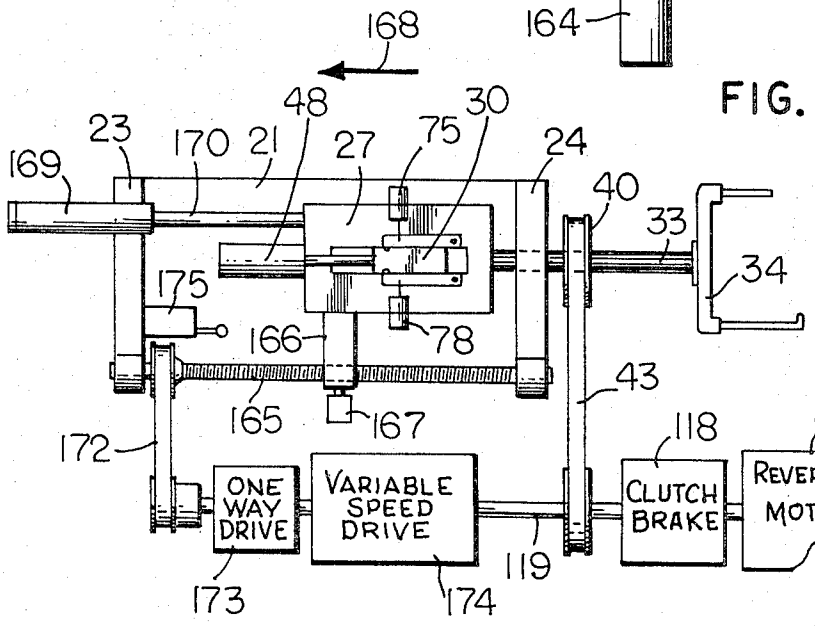


FIG. 17

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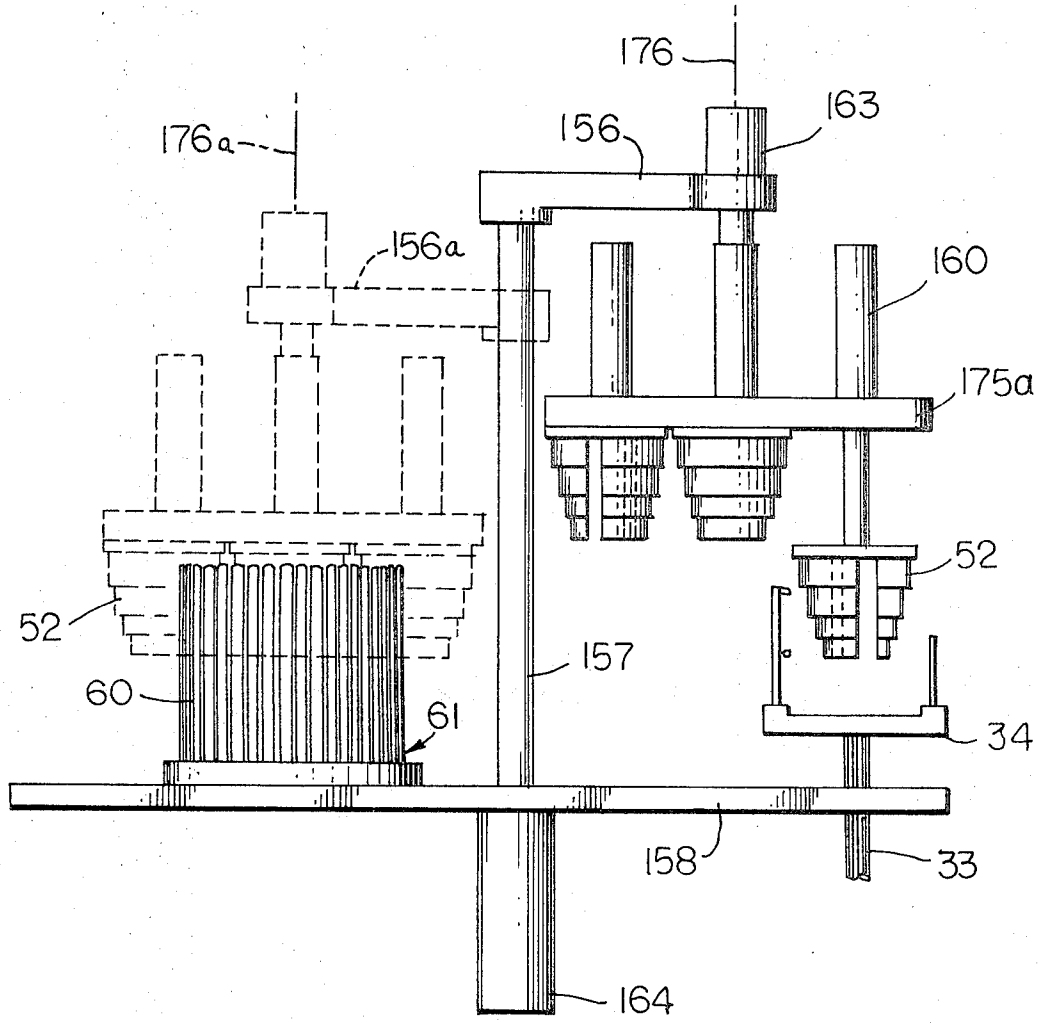


FIG. 18

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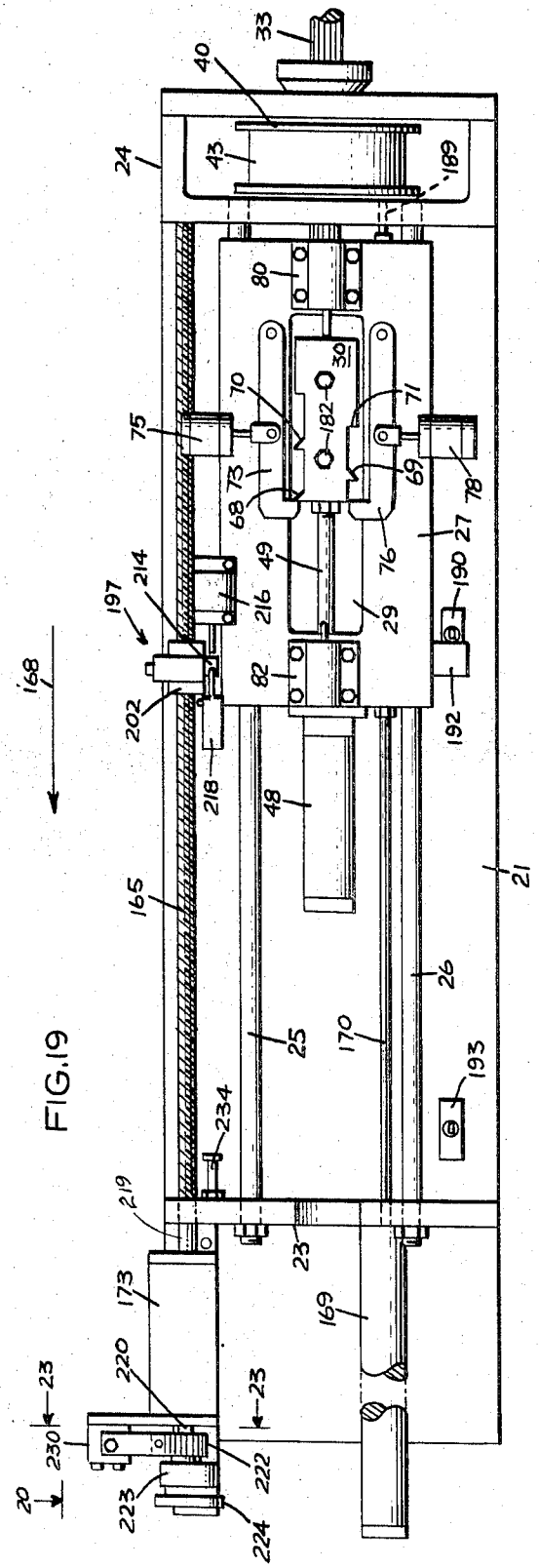


FIG. 19

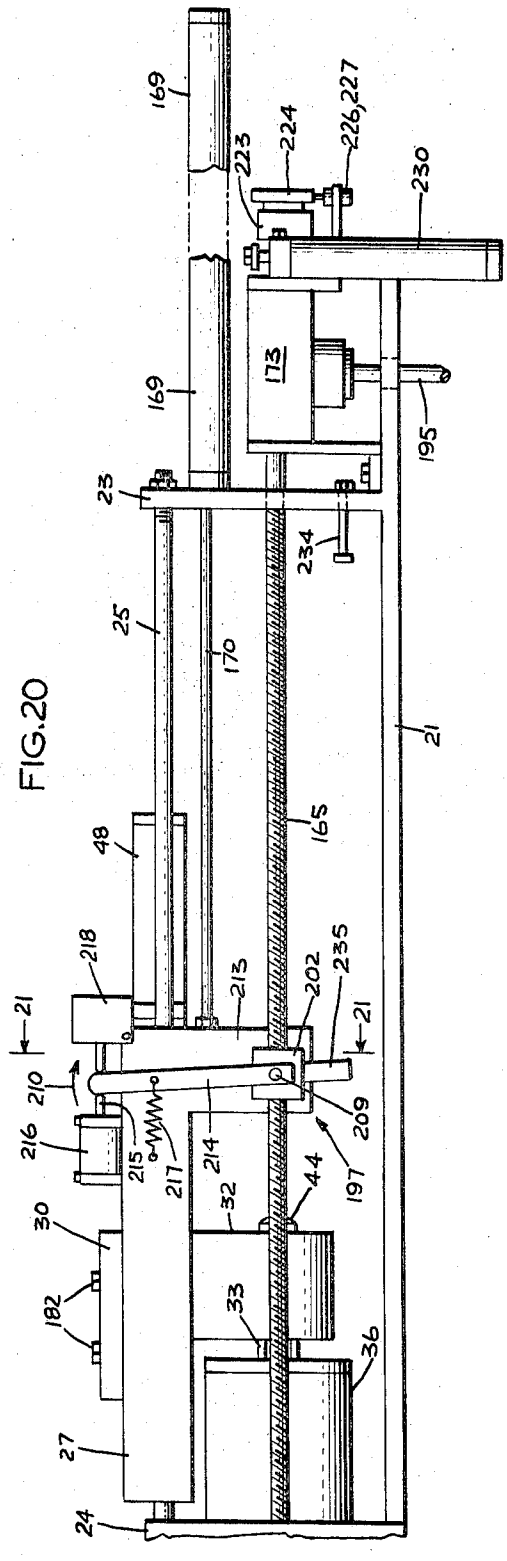


FIG. 20

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FIG.21

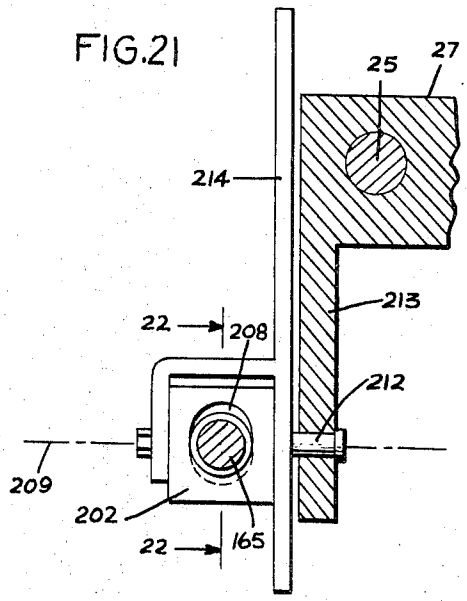


FIG.22

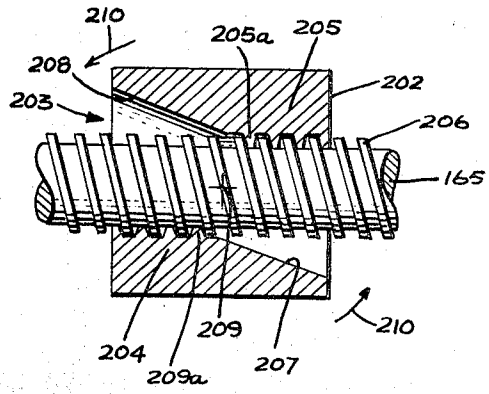
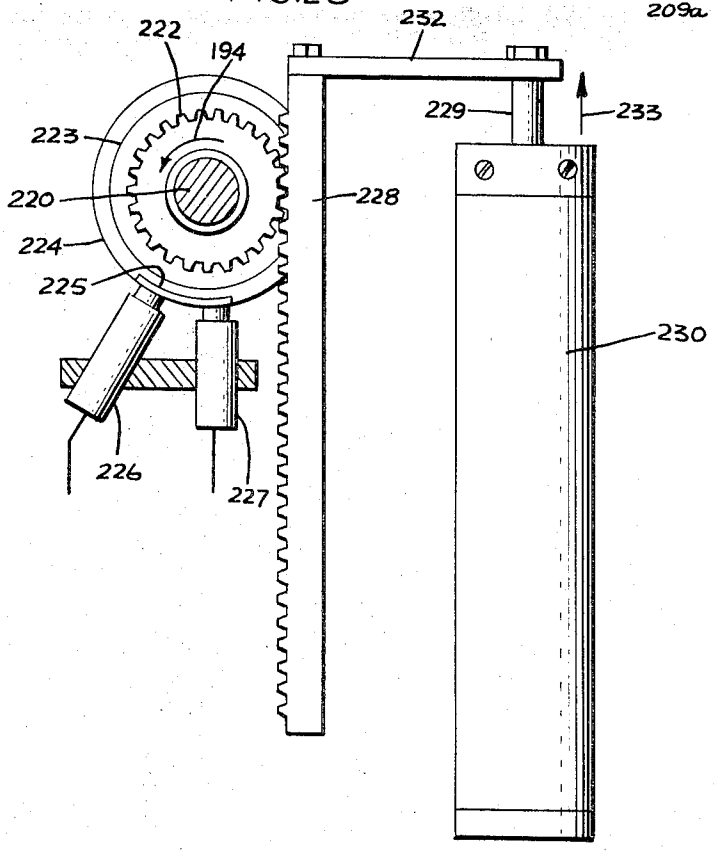


FIG.23



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FIG. 24

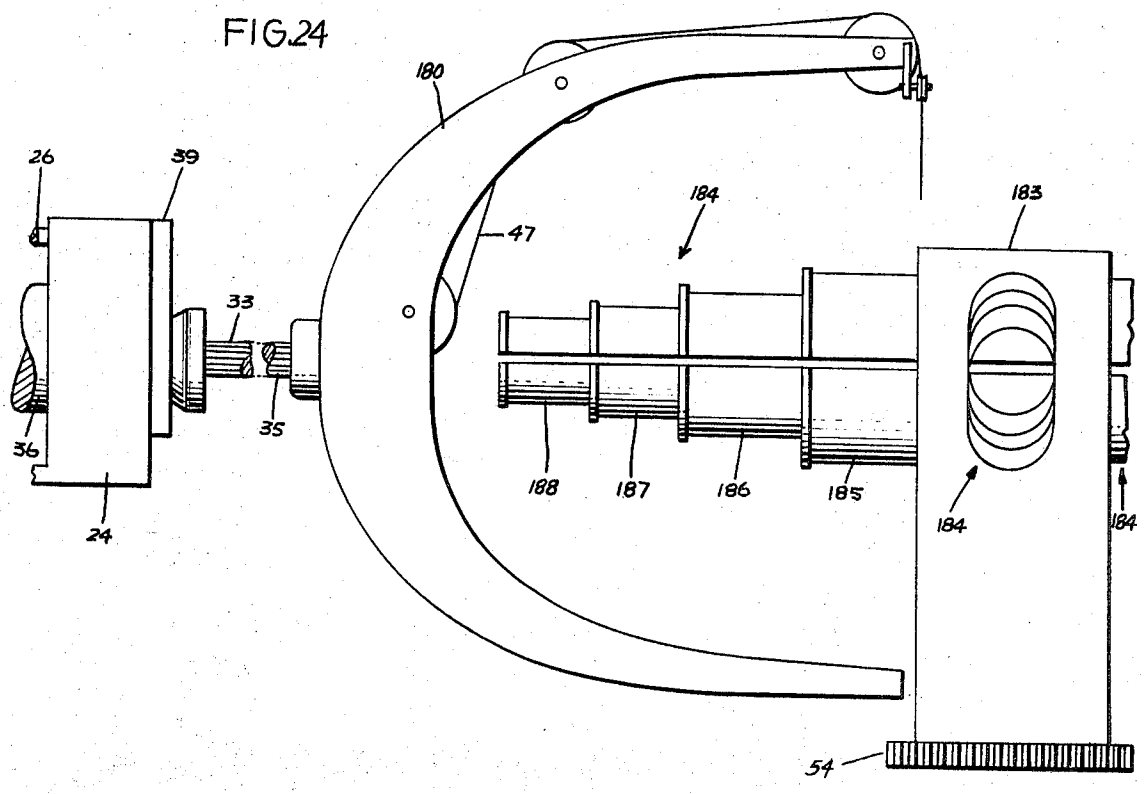
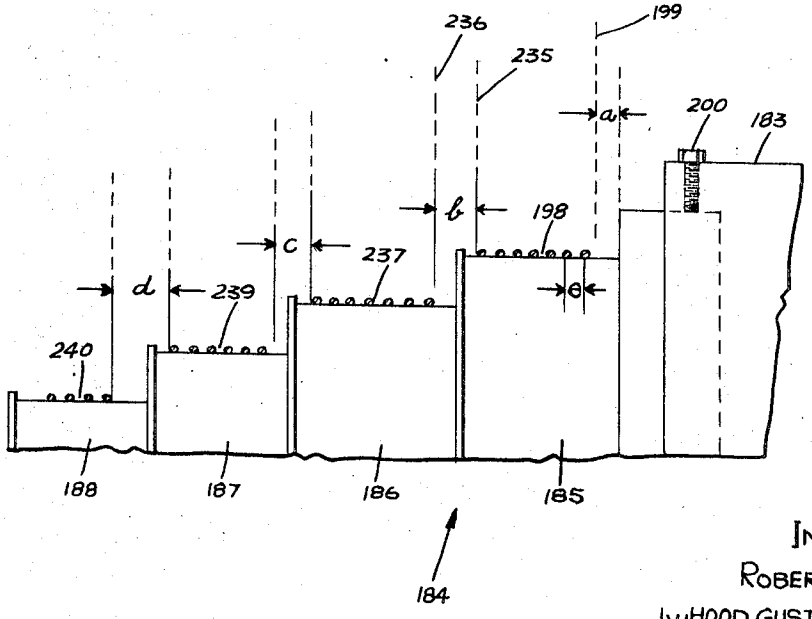
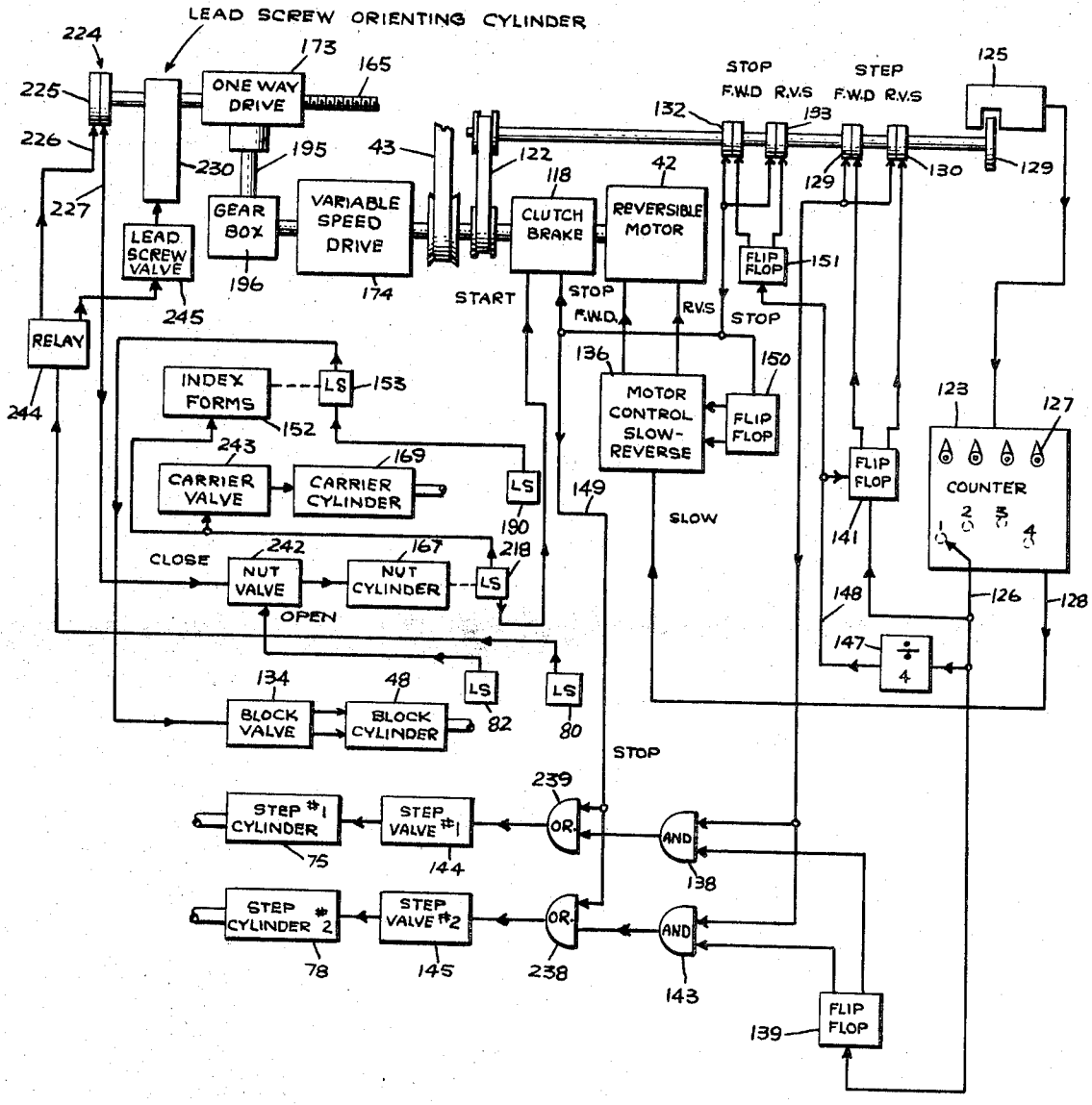


FIG. 25



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FIG.26



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COIL WINDING APPARATUS AND METHOD

This application is a continuation-in-part of application Ser. No. 717,819.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to coil winding apparatus, and more particularly to apparatus for winding dynamoelectric machine coils upon a coil form having a plurality of steps of progressively smaller size.

2. Description of the Prior Art

In U.S. Pat. No. 3,415,292, there is disclosed apparatus for winding dynamoelectric machine coils upon stepped coil forms which are adapted to be transferred, with the coils thereon, to another location in cooperative relationship with the blades of the coil insertion apparatus so as to permit the coils to be transferred directly from the coil forms to the blades. That apparatus incorporated a conventional flyer winder for winding the coils upon the steps of the coil forms.

SUMMARY OF THE INVENTION

In the design of coil winding apparatus suitable for use with apparatus of the type disclosed in the aforesaid Ericson Patent, a number of interrelated functions must be performed. It is necessary that the flyer be traversed across each step of the form, either in oscillatory fashion to provide a conventional multilayer coil, or continuously to provide a single-layer coil. It is further necessary that the flyer be moved axially from one step to the next of the coil form in order to wind the successive coils thereon. In some instances, some of the steps of the coil form may be axially longer than others and, in such cases, it is desirable that the throw of the oscillatory motion of the flyer be adjusted accordingly. Further, it is desirable that the flyer be positioned to have the same starting point both axially and rotationally with respect to each step of the coil form. Additionally, most commonly the coils of each successive pole are wound in a direction opposite from that in which the coils of the preceding pole were wound and thus it is necessary to stop and reverse the flyer at the completion of each pole. Finally, it is highly desirable that the entire winding operation be automatically performed at high speed.

The invention in its broader aspects therefore provides apparatus for winding coils upon a coil form having means which form a plurality of axially extending steps of progressively smaller size. The apparatus comprises flyer means mounted on a shaft and including means for winding an elongated strand on the steps to form the coils. First means is provided for rotatably supporting the shaft and drive means is provided coupled to the shaft for rotating the same thereby to rotate the flyer means. Second means is provided for supporting the first support means for longitudinal movement parallel with the axis of the shaft. First means is provided on the second support means and operably connected to the first support means for longitudinally moving the first support means and shaft thereby to position the flyer means in winding relationship with the coil form means steps, and second means is provided operably connected to the second support means for moving the same longitudinally thereby moving the first support means and shaft longitudinally to traverse the flyer means with respect to the coil form means.

It is accordingly an object of the invention to provide improved apparatus for winding coils upon a coil form having a plurality of steps of progressively smaller size.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view in perspective showing one embodiment of the improved coil winding apparatus of the invention in conjunction with coil forms of the type illustrated and described in the aforesaid Ericson Application and Patent;

FIG. 2 is a top view of the winding apparatus of FIG. 1 shown in position for winding the largest of the coils;

FIG. 3 is a fragmentary side view as viewed generally along the line 3–3 of FIG. 1, showing one embodiment of the oscillatory transversing and throw shifting mechanism of the invention;

FIG. 4 is a fragmentary view, partly in cross section, taken generally along the line 4–4 of FIG. 2;

FIG. 5 is a fragmentary top view, similar to FIG. 2, showing the positioning of the latching mechanism and block for winding the largest of the coils;

FIG. 6 is a fragmentary top view showing the positioning of the latching mechanism and block for winding the next-to-largest coil;

FIG. 7 is a fragmentary top view showing the positioning of the latching mechanism and block for winding the next-to-smallest coil;

FIG. 8 is a fragmentary top view showing the positioning of the latching mechanism and block for winding the smallest coil, and also showing the operation of the latching mechanism;

FIG. 9 is a fragmentary view, partly in section and partly broken away, showing the positioning of the coil forms of FIG. 1, with respect to the blades of coil inserting apparatus;

FIG. 10 is a fragmentary side view, similar to FIG. 3, showing the throw shifting mechanism in one of its positions;

FIG. 11 is a fragmentary side view, similar to FIG. 10, showing the throw shifting mechanism in the other of its positions;

FIG. 12 is a fragmentary side view, similar to FIG. 3, further showing the oscillatory traversing mechanism and the action of the shifting mechanism;

FIG. 13 is a fragmentary, schematic view showing another form of shifting mechanism;

FIG. 14 is a schematic view showing the control system employed with the apparatus of FIG. 1;

FIG. 15 is a fragmentary, schematic view showing the provision of retractable coil forms for use with the winding apparatus of the invention;

FIG. 16 is a fragmentary, schematic view showing transferring of the retractable coil forms of FIG. 15, from the winding position to the coil inserting position;

FIG. 17 is a fragmentary, schematic view showing another embodiment of the invention employing continuous traversing of the flyer;

FIG. 18 shows a modified and preferred form of the embodiments of FIGS. 15 and 16;

FIG. 19 is a top view of another embodiment employing continuous traversing of the flyer;

FIG. 20 is a side view of the embodiment of FIG. 19 taken generally along the line 20–20 of FIG. 19;

FIG. 21 is a fragmentary side cross-sectional view taken generally along the line 21–21 of FIG. 20;

FIG. 22 is a fragmentary cross-sectional view taken generally along the line 22–22 of FIG. 21;

FIG. 23 is a fragmentary cross-sectional view taken generally along the line 23–23 of FIG. 19;

FIG. 24 is a fragmentary side view illustrating the flyer and coil forms employed with the embodiment of FIGS. 19 and 20;

FIG. 25 is a fragmentary view further illustrating the coil forms of FIG. 24 and useful in explaining the operation of the embodiment of FIGS. 19 and 20; and

FIG. 26 is a schematic view showing the control system employed with the apparatus of FIGS. 19 and 20.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1 through 12 of the drawings, one embodiment of the improved coil winding apparatus of the invention, generally indicated at 20, is shown in conjunction with four collapsible coil forms, generally indicated at 22, of the type further described and illustrated in the aforesaid Ericson Patent.

The winding apparatus 20 comprises a frame 21 which may be mounted upon the inserting apparatus in the manner shown in the aforesaid Ericson Patent. Frame 21 includes longitudinally spaced, upstanding end portions 23 and 24 having a pair of transversely spaced-apart guide rods 25 and 26 extending longitudinally therebetween. A carrier member 27 is mounted upon the guide rods 25 and 26 for longitudinal movement thereon in the direction shown by the arrows 28.

Carrier 27 has a longitudinally extending slot 29 formed therein. A block 30 is supported on the carrier 27 for longitudinal movement in the direction 28 independently of the movement of the carrier 27. Block 30 has a portion 32 which extends downwardly through the slot 29 in the carrier 27.

A splined shaft 33 is provided having a conventional flyer 34 secured to its end 35. A bearing member 36 supports the splined shaft 33 for axial movement in the direction 28, and is in turn supported for rotational movement by bearings 37 and 38 respectively mounted on end portion 24 of frame 21 and bracket 39 spaced from end portion 24, as best seen in FIGS. 1 and 4. Thus, splined shaft 33 and flyer 34 are supported for both rotational and axial movement.

A suitable drive pulley 40 is mounted on the bearing member 36 between frame end portion 24 and bracket 39 and is rotatably driven through a suitable belt 43 by a suitable drive motor 42 mounted beneath the frame 21. Thus, splined shaft 33 and the flyer 34 are rotated by means of pulley 40, belt 43 and the motor 42.

The inner end 44 of the splined shaft 33 is secured to and rotatably supported in portion 32 of the block 30 by means of suitable bearings 45. Thus, movement of block 30 in the direction 28 will result in axial movement of splined shaft 33 and the flyer 34. Splined shaft 33 has an aperture 46 extending axially therethrough through which the wire 47 passes to the flyer 34 in conventional fashion. Wire 47 is drawn from a conventional source (not shown) such as a spool or other wire container.

A conventional fluid cylinder 48 is provided mounted on carrier 27 and having its piston rod 49 connected to the block 30, as at 50. Thus, actuation of the fluid cylinder 48 will move the block 30 together with splined shaft 33 and the flyer 34 axially in direction 28 with respect to the carrier 27, as will hereinafter be more fully described. Further, in any of the several positions of block 30 with respect to carrier 27 to be described, block 30 together with splined shaft 33 and flyer 34 will move in unison with movement of the carrier 27 in the direction 28.

Referring now particularly to FIGS. 1, 5 and 9, in the illustrated embodiment intended for winding four sets of coils for a four-pole motor, four identical sets of coil forms 52 are provided each pivotally mounted upon a support 53 which, in turn, is supported by an indexing gear 54, as more fully described in the aforesaid Ericson Patent. Each of the coil forms 52 is thus arranged for pivotal movement between a winding position with its axis parallel with the axis of the splined shaft 33 and flyer 34, as shown in FIGS. 1 and 5, and a coil transferring position, as shown in FIG. 9. Indexing gear 54 is, in turn, rotatably supported by a member 55 which is mounted for longitudinal movement upon guide rods 56 and 57 which form a part of the transfer mechanism shown and described in the aforesaid Ericson Patent. As likewise disclosed in that Patent, mechanism 58 is provided for pivoting coil forms 52 from their winding position to their transferring position. Each of the coil forms 52 is provided with a part-annular groove 59 permitting the coil form with the coils thereon to be interfitted with the circular array of blades 60 of coil inserting apparatus 61, all as more fully described and illustrated in the aforesaid Ericson Patent.

In the illustrated embodiment, each of the coil forms 52 is provided with four axially extending steps 63, 64, 65 and 66 of progressively smaller size for forming four concentric coils which collectively comprise one pole of the motor. Further, in the illustrated embodiment, the largest step 63 and the next-to-largest step 64 are axially wider than the next-to-smallest step 65 and the smallest step 66, as best seen in FIG. 5.

It is necessary that the flyer 34 be positioned successively to wind coils on the progressively smaller steps 63, 64, 65 and 66 of the coil form 52, in FIG. 5 the flyer 34 is shown positioned for winding a coil on the largest step 63.

In order to provide this sequential stepping of the flyer 34 in the direction shown by the arrow 67, in FIG. 5, so as sequentially to wind the four progressively smaller coils on the progressively smaller steps 63, 64, 65 and 66, block 30 is provided with four longitudinally spaced abutments 68, 69, 70 and 71, abutments 68 and 70 being disposed in spaced-apart relationship on one side of the block and abutments 69 and 71 being disposed in spaced-apart relationship on the other side of the block and respectively intermediate abutments 68 and 70, as shown in FIG. 2.

Latch 73 is pivotally mounted on carrier 27, as at 74, and cooperates with abutments 68 and 70. Latch 73 is selectively actuated by fluid cylinder 75. Latch 76 is pivotally mounted on carrier 27, as at 77, and cooperates with abutments 69 and 71. Latch 76 is selectively actuated by fluid cylinder 78.

In operation, as will hereinafter be more fully described, cylinder 48 is initially actuated to move block 30 together with the splined shaft 33 and flyer 34 outwardly in the direction shown by the arrow 79 to its extreme forward position so that the flyer 34 is positioned for winding the largest coil on the step 63 of the coil form 52, as shown in FIG. 5, latch 73 engaging abutment 68 to retain block 30 together with the splined shaft 33 and the flyer 34 in that position. The actuation of the cylinder 48 is then reversed to apply a biasing force on the block 30 rearwardly in the direction shown by the arrow 67 in FIG. 5, rearward movement of the block 30 however being restrained by engagement of latch 73 with abutment 68. When the requisite number of turns have been wound on the largest step 63 of coil form 52, as will hereinafter be described, cylinder 75 is actuated thereby to pivot the latch 73 away from the abutment 68, in the manner shown in FIG. 8, thereby permitting the cylinder 48 to move the block 30 together with splined shaft 33 and flyer 34 rearwardly in direction 67. However, this rearward movement is only for the incremental distance between abutment 68 and abutment 69 which engages the latch 76, as shown in FIG. 6, thereby positioning the flyer 34 for winding the coil on the step 64 of the coil form 52.

When the requisite number of turns have been wound on the step 64, cylinder 78 is actuated thereby pivoting the latch 76 and permitting the block 30 together with splined shaft 33 and the flyer 34 to be moved the next incremental distance until latch 73 engages abutment 70, as shown in FIG. 7, thereby positioning the flyer 34 for winding a coil on the step 65 of the coil form 52. When the requisite number of turns have been wound on that step, the cylinder 75 is again actuated to release the latch 73 and the block 30 is then moved by the cylinder 48 the final incremental distance until latch 76 engages abutment 71, as shown in FIG. 8. It will be seen that abutments 68 and 69 are provided with beveled rear edges thereby permitting cylinder 48 to return block 30 to its initial position as shown in FIGS. 2 and 5 without necessitating actuation of the cylinders 75 and 78.

Limit switches 80 and 82 may be provided for sensing proper locationing of the block 30 together with splined shaft 33 and flyer 34 at the extreme outer and inner positions.

Referring now particularly to FIGS. 3, 10, 11 and 12, carrier 27 along with block 30, splined shaft 33 and flyer 34 is oscillated thereby to provide the requisite traversing motion by means of a slide member 83 mounted for longitudinal movement on the frame 21 by means of suitable guides 84 and 85. A heart-shaped cam 86 is provided driven by the motor 42 through a suitable right-angle gearbox 87 and conventional variable speed belt drive 88. The heart-shaped cam 86 cooperates with a cam follower roller 89 mounted on the slide 83 and it will thus be seen by reference to FIGS. 3 and 12 that rotation of the heart-shaped cam 86 will cooperate with the cam follower roller 89 to provide a reciprocatory motion to the slide 83 as shown by the arrows 90.

End 92 of slide 83 is coupled to carrier 27 by a lever member 93. More particularly, lever member 93 has slots 94, 95 in its opposite ends which accommodate and cooperate with rollers 96 and 97 respectively mounted on end 92 of slide 83 and on carrier 27.

Lever member 93 is pivotally connected, as at 98, to member 99 which is slidably mounted on the frame end portion 23 for movement as shown by the arrows 100. Fluid cylinder 102 is mounted on the member 99 and has its piston rod 103 connected to a bracket 104 secured to the frame end portion 23. Particular reference to FIGS. 10 and 11 will reveal that when the cylinder 102 is deactuated, i.e. with its piston rod 103 retracted, member 99 and lever 93 are in an upper position, the linkage being such in this position that the reciprocatory movement of the slide 83 imparts a minimum throw to the slide 27 corresponding to the width of the narrower steps 65 and 66 of the coil form 52. However, when the cylinder 102 is actuated thereby to extend its piston rod 103, member 99 and lever 93 are moved downwardly thereby effectively changing the pivot point of the lever 93 and changing the linkage so that the same reciprocatory movement 90 of the slide 83 now imparts a maximum throw to the carrier 27 and the block 30, splined shaft 33 and flyer 34, which move therewith, corresponding to the wider steps 63 and 64 of the coil form 52. An adjustable stop 105 may be provided on the frame 21 for adjustably setting the lower position of the member 99 and thus the extent of the larger throw, and adjustment of the piston rod 103 on the bracket 104, as by the nut 106, provides comparable adjustment of the upper position and thus the extent of the smaller throw.

It is desirable that the flyer 34 by initially positioned at the same relative point with respect to each of the coil form steps 63, 64, 65 and 66 at the beginning of the winding of the respective coil, as suggested by the dashed line 107 in FIG. 5. In order to provide this initial positioning, a cylinder 108 is provided mounted on the frame end portion 24 and having its piston rod 109 connected to end 110 of the slide 83. When piston rod 109 of cylinder 108 is extended, cam follower roller 89 is in engagement with the heart-shaped cam 86 which thus imparts the reciprocatory motion 90 to the slide 83. However, when piston rod 109 of cylinder 108 is retracted, as shown by the arrow 112 in FIG. 12, slide 83 is moved to one extreme position with the cam follower roller 89 out of engagement with the cam 86, as shown by the dashed lines 89*a*, thus actuating the lever member 93, to move the carrier 27 to its extreme right-hand position, as shown by the dashed lines 27*l*, thereby to position the flyer 34 adjacent the outer edge of the respective coil form step. During normal operation, cylinder 108 is actuated to extend its piston rod 109 in the direction shown by the arrow 113 thereby to maintain the cam follower roller 89 in engagement with cam 86.

Inspection of FIG. 12 will reveal that after actuation of the cylinder 108 has been reversed thereby to extend piston rod 109 in the direction 113, the cam 86 may travel a partial turn before it again engages the cam follower roller 89.

Referring now to FIG. 13, in an alternative arrangement, a pair of cam follower rollers 114, 115 are provided respectively mounted on the slide 83 and engaging the cam 86. Here, a fluid actuated clutch 116 is provided interposed between the cam 86 and the gearbox 87 (FIG. 2). With this arrangement, when valve 117 is actuated so as to actuate the cylinder 108 to retract its piston rod 109, the fluid actuated clutch 116 is actuated to release 27 driving connection of the cam 86 with the two cam follower rollers 114 and 115 thus rotating the cam 86 from whatever position it may have been in to its position 19 in FIG. 13 so that the cam has the same starting position for each coil, thus eliminating a small amount of lost motion.

Referring now to FIG. 14, a control system is shown for automatically sequencing the apparatus shown in the previous FIGS. Here, motor 42 is of the reversible-type and drives the belt 43, which in turn drives pulley 40, splined shaft 33 and the flyer 34, through a conventional clutch-brake 118. Output shaft 119 of clutch brake 118 drives a timing shaft 120 through a suitable belt drive 122. A conventional revolution counter 123, preferably of the solid-state type, is provided for counting the number of turns of the respective coils. Counter 123 is actuated in conventional fashion by a counting wheel 124 on the timing shaft 120 which cooperates with a conventional photo cell 125. Counter 123 is of the type which provides a signal responsive to the number of turns wound in each of the four coils in its turns signal output circuit 126, as determined by the four turns selection dials 127. Counter 123 further provides an early warning signal in early warning line 128 a predetermined number of turns, such as six, in advance of completion of the winding of the present number of turns of each coil. It will be readily understood that counters of the type here described are commercially available and thus that counter 123 need not be further described.

Forward and reverse stepping commutators 129 and 130, and forward and reverse stopping commutators 132 and 133 are respectively driven by the timing shaft 120, these commutators determining the proper rotational position of the flyer 34 for the stepping and stopping operations for each direction of rotation.

Assuming now that it is desired to wind a set of coils on a coil form 52, dials 127 of the counter 123 are respectively set to the desired number of turns in each of the four coils. A start switch (not shown) is then actuated which will actuate block valve 134, in turn to actuate the block cylinder 48 to move the block 30, splined shaft 33 and flyer 34 to their extreme forward positions, as shown in FIGS. 2 and 5, shift valve 117 is actuated to actuate the shift cylinder 108 so as to shift carrier 27, block 30, splined shaft 33 and flyer 34 to the outer edge of step 63 of coil form 52, as shown by the dashed line 107 in FIG. 5, the change throw valve 135 is actuated to actuate change throw cylinder 102 thereby to shift the lever 93 to provide the longer throw for carrier 27, and the motor control 136 is actuated to start the motor at a predetermined high speed in the forward winding direction. Actuation of the shift cylinder 108 is only momentary and thus the cam 86 immediately begins to impart the reciprocatory motion 90 to the slide 83.

At the predetermined number of turns in advance of completion of the winding of the first coil on the step 63, an early warning signal 137 is provided in early warning line 128 which persists until completion of the first coil. Early warning line 128 is coupled to the motor control 136 which is thus actuated in response to the early warning signal 137 to reduce the motor speed from its higher winding speed to a predetermined lower speed. Early warning line 128 is also connected to the shift valve 117 and the early warning signal 137 thus actuates the shift valve, in turn to actuate the shift cylinder 108 to shift the slide 83 in the direction 112 thereby to return the flyer 34 to the forward position 107.

At the conclusion of the winding of the requisite number of turns in the first coil on step 63, counter 123 provides a signal in the turns signal line 126. Turn signal line 126 is coupled by a flip-flop 141 to the forward commutator 129 which, at the predetermined desired rotational position of flyer 34, connects line 126 to line 137*a* to apply the turn completion signal to AND gate 138. Turn signal line 126 is also coupled to conventional flip-flop circuit 139 having its two output circuits 140 and 142 respectively coupled to AND gates 138 and 143. Appearance of the first turn completion signal in line 126 actuates the flip-flop 139 to apply a signal to line 140 and coincidence of the turn completion signals in line 140 and in line 137*a* responsive to proper rotational positioning of the forward step commutator 129 will result in application of a signal by the AND gate 138 to the step valve 144. ACtuation of step valve 144 will in turn actuate step cylinder 75 to release latch 73 thereby permitting the block cylinder 48 to move the block 30, splined shaft 33 and flyer 34 rearwardly until latch 76 engages abutment 69, as shown in FIG. 6. Termination of the early warning signal 137 at the end of the predetermined count for the first coil, i.e. in coincidence with the appearance of the turns signal in line 126, will actuate motor control 136

to increase the motor speed to its higher level, and will deactuate the shift valve 117 thereby deactuating the shift cylinder 108.

Flyer 34 now proceeds to wind the second coil on step 64 of the coil form 52, as above-described in connection with the first coil. However, upon appearance of the turn completion signal in line 126 indicating completion of the second coil, flip-flop 139 is actuated to apply a signal in its output line 142 and thus to the AND gate 143 thereby to actuate step valve 145 and the step cylinder 78 to release latch 76 from abutment 69 and in turn to permit block cylinder 48 to move block 30, shaft 33 and flyer 34 to the third position for winding the coil on step 65 of the coil form 52 with latch 73 now in engagement with abutment 70, as shown in FIG. 7.

Turn signal line 126 is coupled to the change throw valve 135 by a conventional divide-by-two circuit 146. Thus, upon the appearance of the second turn completion signal indicating completion of the second coil, a signal is applied to the change throw valve 135 to deactuate the change throw cylinder 102 thereby to shift the lever 93 to provide the shorter throw for carrier 27 for subsequently winding coils on the narrower steps 65 and 66 of the coil form 52. Winding of the next two coils on the steps 65 and 66 of coil form 52 then continues as above-described.

The turns signal line 126 is coupled to the stop commutators 132, 133 by a conventional divide-by-four circuit 147 and flip-flop 151. Thus, appearance of the fourth turn completion signal in line 126 indicating completion of the fourth and final coil, results in appearance of a signal in line 148 coupled to the forward stop commutator 132. That signal is applied at the proper rotational position of the flyer 34 by commutator 132 to clutch brake 118 which actuates the same to release the clutch and apply the brake thereby to stop the flyer 34 at the desired position. The stop signal appearing in line 149 is also applied to another conventional flip-flop circuit 150 which is coupled to the motor control 136 and thus actuates the same to reverse the direction of rotation of the motor 42.

The stop signal in line 149 is applied to the form indexing mechanism 152 which rotates the indexing gear 54 and the forms by 90° so as to position a new set of forms 52 for winding. A stop signal in line 149 is also applied to the block valve 134 which actuates the block cylinder 48 to return the block 30, shaft 33 and flyer 34 to their initial forward position. Return of the block 30 to its forward position, as shown in FIG. 2, actuates the limit switch 80 which, upon completion of indexing the forms and closing of the limit switch 153, actuates the clutch brake 118 to release the brake and actuate the clutch thereby to initiate a new winding operation in the opposite direction. The signal from divide-by-four circuit 147 actuates flip-flop 141 to couple line 126 to reverse step commutator 130, and actuates flip-flop 151 to couple line 148 to reverse stop commutator.

Referring now to FIGS. 15 and 16, instead of the pivotal mounting of the coil forms 52 as shown in FIGS. 1 and 9, coil forms 52 may be mounted upon a rotatable plate member 154 with their axes 155 parallel with the axis of the splined shaft 33 and flyer 34. Plate member 154 is in turn rotatably mounted upon an arm 156 which is pivotally mounted by means of a post 157 upon the baseplate 158 of the coil insertion apparatus 61. In this embodiment, the coil winding apparatus 20 of this invention is likewise mounted on the base plate 158 with the shaft 33 vertically disposed, as shown. Coil forms 52 are respectively mounted on the piston rods 159 of conventional fluid cylinders 160 which thus serve to move the coil forms 52 vertically in the direction shown by the arrows 162 between an upper retracted position and a lower winding position in winding relationship with the flyer 34. Thus, with this arrangement, plate member 154 is rotated by means of a suitable drive motor 163 to position a coil form 52 in axial alignment with the shaft 33 and flyer 34, and then the respective cylinder 160 is actuated to move the coil form 52 downwardly to its winding position, as shown in solid lines in FIG. 15. When all four coils have been wound on that coil form 52, cylinder 160 is again actuated to retract the coil form to its position shown in dashed lines, and the plate member 154 is then rotated to bring another coil form 52 into axial alignment with the shaft 33 and flyer 34 for winding coils thereon.

Referring particularly to FIG. 16, when coils have been wound as above-described on all of the coil forms 52, the arm 156 is then rotated to the position shown in dashed lines 156*a* with one of the coil forms 52 in alignment with the blades 60 of the coil insertion apparatus 61, similar to the positioning shown in FIG. 9. A suitable fluid cylinder 164 is then actuated to move the post 157 and arm 156 downwardly so as to move the coil form 152 with the coils thereon into cooperative coil-transferring relationship with the inserter blades 60. Upon transfer of the coils from the first coil form 52 to the inserter blades 60, post 157 and the arm 156 are then moved upwardly, plate member 154 is rotated to bring another coil form with the coils thereon into alignment with the inserter blades 60. The inserter blades are indexed, and the arm 156 is again moved downwardly to bring the new coil form 52 with the coils thereon into cooperative coil transferring relationship with the inserter blades 60. After all of the coils have thus been transferred to the inserter blades, post 157 is then moved upwardly and arm 156 is rotated back to its winding position, as shown in FIG. 15, and the winding of a new set of coils is initiated.

Referring now to FIG. 17, it may be desirable to provide single layer-wound coils rather than multilayer coils provided by the embodiment of FIGS. 1 through 12. In this embodiment, carrier 27 along with the block 30, splined shaft 33 and flyer 34 is traversed by a lead screw 165 mounted on the frame end portions 23 and 24. Carrier 27 is connected to the lead screw 165 by a conventional half-nut, shown schematically at 166, actuated by a suitable fluid cylinder 167. Carrier 27 is thus traversed in the direction shown by the arrow 168 by the lead screw 165 and upon release of the half-nut 166, by the fluid cylinder 167, is returned to its initial forward position by means of a suitable fluid cylinder 169 mounted on frame end portion 23 and having its piston rod 170 connected to carrier 27. Lead screw 165 is driven by a suitable belt drive 172 through a conventional one-way drive 173 and a conventional variable speed drive 174 from the drive shaft 119.

In this embodiment, the reciprocatory mechanism actuated by the cam 86, the change throw mechanism actuated by the cylinder 102, and the shift mechanism actuated by the cylinder 108 are not required, carrier 27 being moved transversely in direction 168 by lead screw 165. However, the latching mechanism actuated by cylinders 75 and 78 and the block cylinder 48 for shifting the block 30, splined shaft 33 and carrier 34 is retained. A suitable limit switch 175 is provided in this embodiment for indicating that the carrier 27 has reached its extreme inner position and thereby to actuate the return cylinder 169.

Referring now to FIG. 18 in which like elements are indicated by like reference numerals employed in FIGS. 14 and 15, coil forms 52 are preferably mounted on rotatable plate member 175 in the same relative positions as the pivoted positions of the coil forms shown in FIG. 9. Here, each coil form 52 is again mounted on the piston rod of a conventional fluid cylinder 160 which moves the coil form between a lower protracted winding position and an upper retracted position. Coil forms 52 are equally radially spaced about axis 176, which here is the axis of rotation of plate member 175*a* Plate member 175*a* is rotatably mounted on arm 156 and is indexed by drive motor 163.

In operation of the embodiment of FIG. 18, plate member 175*a* is indexed to bring the axis of a respective coil form 52 into alignment with the axis of flyer 34 and shaft 33, and the respective cylinder 160 is actuated to move the coil form downwardly to its position in winding relationship with flyer 34. The coils are now wound on the coil form following which the coil form with the coils thereon is retracted to its upper position, plate member 175*a*, is indexed to bring a new coil form into alignment with flyer 34, and the process is repeated.

When all of the coils have been so wound, arm 156 is pivoted to a position with axis 176 in alignment with the axis of the inserter blades 60, as shown in dashed lines at 176*a*. The coil forms 52, with the coils thereon, are now in the same relationship with the inserter blades as shown in FIG. 9. Arm 156 is then lowered by cylinder 164 to the position shown in dashed lines at 156*a* with all of the coil forms 52 in cooperative interfitting relationship with inserter blades 60. The forms are then collapsed and all of the coils are simultaneously transferred to the blades 60. It will be seen that in this embodiment in which the coil forms 52 are in the same position during winding as in unloading (in contrast with the pivoting of the coil forms in the embodiment of FIGS. 1 and 9), shorter interpole connections are provided.

Referring now to FIGS. 19 through 25 of the drawings, in which like elements are indicated by like reference numerals, another embodiment of the invention is shown for winding single layer coils. Here, carrier 27 is again mounted on guide rods 25, 26 for longitudinal movement thereon, guide rods 25, 26 extending between end portions 23, 24 of frame 21. Block 30 is supported on carrier 27 for longitudinal movement independently of the movement of carrier 27, block 30 having a portion 32 which extends downwardly through slot 29.

Splined shaft 33 having flyer 180 secured to its end 35 is provided mounted to rotational and axial movement by bearings 36, 37 and 38 (FIG. 3). Drive pulley 40 is mounted on bearing member 36 and is rotatably driven through belt 43 by drive motor 42. Inner end 44 of splined shaft 33 is secured to and rotatably supported in portion 32 of block 30.

Fluid cylinder 48 is mounted on carrier 27 and has its piston rod 49 connected to block 30 thus moving block 30 together with splined shaft 33 and flyer 180 axially with respect to carrier 27. It will thus be seen that splined shaft 33 and flyer 180 are supported for both rotational and axial movement, that movement of block 30 by cylinder 48 will move splined shaft 33 and flyer 180 axially, and that movement of carrier 27 on guide rods 25, 26 will also move block 30 together with splined shaft 33 and flyer 180.

Block 30 again is provided with longitudinally spaced abutments 68, 69, 70 and 71 which cooperate with pivoted latches 73 and 76 respectively actuated by fluid cylinders 75 and 78, as above described. In the illustrated embodiment, block 30 is removably secured to portion 32, as by threaded fasteners 182 in order to provide for substitution of different blocks having different spacings of the abutments 68—71 for winding different coils, as will hereinafter be more fully described. Limit switches 80 and 82 mounted on carrier 27 sense the extreme forward and rearward positions of block 30 respectively.

The embodiment of FIGS. 19—25 is shown employed as a prewinder, i.e. for winding dynamoelectric machine coils which are manually removed from the coil forms after winding and thereafter inserted in the slots of A dynamoelectric machine stator core member. However, it will be readily understood that this embodiment may also be employed for winding coils on coil forms arranged for direct transfer of the coils to the fingers of coil transfer apparatus, as in the embodiments illustrated in FIGS. 9, 15, 16 and 18. Here, block 183 is provided having four identical, collapsible, stepped coil forms 184 for forming the four-pole groups of coils for a four-pole dynamoelectric machine, only three of the coil forms 184 being shown in FIG. 24. In the illustrated embodiment, each of the coil forms 184 has four progressively smaller steps 185, 186, 187, and 188 for forming four concentric coils of one pole group. It will be readily understood that a lesser number of coil forms, such as two for a two-pole machine, or a greater number such as six for a six-pole machine, and that lesser or greater numbers of steps on each coil form 184 may be employed. Block 183 and the coil forms 184 are mounted on indexing gear 54 so that the coil forms may selectively be indexed to rotate an unwound coil form 184 to the winding position, and at the same time to rotate a wound coil form to an unloading station.

As in the case of the embodiment of FIG. 17, carrier 27 together with block 30, splined shaft 33, and flyer 180 is moved axially in the direction shown by the arrow 168 by lead screw 165 thereby to traverse flyer 180 across the coil forms 184, the winding of the coils upon the steps 185, 186, 187 and 188 progressing in direction 168 from the largest step 165 to the smallest step 188. Carrier 27 along with block 30, splined shaft 33 and flyer 180 is moved axially in the direction opposite that shown by arrow 168, thereby to return flyer 180 to its initial position, as shown in FIG. 24, by fluid cylinder 169 mounted on frame portion 23 and having its piston rod 170 connected to carrier 27. Forward motion of carrier 27 by cylinder 169, i.e. toward block 183, is limited by a stop 189 on end wall portion 24. Proper locating of carrier 27 at its extreme forward position is sensed by a limit switch 190 which is engaged by a projection 192 on carrier 27. Movement of carrier 27 to its extreme rearward position by lead screw 165 is sensed by limit switch 193 which is also engaged by projection 192.

Lead screw 165 is rotatably driven in one direction only, as shown by the arrow 194 in FIG. 23, by a conventional one-way drive 173 having its input shaft 195 operatively coupled to reversible motor 42 by right-angle gearbox 196, variable speed drive 174 and clutch-brake 118 (FIG. 26). Lead screw 165 is operatively coupled to carrier 27 for moving the carrier in direction 168 by means of a nut assembly 197, to be hereinafter more fully described, which selectively engages and disengages lead screw 165.

It will be readily understood that in order to permit cylinder 169 to return carrier 27, block 30, splined shaft 33 and flyer 180 to the forward winding position, it is necessary to actuate nut assembly 197 to disengage lead screw 165. Likewise, after carrier 27 has been returned to its extreme forward position, nut assembly 197 must be actuated again to engage lead screw 165. It is desired that the flyer 180 initiate the winding of each largest coil 198 on the largest step 185 of coil form 184 at the same point with respect to block 183, as shown by the dashed line 199 in FIG. 25, this location of the starting end of the largest coil 198 being selectively adjusted by provision for axial movement of coil forms 184 in block 183, suitable threaded fasteners 200 being employed to retain coil forms 184 in the desired axial position, as shown in FIG. 25.

Nut assembly 197 includes a half-nut 202, as best seen in FIG. 22. Nut 202 has an aperture 203 formed therethrough through which lead screw 165 extends. Aperture 203 is provided with complimentary threaded portions 204, 205 which threadingly engage threads 206 of lead screw 165 when the nut is in the position shown in FIG. 22. Nut 202 further has complimentary outwardly tapered portions 207, 208 so that, when nut 202 is pivoted about axis 209 in the direction shown by the arrows 210, threaded portions 204, 205 will be disengaged from threads 206 so that lead screw 165 will freely turn within portions 207, 208.

Nut 202 is mounted for pivotal movement about axis 209 by means of stud 212 secured to depending flange portion 213 of carrier 27 (FIG. 21). Nut 202 is pivotally moved between its lead screw-engaging position, as shown in FIG. 22, and its disengaged position by means of a lever member 214 actuated by extension of piston rod 215 of fluid cylinder 216. Thus, actuation of fluid cylinder 216 and extension of its piston rod 215 will pivotally move lever member 214 in the direction shown by the arrow 210 thereby to pivot nut 202 about axis 209 so as to disengage threaded portion 204, 205 from lead screw 165. A coil spring 217 connected between lever member 214 and carrier 27 serves to return lever member 214 and nut 202 to the lead screw-engaging position upon deactuation of fluid cylinder 216. Limit switch 218 actuated by lever member 214 senses the engaged and disengaged positions of lever member 214 and nut 202.

It will now be seen that when cylinder 169 has returned carrier 27 to its extreme forward position properly locating flyer 180 for initiating winding of the largest coil 198, there will be only one rotational position of lead screw 165 with respect to

nut 202 in which nut 202 can be pivotally returned to its initial position with threaded portions 204, 205 engaging threads 206. However, without the feature of the invention now to be described, there is no assurance that the lead screw will have this rotational relationship with respect to threaded portions 204, 205, nut 202, e.g. lead screw 165 may be as much as 180° rotationally displaced from the position required for engagement of nut 202. Due to the taper on teeth 206 of lead screw 165 and on threaded portions 204, 205 of nut 202, the center portions 204*a*, 205*a* of threaded portions 204, 205 tend partially to engage lead screw threads 206 while nut 202 and lever member 214 have yet to travel a substantial angular amount before the threaded portions 204, 205 are in complete engagement with threads 206, however the angular position of lever member 214 at which this partial engagement takes place will not be sufficient to actuate limit switch 218. Since limit switch 218 is employed, as will hereinafter be described to initiate the new winding operation, the system is electrically dead and thus, with such partial engagement of nut 202 with lead screw 165, the new winding operation will not be initiated.

In order to eliminate this difficulty in accordance with the invention, the lead screw 165 is properly rotationally oriented to the extent necessary with respect to nut 202 prior to deactuation of cylinder 216 so that, upon the actuation of cylinder 216, nut 202 will pivot completely into driving engagement with threads 206 of lead screw 165 thereby actuating limit switch 218 to initiate the new winding operation. In order to provide this rotational orientation of lead screw 165 with respect to threaded portions 204, 205 of nut 202, the arrangement now to be described is provided. One-way drive mechanism 173 is provided with opposite output shafts 219, 220, both of which are driven in the same one direction 194 in response to rotation of input shaft 195 in either direction. A pinion 222 is coupled to output shaft 220 of one-way drive mechanism 173 by another conventional one-way drive device 223. Thus, rotation of pinion 222 in direction 194 will drive output shaft 220, output shaft 219 and lead screw 165 in direction 194, whereas rotation of pinion 222 in the opposite direction will not be transmitted to lead screw 165.

Commutator 224 is attached to output shaft 222 of one-way drive mechanism 173 and rotates therewith and thus with lead screw 165. Commutator 224 has a contact segment 225 thereon which thus has a fixed rotational relationship with respect to lead screw 165 and, in turn, with the desired rotational positioning of lead screw 165 with respect to nut 202 to permit full engagement of the nut with the lead screw. Contact segment 225 cooperates with a pair of brushes 226, 227 and completes an electrical circuit therewith when the lead screw 165 is properly oriented with respect to nut 202.

Pinion 222 and lead screw 165 is rotated, independently of the main drive motor 42, by means of a rack 228 secured to piston rod 229 of fluid cylinder 230 by a suitable bracket 232. It will thus be seen that extension of piston rod 229 of cylinder 230 in direction 233 will linearly move rack 228 thereby to rotate pinion 222, shaft 220, shaft 219 and lead screw 165 in direction 194. It will be readily understood that driving of the one-way drive mechanism 173 by shaft 220 in direction 194 is in a direction relative to the direction of rotation of input shaft 195 to cause slippage of the one-way drive mechanism 173 so that the driving of lead screw 165 by rotation of pinion 222 in direction 194 is not transmitted back to input shaft 195. It will further be seen that when the lead screw 165 is properly rotationally oriented with respect to nut 202 as sensed by contact segment 225, contacting brushes 226 and 227 to complete a circuit therethrough, as will hereinafter be described, return of rack 228 and piston rod 229 of cylinder 230 to their initial positions, as shown in FIG. 23, resulting in rotation of pinion 222 in the opposite direction, will not result in rotation of shafts 220, 219 and lead screw 165.

Thus, with carrier 27 and block 30 in their extreme forward positions so as properly to position flyer 180 for initiating winding of the first coil 198 on the largest step 185 of coil form 184, commutator 224 and brushes 226, 227 sense whether lead screw 165 is properly oriented with respect to nut 202 to permit complete engagement with the lead screw threads. If by chance lead screw 165 is properly oriented, cylinder 216 is deactuated to permit lever 214, under the influence of spring 271, to pivot nut 202 to its lead screw-engaging position, whereupon limit switch 218 is actuated to energize clutch brake 118 thereby to initiate the winding operation together with rotation of lead screw 165 by one-way drive mechanism 173. On the other hand, if lead screw 165 is not properly oriented, fluid cylinder 230 is actuated thereby linearly moving rack 228 to rotate pinion 222, thereby rotating lead screw 165 through one-way drive mechanism 223 until proper rotational orientation is obtained, as sensed by commutator 224 and brushes 226,227 at which point cylinder 230 is deactuated and nut 202 is engaged with lead screw 165, as above-described.

In order mechanically to disengage nut 202 from lead screw 165 in case carrier 27 has been moved to its extreme rearward position, a stop 234 is provided on end wall portion 23 which engages downwardly projecting portion 235 of lever member 214, thereby mechanically pivoting lever member 214 and nut 202 to the disengaged position.

Referring now additionally to FIG. 26 in which like elements are still indicated by like reference numerals, it is assumed that motor 42 is operating in the forward direction, block 30 is in its extreme forward position thereby actuating limit switch 80, carrier 27 is in its extreme forward position thereby actuating limit switch 190, block 183 and forms 184 are properly positioned, thereby actuating limit switch 153, and lead screw 165 is properly oriented with nut 202 closed to engage lead screw 165 thereby actuating limit switch 281. Under these conditions, actuation of a start switch (not shown) will energize clutch brake 118 to drive splined shaft 33 and flyer 180 to commence winding the first coil 198 on step 185 of coil form 184, motor 42 being operated at high speed.

A predetermined number of turns in advance of completion of the coil 198, such as four turns, an early warning signal appears in line 128 which actuates motor control 136 to reduce the speed of motor 42 from its high winding speed to a predetermined lower speed. When the proper number of turns have been wound on the largest coil 198, as determined by the setting of counter 123, a signal appears in line 126 which is applied by flip-flop 141 to the forward stepping commutator 129. Thus, when flyer 180 is in the proper rotational position, commutator 129 applies the turn completion signal in line 26 to AND gate 138. Flip-flop 139 also applies the signal in line 26 responsive to completion of the first coil 198 to AND gate 138, which thus applies a signal through OR gate 234 to step valve 144 which actuates step cylinder 75 to release latch 73 thereby permitting block 30 to be moved rearwardly by cylinder 48 until abutment 69 engages latch 76.

Referring additionally to FIG. 25, variable speed drive 174 is selectively adjusted to drive lead screw 165 at the proper speed so that the last turn of winding 198 is completed at the location shown by the dashed line 235, the spacing between abutments 68 and 69 of block 30 being arranged so that actuation of latch 73 causes flyer 180 to move rearwardly to the position shown by the dashed line 236 at which it is properly positioned for initiating winding of the second coil 237 on step 186 of coil form 184. The axial location of the terminal end of the coil with respect to the rear end of the coil form step is important, and it will be observed that the location of the terminal end can be determined by variation of the helix *e* of the coil by adjustment of the variable speed drive 174 to adjust the rotational speed of lead screw 165. It will further be seen that the axial location of the starting end 236 of the next coil 237 can be determined by selection of the axial distance *b* between abutments 68 and 69 of block 30.

The early warning signal in line 128 persists until appearance of the turn completion signal in line 126, and thus upon completion of the first coil 198, the early warning signal is removed from motor control 136 thereby actuating motor 42 to its high speed for winding the second coil 237. At the

predetermined number of turns in advance of completion of the second coil 237, the early warning signal again appears in line 128 which actuates motor control 136 to reduce the speed of motor 42 to its predetermined lower speed. Upon completion of coil 237, the signal again appears in line 126 which is applied by flip-flop 141 through the forward step commutator 129 to AND gate 143. The turn completion signal in line 126 responsive to completion of coil 237, being the second successive signal, actuates flip-flop 139 to apply the turn completion signal to AND gate 143 which thus applies a signal through OR gate 238 to step valve 145 which actuates step cylinder 78 to release latch 76, thereby permitting block 30 to be moved rearwardly until abutment 70 engages latch 73, thus moving splined shaft 33 and flyer 180 rearwardly to position the flyer for initiating winding of the third coil 239 on step 187 of coil form 184. Coils 239 and 240 are wound in like fashion on steps 187 and 188, flip-flop 139 being actuated by the third turn completion signal in line 26 responsive to completion of coil 239 to apply the turn completion signal to AND gate 138 thereby to actuate step valve 144 and step cylinder 75.

Turn completion signal line 126 is coupled to a conventional divide-by-four circuit 147 which thus provides a signal in line 148 in response to completion of the winding of four coils on a coil form 184. The signal in line 148 is applied by flip-flop 151 to the forward stop commutator 132 and, when the flyer 180 is properly rotationally positioned, a stop signal is provided in stop line 149. Stop line 149 is coupled to the clutch brake 118 and thus appearance of the stop signal actuates the clutch brake to stop flyer 180 and lead screw 165. Stop line 149 is also coupled to flip-flop 150 which actuates motor control 136 to reverse the direction of rotation of motor 42 for winding the next pole group of coils in the opposite direction. Stop line 149 is also coupled to both OR gates 234 and 238 thus applying the stop signal to both step valves 144 and 145 thereby actuating both of the step cylinders 75 and 78 to retract latches 73 and 76 so that cylinder 48 moves block 30, splined shaft 33 and flyer 180 to the extreme rearward position thereby actuating limit switch 82. This movement of flyer 180 to the extreme rearward position is required in order to provide clearance for indexing block 183 and forms 184.

Actuation of limit switch 82 in response to movement of block 30 to its extreme rearward position actuates nut valve 242 which, in turn, actuates nut cylinder 167 to open nut 202. Opening of nut 202 actuates limit switch 218 which, in turn, actuates carrier valve 243. Actuation of carrier valve 243 actuates carrier cylinder 169 to return carrier 27 to its forward position at which limit switch 190 is actuated. Actuation of limit switch 218 in response to opening of nut 202 also actuates form indexing mechanism 152 so as to index the forms 184 by the requisite amount (90° in the illustrated embodiment), limit switch 153 being actuated when the forms have been properly indexed. Actuation of both limit switches 190 and 153 actuates block valve 134 to actuate block cylinder 48 to return block 30, splined shaft 33 and flyer 180 to their extreme forward positions, movement of block 30 to its forward position actuating limit switch 80.

Limit switch 80 is coupled to relay 244, relay 244 being coupled to commutator 224 and to lead screw orienting valve 245. Assuming that lead screw 165 is properly oriented for engagement therewith by nut 202, a circuit is completed through brush 226, contact segment 225, and brush 227 and thus, actuation of limit switch 80 completes a circuit to nut valve 242 which deactuates nut cylinder 167 thereby permitting lever member 214 to pivot nut 202 to its lead screw-engaging position. On the other hand, if lead screw 165 is not properly oriented, relay 244 couples limit switch 80 to lead screw orienting valve 245, actuation of limit switch 80 thus actuating valve 245 to actuate cylinder 230 so as to rotate lead screw 165 until completion of the circuit through brush 226, contact segment 225 and brush 227 at which point, relay 244 deactuates valve 245 in turn deactuating cylinder 230, nut valve 242 and nut cylinder 167 then being actuated as above-described. Actuation of limit switch 218 in response to engagement of nut 202 with lead screw 165 actuates clutch brake 118 again to rotate flyer 180 and lead screw 165, motor 42 now operating flyer 180 in the reverse direction thereby to wind the next set of coils in the opposite direction. Appearance of the first signal in line 148 in response to completion of the fourth coil of the first pole group actuated flip-flop 141 to couple turn completion line 126 to the reverse step commutator 130, and also actuated flip-flop 151 to couple line 148 to the reverse stop commutator 133. Winding of the second pole group of coils then continues in the reverse direction as above-described with reverse step commutator 130 and reverse stop commutator 133 being effective to determine the stepping and stopping rotational positions of flyer 180.

Referring again briefly to FIG. 25, it will be seen that the axial spacing *a* of the starting end 199 of the first coil 198 is determined by axial adjustment of form 184 with respect to block 183. It is further seen that the stepping distances, *b*, *c* and *d* are determined by the spacing of abutments 68, 69, 70 and 71 of block 30, the location of the terminal ends of the respective coils being determined by the helix *e* of the coils, in turn determined by the rotational speed of the lead screw 165. It will further be seen that with a block 30 having the abutments 68, 69, 70 and 71 properly spaced for a given set of four coils, the same block may be employed for another set of coils having the same percentage ratio of turns in each coil by adjustment of the helix *e*, which is determined by the speed of lead screw 165, i.e. a block 30 proportioned to wind coils 198, 237, 239 and 240 respectively having 100, 60, 40 and 20 turns, is also suitable for winding coils having 50, 30, 20 and 10 turns, respectively, by adjusting variable speed drive 174 to increase the rotational speed of lead screw 165 so as to double the helix *e* (it being understood that the helix spacing *e* can be decreased only to that point at which the individual turns are directly abutting).

While there have been described above the principles of this invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation of the scope of the invention.

I claim:

1. Apparatus for winding coils upon a coil form having means forming a plurality of steps of progressively smaller size, said apparatus comprising: flyer means mounted on a shaft and including means for winding an elongated strand on said steps to form said coils; first means for rotatably supporting said shaft; drive means coupled to said shaft for rotating the same thereby to rotate said flyer means; second means for supporting said first support means for longitudinal movement thereon parallel with the axis of said shaft; frame means for supporting said second support means for longitudinal movement thereon parallel with the axis of said shaft; first means on said second support means and operatively connected to said first support means for sequentially moving said first support means and shaft in incremental steps respectively corresponding to said coil form means steps thereby to position said flyer means in winding relationship with said coil form means steps; and second means on said frame means operatively connected to said second support means for moving the same longitudinally thereby moving said first support means and shaft longitudinally to traverse said flyer means with respect to said coil form means.

2. The apparatus of claim 1 wherein said first moving means comprises power means on said second support means operatively connected to said first support means and selectively operable to move said first support means and shaft longitudinally in a first direction from a first position to a second spaced position, and latching means on said second support means and cooperating with said first support means for selectively restraining said movement of said first support means and shaft in said first direction at least one intermediate position.

3. The apparatus of claim 2 wherein said power means comprises a first fluid cylinder, said first cylinder being selectively

operable to move said first support means and shaft in the opposite direction from said second to said first position said latching means comprising at least a second fluid cylinder and a latch operated thereby, said first support means having a least one abutment thereon cooperating with said latch whereby actuation of said first cylinder to move said first support means and shaft in said first direction away from said first position moves the same to said intermediate position with said abutment engaging said latch, and actuation of said second cylinder disengages said latch from said abutment thereby permitting movement of said first support means and shaft to said second position.

4. The apparatus of claim 3 wherein said latching means comprises second and third fluid cylinders and latches respectively operated thereby, said first support means having at least two longitudinally spaced abutments thereon respectively cooperating with said latches and defining at least two intermediate positions.

5. The apparatus of claim 1 wherein said second moving means comprises means for longitudinally oscillating said second support means with said first support means and shaft thereon with a predetermined throw corresponding to the axial length of said coil form means steps.

6. The apparatus of claim 5 wherein said oscillating means comprises cam means operatively connected to said drive means, and cam follower means cooperating with said cam means and operatively connected to said second support means.

7. The apparatus of claim 5 wherein there are at least first and second predetermined throws, said oscillating means including means for selectively changing from said first to said second throw.

8. The apparatus of claim 6 further comprising a pivotal lever member operatively connecting said cam follower means to said second support means, and third means for moving the pivot point of said lever member between at least first and second predetermined position thereby to provide at least first and second predetermined throws.

9. The apparatus of claim 8 wherein said third moving means comprises a fluid cylinder having an actuating member selectively operable thereby between first and second positions, said actuating member being pivotally connected to said lever member.

10. The apparatus of claim 6 wherein said throw of said cam follower means has first and second extremities, and further comprising third means for selectively independently moving said cam follower to one of said extremities.

11. The apparatus of claim 10 wherein said cam follower means comprises a member movable between said first and second extremities and having means thereon cooperating with said cam means, said third moving means comprising a fluid cylinder operatively connected to said member for selectively moving the same to said one extremity.

12. The apparatus of claim 1 wherein said second moving means comprises means for continuously linearly moving said second support means longitudinally in a first direction between first and second spaced positions thereby traversing said flyer means in said direction.

13. The apparatus of claim 12 wherein said continuous moving means includes lead screw means operatively coupled to said drive means, and means operatively connecting said second support means to said lead screw means.

14. The apparatus of claim 1 wherein said first moving means comprises means for selectively sequentially moving said first support means and shaft in incremental steps longitudinally in a first direction from a first position to at least one second intermediate position and then to a second spaced position, said second moving means comprising means for longitudinally oscillating said second support means with said first support means and shaft thereon with a predetermined throw having first and second extremities, and third means for selectively independently moving said second support means with said first support means and shaft thereon to one of said extremities.

15. The apparatus of claim 14 wherein said drive means includes means for selectively driving said shaft at higher and lower speeds, means for stopping rotation of said shaft and flyer means, and means for counting the number of revolutions of said shaft and flyer means, and further comprising means responsive ro said counting means for actuating said drive means from said higher to said lower speed in response to a first predetermined number of revolutions of said shaft, means responsive to said counting means for actuating said third moving means in response to said first predetermined number to move said second support means to said one extremity, means responsive to a second predetermined number of revolutions of said shaft higher than said first number for actuating said stopping means to stop said shaft, and means responsive to said counting means for actuating said first moving means in response to said second number to move said first moving means to said intermediate position.

16. The apparatus of claim 15 wherein said stopping means includes means for stopping said shaft and flyer means at a predetermined rotational position.

17. The apparatus of claim 15 wherein there are first and second predetermined throws of said second support means, and further comprising means coupled to said second moving means for selectively changing from said first to said second throw, and means responsive to said counting means for actuating said changing means in response to said second member thereby to change from said first to said second throw.

18. The apparatus of claim 1 further comprising a coil form having an axis and means forming a plurality of axially extending steps of progressively smaller size, means for supporting said coil form with its axis parallel with the axis of said shaft, and means for moving said coil form means axially from a first protracted position in winding relationship with said flyer means and a second retracted position spaced axially from said first position and out of winding relationship with said flyer means.

19. The apparatus of claim 18 wherein there are a plurality of said coil forms equally radially spaced about an axis parallel with said coil form axes, and means for mounting said coil forms for rotation about said last-named axis thereby successively to bring the respective coil forms into winding relationship with said flyer means.

20. The apparatus of claim 1 wherein said coil form has axially spaced forward and rear ends with said rear end facing said flyer means, the largest of said steps being at said forward end and the smallest at said rear end, each of said coil form steps having a predetermined axial length, said first moving means including means for selectively sequentially moving said first support means, shaft and flyer means from a forward to a rear position in incremental axial steps respectively corresponding to the length of said coil form steps, said first moving means in said forward position thereof locating said flyer means in winding relationship with the largest of said coil form steps and in each successive step locating said flyer means in winding relationship with the next smaller coil form step, said second moving means including means for oscillating said second support means between axially spaced forward and rear positions thereby to level wind a coil in multiple layers on a respective coil form step; and further comprising means for counting the number of revolutions of said flyer means, and means responsive to said counting means for actuating said first moving means to move the same one incremental step in response to a predetermined number of revolutions of said flyer means thereby to move said flyer means into winding relationship with the next smaller coil form step upon completion of winding a coil on the next larger step.

21. The apparatus of claim 20 wherein said flyer means is located adjacent the rear end of a respective coil form step when said second support means is in said rear position thereof, and further comprising means responsive to said counting means for moving said second support means to said rear position thereof in response to a predetermined number of revolutions of said flyer means less than said first-named

number whereby said flyer means is moved to a location adjacent the rear edge of a respective step prior to said movement of said first moving means by one step.

22. The apparatus of claim 20 wherein said drive means includes means for selectively rotating said shaft and flyer means at predetermined higher and lower speeds, and further comprising means for initially actuating said drive means to said higher speed, means responsive to said counting means for actuating said drive means to said lower speed in response to a predetermined number of revolutions of said flyer means less than said first-named number, and means responsive to said counting means for actuating said driving means to said higher speed in response to said first-named number.

23. The apparatus of claim 1 wherein said second moving means comprises lead screw means operatively coupled to said drive means and driven thereby for moving said second support means longitudinally in a first direction between first and second spaced positions thereby to traverse said flyer means in said direction, coupling means connected to said second support means for selectively engaging and disengaging said lead screw means thereby operatively to connect said second support means to said lead screw means, and power means selectively operable to move said support means longitudinally in the direction opposite said first direction from said second to said first positions.

24. The apparatus of claim 23 further comprising first means for actuating said coupling means to disengage the same from said lead screw means at a selected position spaced from said first position in said first direction thereby permitting said power means to move said second support means to said first position, means for detecting a predetermined rotational position of said lead screw means with respect to said coupling means when said second support means is in said first position, means for rotating said lead screw means to said predetermined rotational position, and second means for actuating said coupling means to engage the same with said lead screw means at said first position in response to said detecting means.

25. The apparatus of claim 24 wherein said coil form has an axis parallel with the axis of said shaft, said first direction being parallel with said shaft axis, said coil form steps progressing from largest-to-smallest in said first direction, said first position of said second support means locating said flyer means to initiate winding of a coil on said largest step, the winding of said coils progressing in said first direction in response to rotation of said lead screw means, said second support means being at said selected position when said flyer means is located at the end of a coil on said smallest step; and further comprising means for stopping said drive means and lead screw means in response to completion of the winding of said coil on said smallest step, said rotating means rotating said lead screw means independently of said drive means, means for actuating said power means to move said second support means to said first position in response to actuation of said first actuating means, and means for starting said drive means and lead screw means in response to actuation of said second actuating means.

26. The apparatus of claim 24 wherein said coupling means comprises a member having an aperture therethrough receiving said lead screw means, said aperture having a portion adapted threadingly to engage said lead screw means, and means for pivotally mounting said member on said second support means for movement between a first position with said portion engaging said lead screw means and a second position with said portion out of engagement with said lead screw means.

27. The apparatus of claim 25 wherein said lead screw rotating means comprises a gear mounted on said lead screw means, a rack cooperating with said gear for rotating the same and said lead screw means in response to linear motion of said rack, and power means for linearly moving said rack thereby to rotate said gear and lead screw means to said predetermined rotational position.

28. The apparatus of claim 25 wherein said drive means includes means for selectively rotating said shaft and flyer means in opposite directions, and first one-way drive means for coupling said first-named drive means to said lead screw means for rotating the same in one direction thereby to move said second support means in said first direction despite the direction of rotation of said shaft and flyer means; said lead screw rotating means comprising a gear; second one-way drive means for coupling said gear to said lead screw means for rotating the same in said one direction, gear means cooperating with said gear for rotating the same and said lead screw means in said one direction, and second power means for actuating said gear means.

29. The apparatus of claim 25 wherein said detecting means comprises a commutator coupled to said lead screw means and rotatable therewith, said commutator having a contact segment thereon having a fixed rotational relationship with respect to said lead screw means, contact means cooperating with said commutator for completing a circuit through said contact segment when said lead screw means is in said predetermined rotational position, and further comprising means for actuating said lead screw rotating means in response to movement of said second support means to said selected position thereof and in the absence of completion of said circuit, said second actuating means including means for actuating said coupling means to engage said lead screw means in response to completion of said circuit, and means for deactuating said lead screw rotating means in response to completion of said circuit.

30. The apparatus of claim 25 wherein said first moving means comprises second power means selectively operable to move said first support means and shaft with respect to said second support means longitudinally in said first direction from a first position to a second position spaced therefrom, latching means selectively operable to restrain movement of said first support means and shaft in said first direction at a plurality of spaced positions corresponding to the number of steps on said form, means for actuating said latching means responsive to completion of winding the coil on each of said form steps whereby said second power means moves said first support means and shaft in said first direction to a position in which said flyer means is located to initiate winding of the coil on the next smaller step, said first support means in said first position thereof locating said flyer means for initiating winding of the coil on the largest step when said second support means is in said first position thereof, and means for actuating said second power means to move said first support means to said first position thereof in response to actuation of said first actuating means.

31. In apparatus for winding a single layer coil upon a coil form; flyer means mounted on a shaft for winding an elongated strand on said form to said coil; means for rotatably mounting said shaft; drive means coupled to said shaft for rotating the same thereby to rotate said flyer means; means for supporting said mounting means for longitudinal movement parallel with the axis of said shaft; lead screw means operatively coupled to said drive means and driven thereby for longitudinally moving said mounting means and shaft in a first direction between first and second spaced positions thereby to traverse said flyer means with respect to said coil form; coupling means connected to said mounting means for selectively engaging and disengaging said lead screw means thereby operatively to connect said mounting means to said lead screw means; power means selectively operable to move said mounting means and shaft longitudinally in the direction opposite said first direction from said second to said first position thereof; means for stopping said drive means and lead screw means at a selected position of said mounting means spaced from said first position in said first direction thereby terminating winding of said coil; first means for actuating said coupling means to disengage the same from said lead screw means at said selected position thereby permitting said power means to move said mounting means and shaft to said first position;

means for detecting a predetermined rotational position of said lead screw means with respect to said coupling means when said mounting means is in said first position; means for rotating said lead screw means to said predetermined rotational position independently of said drive means; and second means for actuating said coupling means to engage the same with said lead screw means at said first position in response to said detecting means.

32. The apparatus of claim 31 wherein said coupling means comprises a member having an aperture therethrough receiving said lead screw means, said aperture having a portion adapted threadingly to engage said lead screw means, and means for pivotally mounting said member on said second support means for movement between a first position with said portion engaging said lead screw means and a second position with said portion out of engagement with said lead screw means.

33. The apparatus of claim 31 wherein said drive means includes means for selectively rotating said shaft and flyer means in opposite directions, and first one-way drive means for coupling said first-named drive means to said lead screw means for rotating the same in one direction despite the direction of rotation of said shaft and flyer means; said lead screw rotating means comprising a gear, second one-way drive means for coupling said gear to said lead screw means for rotating the same in said one direction, gear means cooperating with said gear for rotating the same and said lead screw means in said one direction, and second power means for actuating said gear means.

34. The apparatus of claim 33 wherein said gear means comprises a rack, said second power means linearly moving said rack thereby to rotate said gear and lead screw means in said one direction to said predetermined rotational position.

35. The apparatus of claim 31 wherein said detecting means comprises a commutator coupled to said lead screw means and rotatable therewith, said commutator having a contact segment thereon having a fixed rotational relationship with respect to said lead screw means, contact means cooperating with said commutator for completing a circuit through said contact segment when said lead screw means is in said predetermined rotational position, and further comprising means for actuating said lead screw rotating means in response to movement of said mounting means to said selected position and in the absence of completion of said circuit, said second actuating means including means for actuating said coupling means to engage said lead screw means in response to completion of said circuit, and means for deactuating said lead screw rotating means in response to completion of said circuit.

36. The method of winding dynamoelectric machine coils upon a stepped coil form having spaced opposite ends with at least two steps of progressively smaller size extending therebetween, said method comprising the steps of; feeding an elongated wire to means for winding said wire upon said coil form; relatively locating one of said winding means and coil form with respect to the other with said winding means in winding relationship with a first step at one end of said coil form; relatively rotating one of said winding means and coil form with respect to the other and simultaneously longitudinally moving one of said winding means and coil form with respect to the other thereby to wind a first coil on said first step; counting the number of turns wound on said first coil; relatively longitudinally moving one of said winding means and coil form with respect to the other in one incremental step to locate said winding means in winding relationship with the second step of said coil form adjacent said first coil form step in response to winding a predetermined number of turns of said first coil; similarly winding a second coil on said second coil form step; said simultaneous moving step being continuous and linear in one direction toward the other end of said coil form thereby to single layer wind each of said coils on the respective coil form step, said movement in one incremental step being independent of said simultaneous movement, said simultaneous moving step further including engaging thread engaging means on one of said winding means and coil form with a lead screw and rotating said lead screw; stopping said relative rotation of said winding means and coil form and said rotation of said lead screw upon completion of winding a coil on the coil form step adjacent said other coil form end, disengaging said thread engaging means from said lead screw, removing said coils from said coil form steps, relatively moving said one of said winding means and coil form means with respect to the other to again locate said winding means in winding relationship with said first coil form step, rotating said lead screw a partial turn to a predetermined rotational position with respect to said thread engaging means, again engaging said thread engaging means with said lead screw, and similarly again winding coils on said coil form steps.

37. The method of winding dynamoelectric machine coils upon a stepped coil form having spaced opposite ends with at least two steps of progressively smaller size extending therebetween, said method comprising the steps of: feeding an elongated wire to means for winding said wire upon said coil form; relatively locating one of said winding means and coil form with respect to the other with said winding means in winding relationship with a first step at one end of said coil form; relatively rotating one of said winding means and coil form with respect to the other and simultaneously longitudinally moving one of said winding means and coil form with respect to the other thereby to wind a first coil on said first step; counting the number of turns wound on said first coil; relatively longitudinally moving one of said winding means and coil form with respect to the other in one incremental step to locate said winding means in winding relationship with the second step of said coil form adjacent said first coil form step in response to winding a predetermined number of turns on said first coil; similarly winding a second coil on said second coil form step; slowing said relative rotation from a first predetermined higher speed to a second predetermined lower speed in response to winding a predetermined number of turns on said first coil less than said first-named predetermined number, the remaining turns of said first coil being wound at said lower speed, and resuming said relative rotation at said higher speed in response to said first predetermined number.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,575,219 Dated April 20, 1971

Inventor(s) Robert J. Eminger

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 47, "271" should read -- 27a --; line 64, "27" should read -- the --; line 66, "19" should read -- show Column 7, line 53, after "commutator" insert -- 133 --. Colum line 12, "coil form 152" should read -- coil form 52 --. Colu line 26, "to" should read -- for --; line 54, "A" should read -- a --. Column 10, line 65, "portion" should read -- portion Column 11, line 41, "output shaft 222" should read -- output shaft 220 --. Column 12, line 5, "spring 271" should read -- spring 217 --; line 32, "limit switch 281" should read -- lim switch 218 --. Column 15, line 4, "a", second occurrence, sho read -- at --; line 48, after "follower" insert -- means --. Column 16, line 6, "ro" should read -- to --. Column 19, line ";" should read -- : --.

Signed and sealed this 18th day of January 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Pat