United States Patent

[11] 3,538,959

[72] Inventor **Robert J. Eminger**
Fort Wayne, Indiana

[21] Appl. No. **783,525**
[22] Filed **Dec. 13, 1968**
[45] Patented **Nov. 10, 1970**

[73] Assignee **Fort Wayne Tool & Die, Inc.**
Fort Wayne, Indiana
a corporation of Indiana

[54] **APPARATUS FOR WINDING MULTITURN, SINGLE LAYER COILS**
23 Claims, 16 Drawing Figs.

[52] **U.S. Cl.** **140/92.1,** 72/66, 72/134
[51] **Int. Cl.** **B21f 3/04**
[50] **Field of Search** 140/1, 92.1, 92.2; 72/66, 134; 242/80, 81.82

[56] **References Cited**
UNITED STATES PATENTS

1,396,033 11/1921 Francis 140/92.2

Primary Examiner—Lowell A. Larson
Attorney—Hood, Gust, Irish and Lundy

ABSTRACT: Apparatus for winding a multiturn, single layer coil including a coil form which is longitudinally elongated and has a substantially uniform, coil-defining, transverse cross-sectional configuration throughout its length, the coil form having opposite ends and a longitudinal axis. A flyer is provided rotatable about the axis for winding a wire on the coil form in a fixed plane which is transverse to the axis and spaced from one of the coil form ends. A wobble plate is provided having an aperture therein for receiving the distal end of the coil form, the surface of the plate which surrounds the coil form defining a wire pushing surface. The wobble plate is inclined with respect to the axis and faces in a direction toward the proximal end of the coil form and toward the flyer. The wobble plate is coupled to the flyer so that a rotary wobbling motion is imparted thereto with respect to the axis in synchronism with rotation of the flyer. The positioning of the distal end of the coil form within the aperture of the wobble plate restrains the rotation of the wobble plate with respect to the coil form so that the wire is pushed, as it is wound, in response to the wobbling motion of the wobble plate, longitudinally on the coil form toward the proximal end, thus pushing previously wound turns on the coil form toward the proximal end to form the single layer coil.

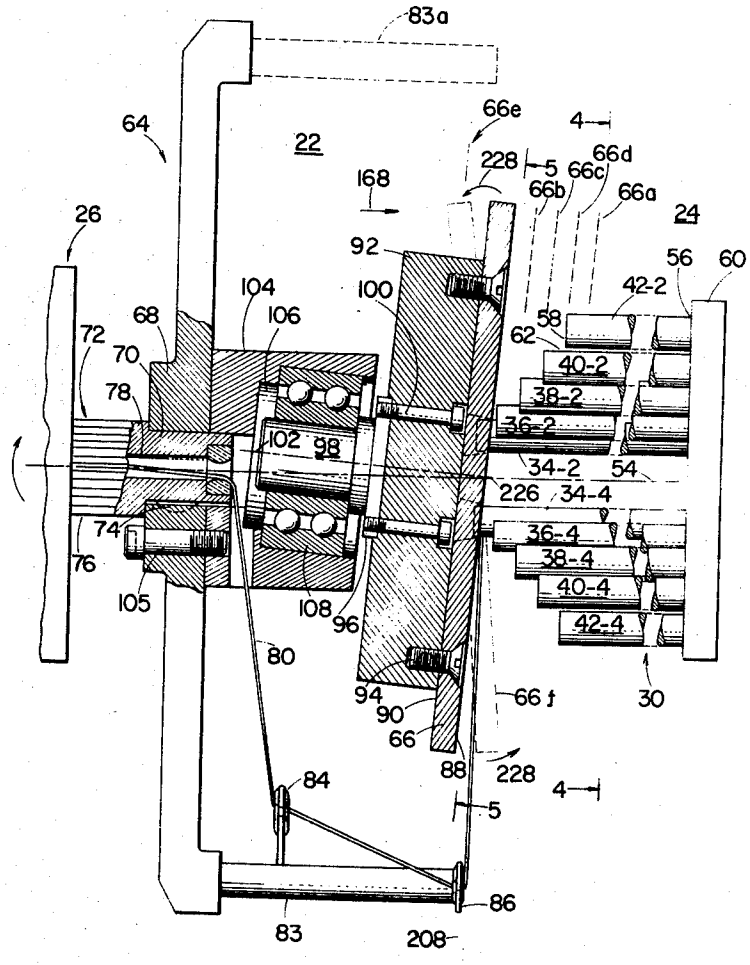
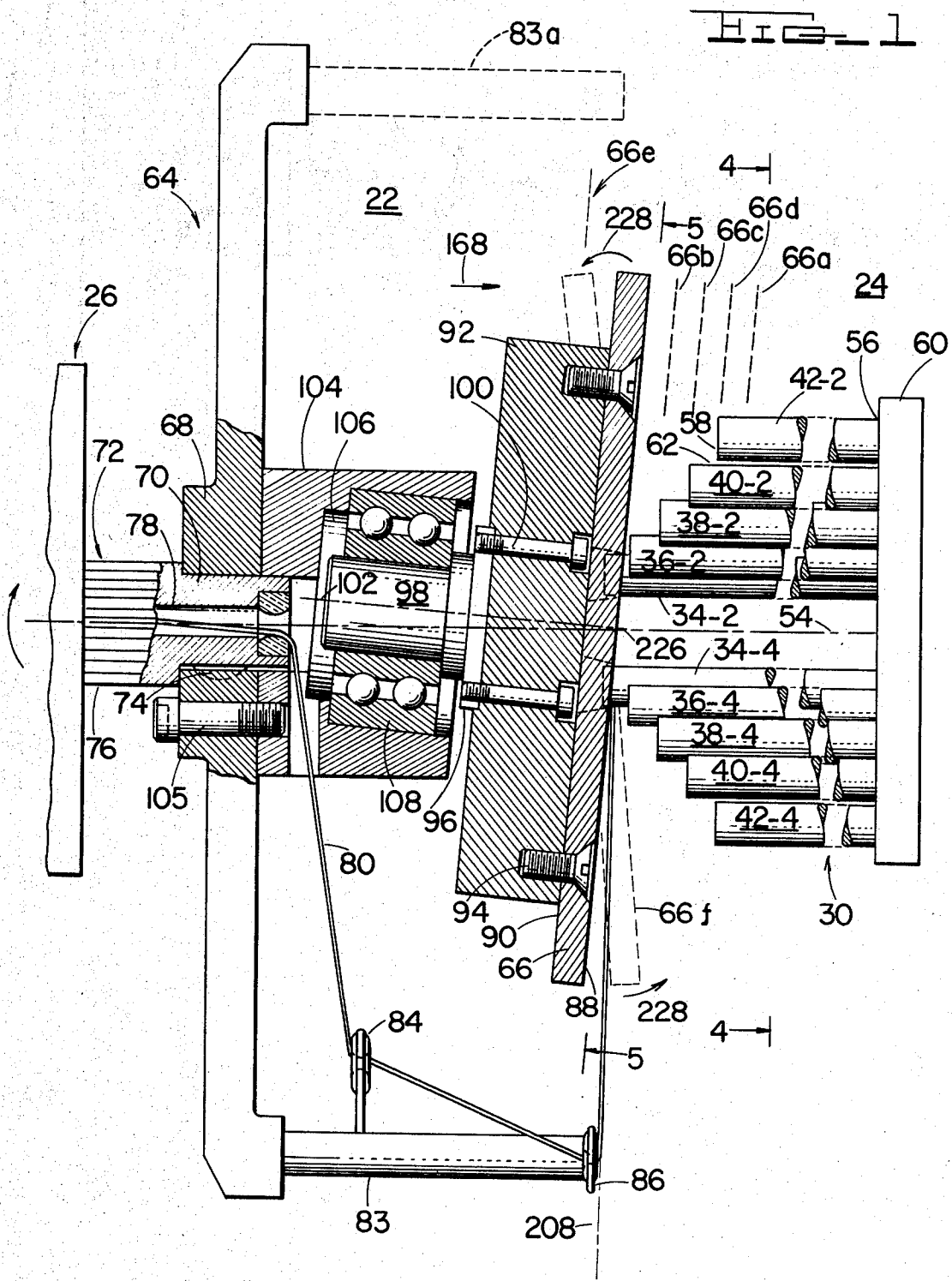


FIG. 1



INVENTOR
ROBERT J. EMINGER
BY Wood, Gust, Irish & Lundy
ATTORNEYS

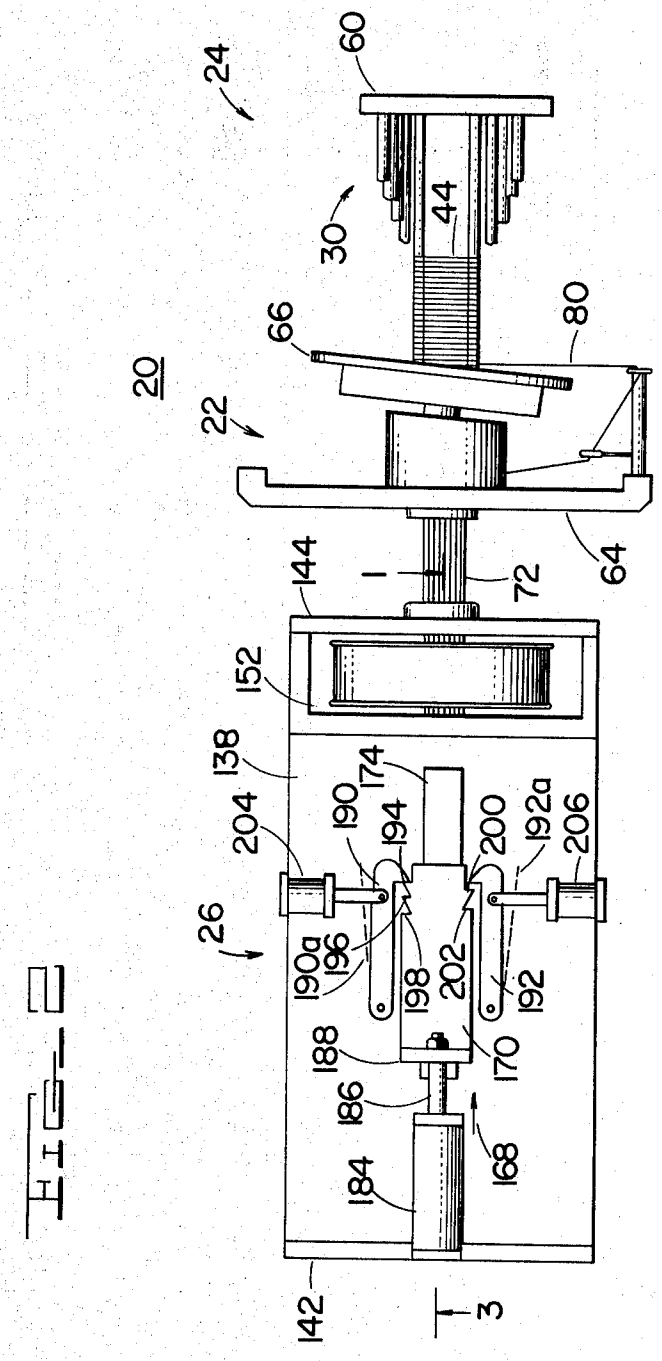


FIG. 2

INVENTOR
ROBERT J. EMINGER
BY Ward, Dust, Irish & Lundy
ATTORNEYS

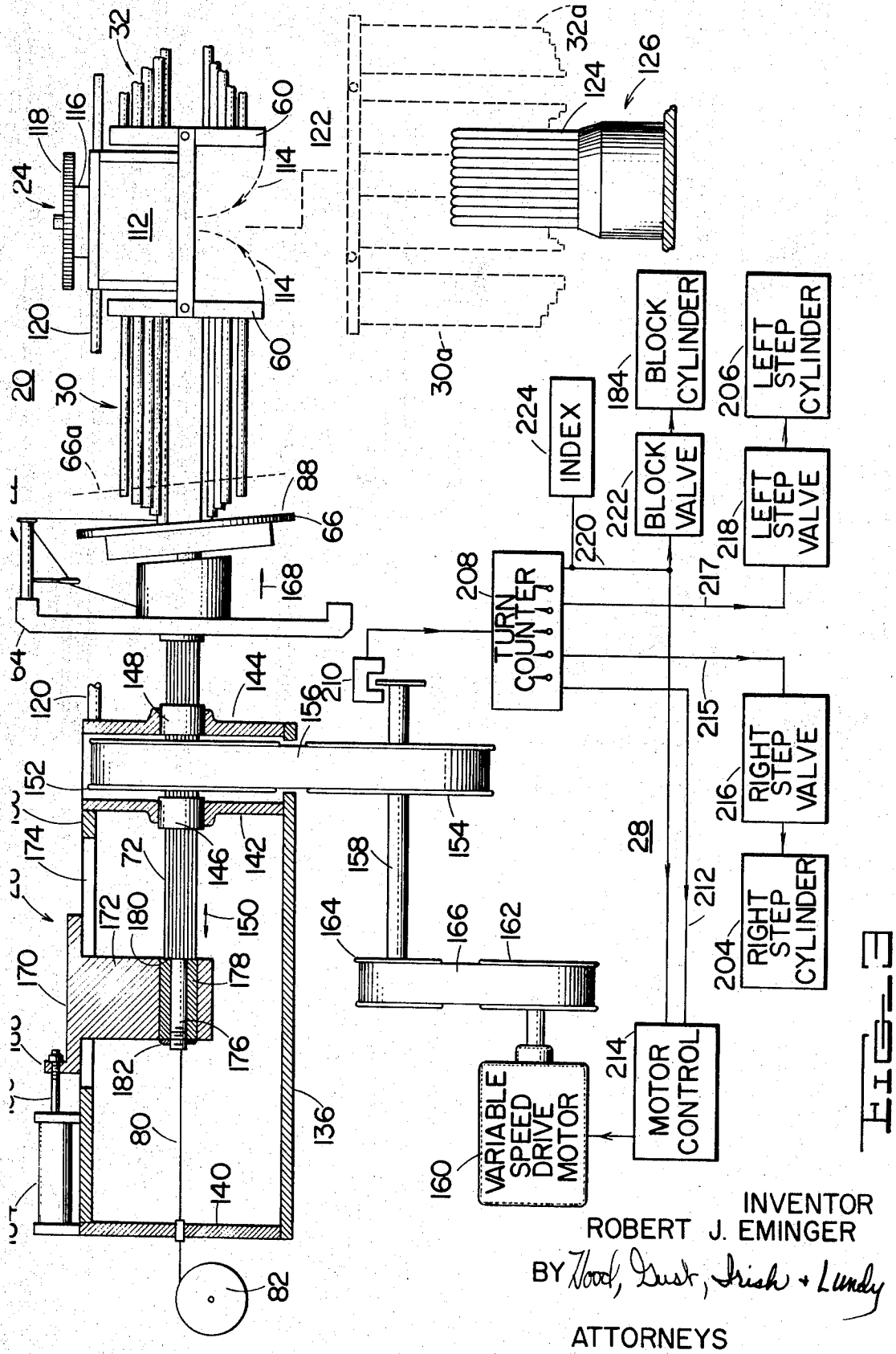


FIG. 3

INVENTOR
ROBERT J. EMINGER
BY Wood, Dust, Irish & Lundy
ATTORNEYS

FIG. 5

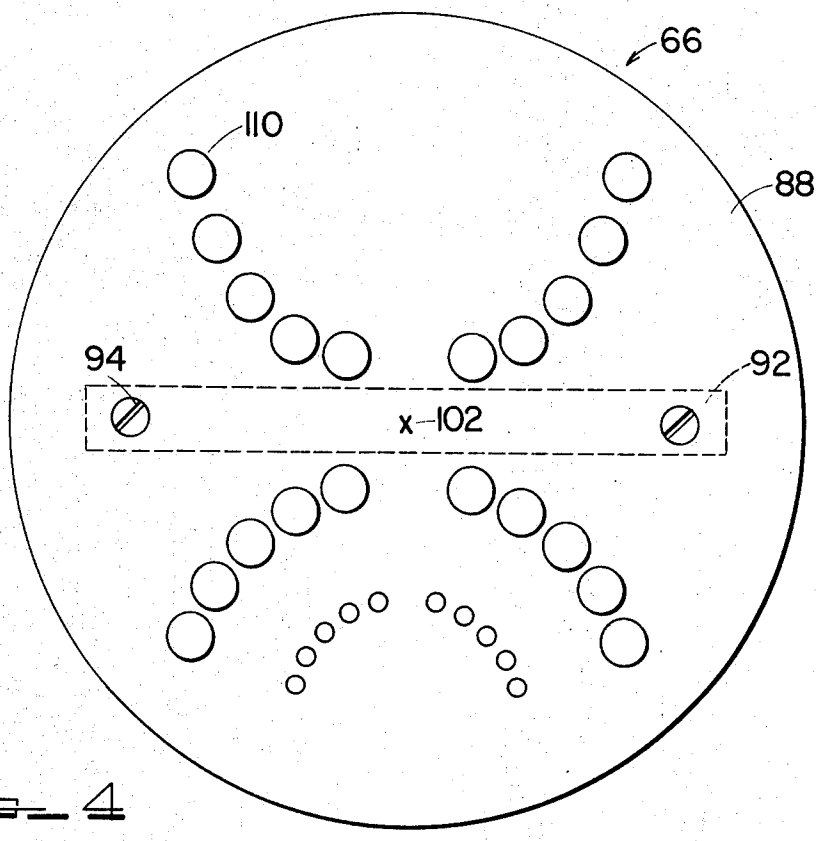
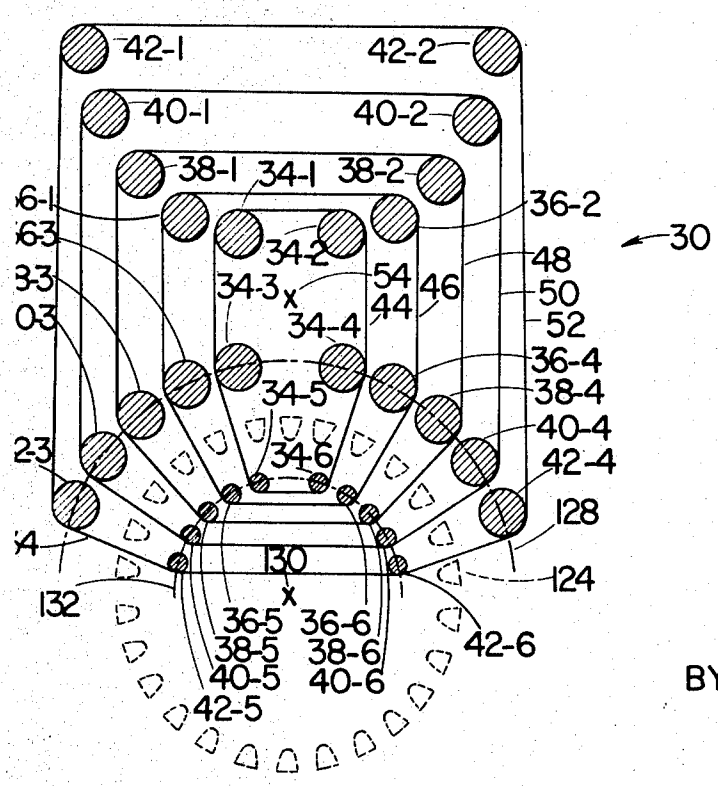


FIG. 4



INVENTOR
ROBERT J. EMINGER
BY Wood, Dalton, Irish & Lundy
ATTORNEYS

FIG. 6A

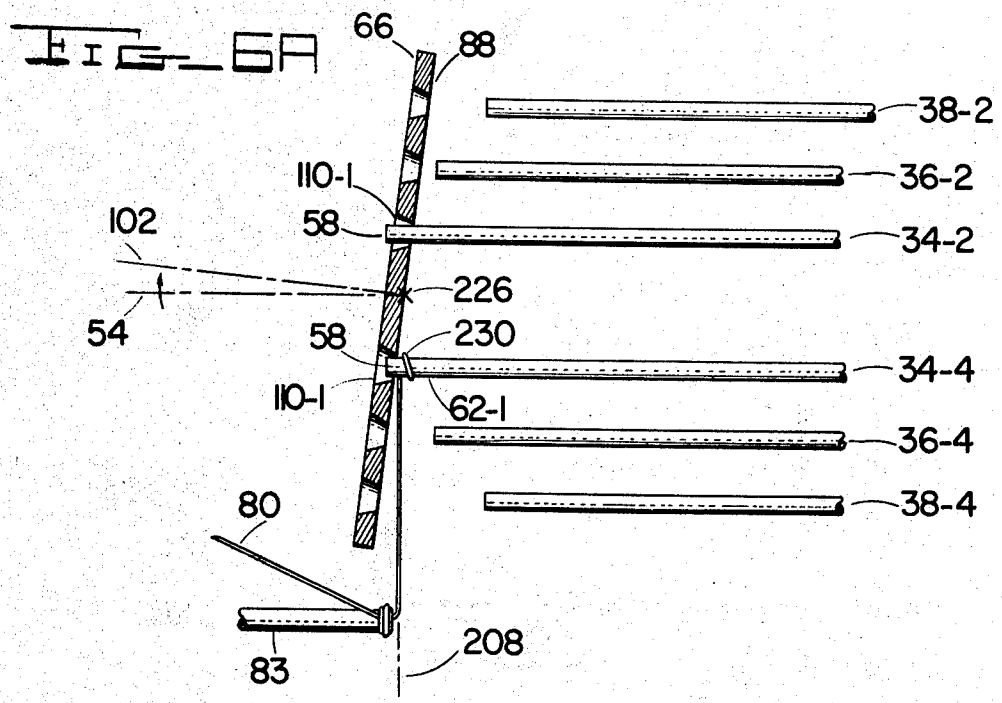
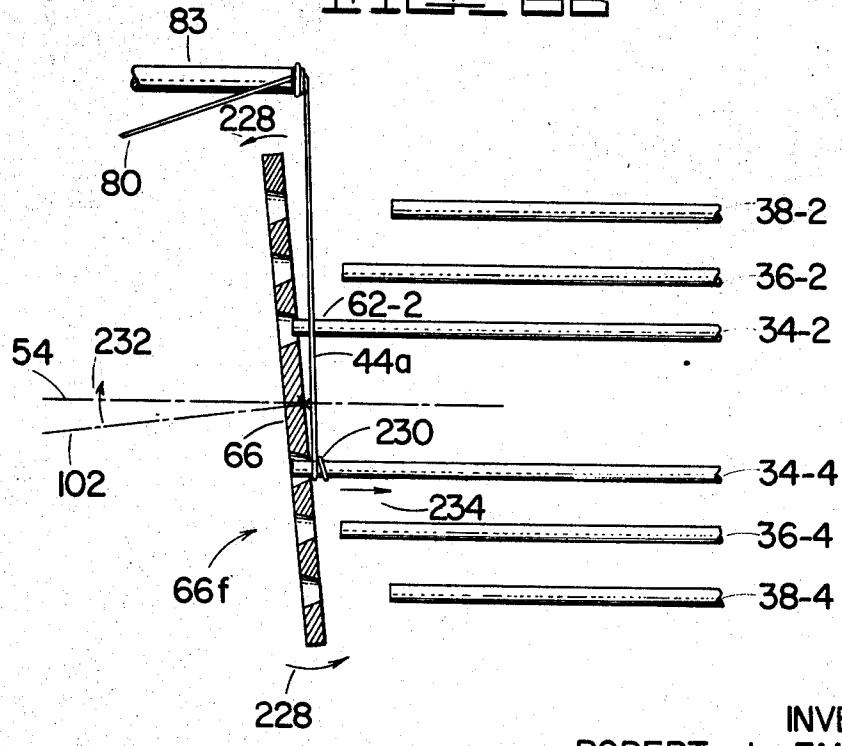


FIG. 6B



INVENTOR
ROBERT J. EMINGER
BY Wood, Dalton, Irish & Lundy
ATTORNEYS

FIG. 6C

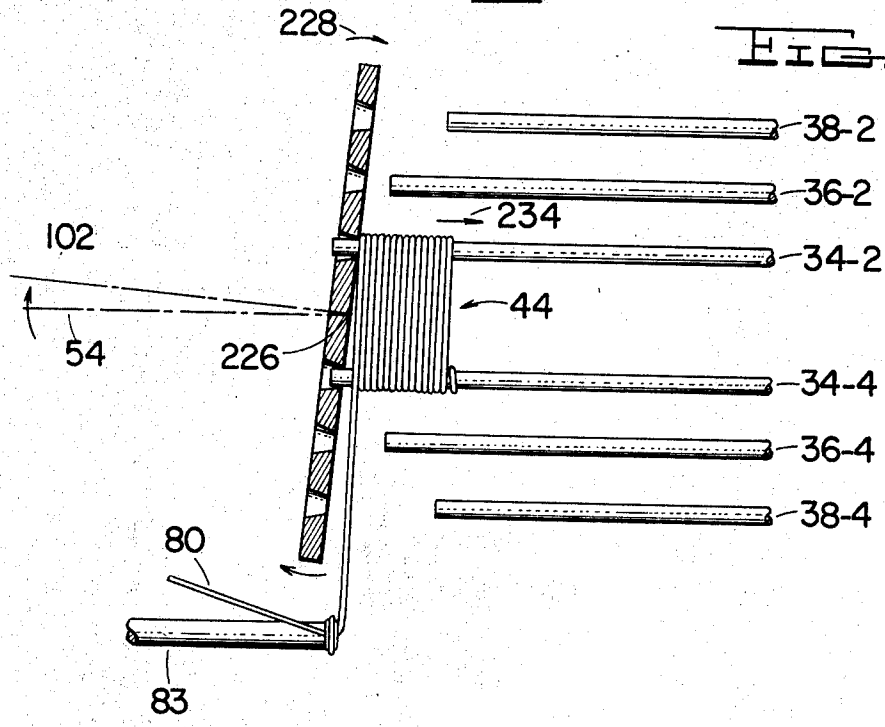
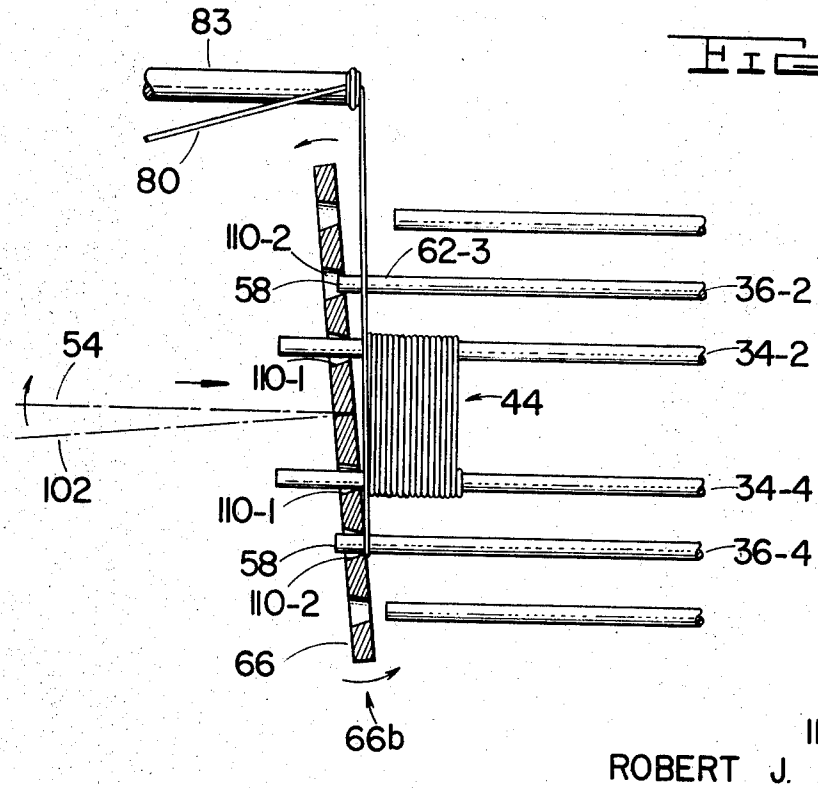
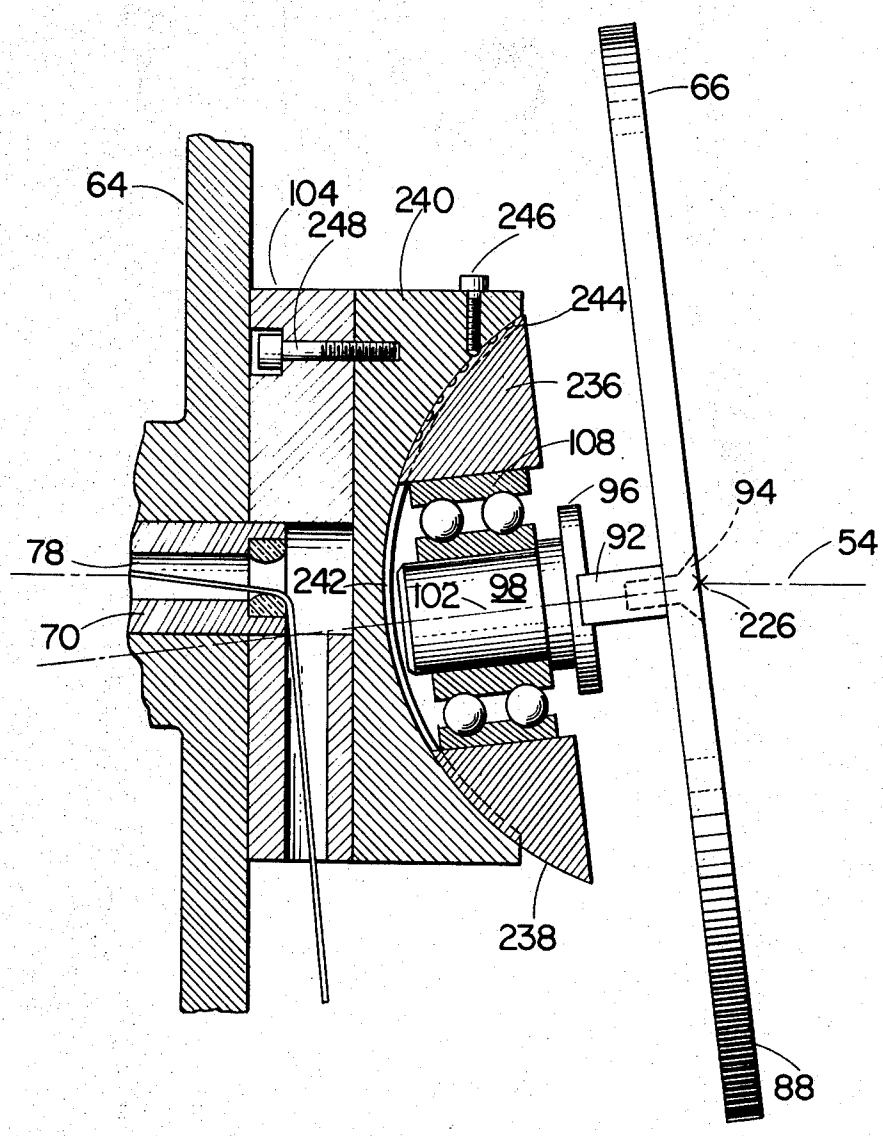


FIG. 6D



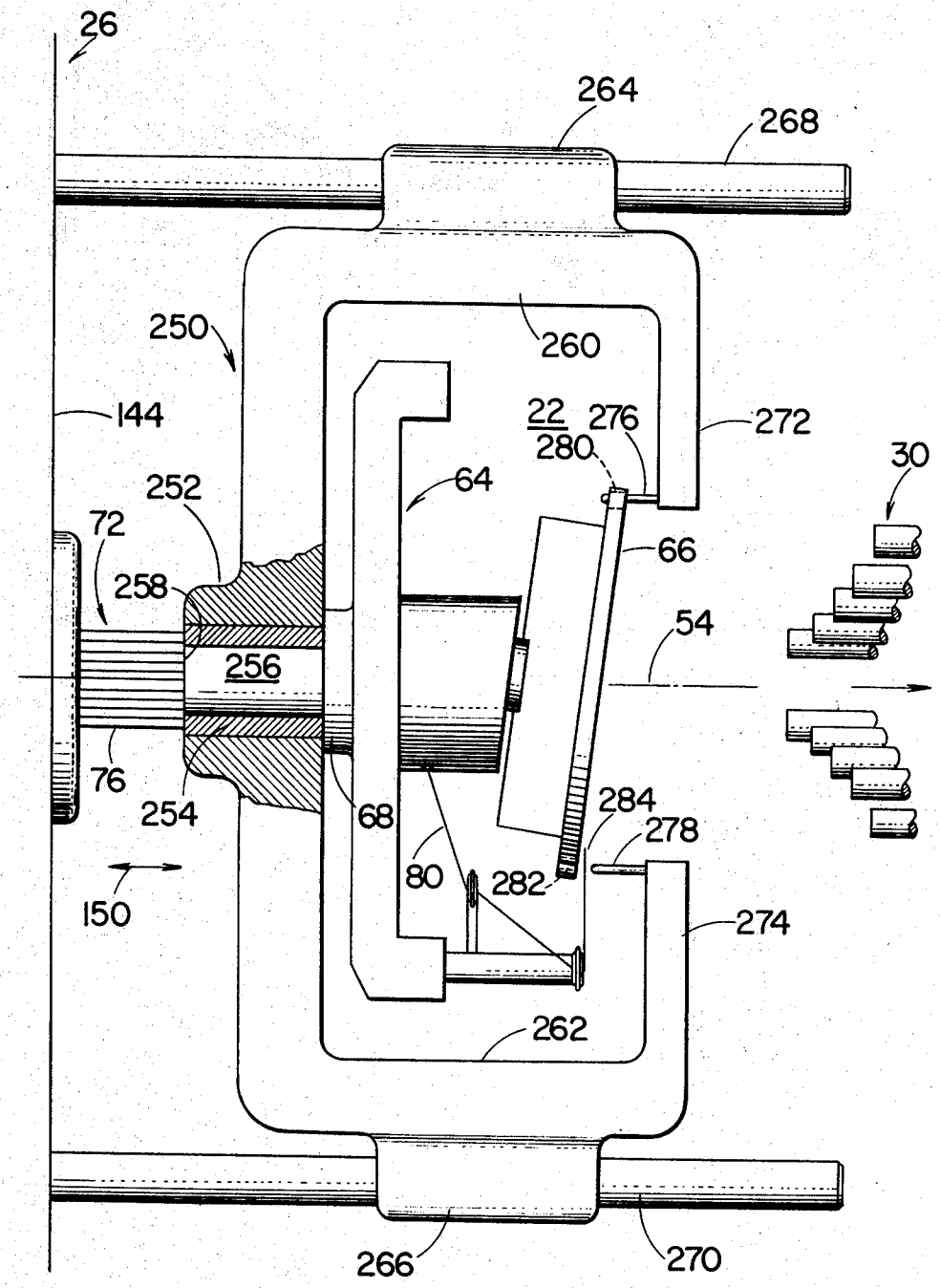
INVENTOR
ROBERT J. EMINGER
BY Wood, Dalton, Phillips & Lundy
ATTORNEYS

FIG. 7



INVENTORS
ROBERT J. EMINGER
BY Wood, Dawson, Irish & Lundy
ATTORNEYS

FIG. 8



INVENTOR
ROBERT J. EMINGER
BY Wood, Dust, Irish & Lundy
ATTORNEYS

FIG. 9

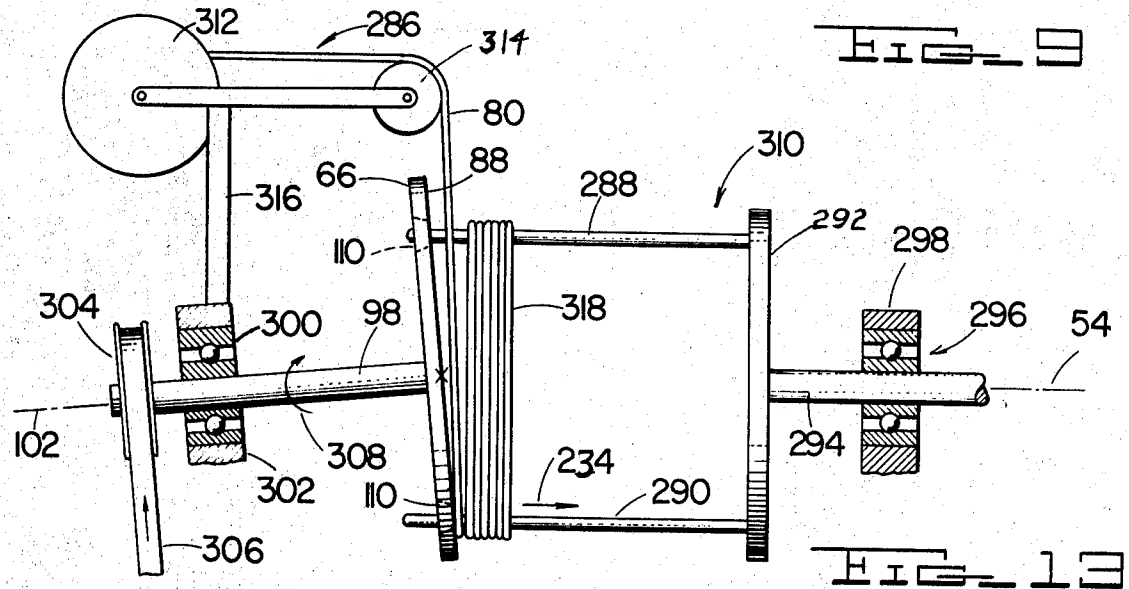


FIG. 13

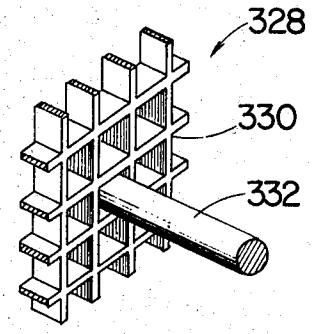


FIG. 10

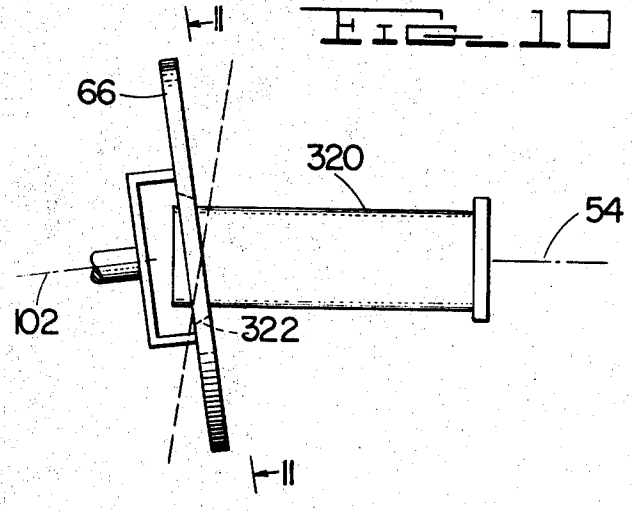


FIG. 11

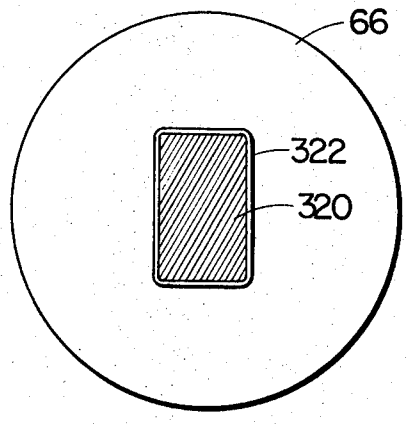
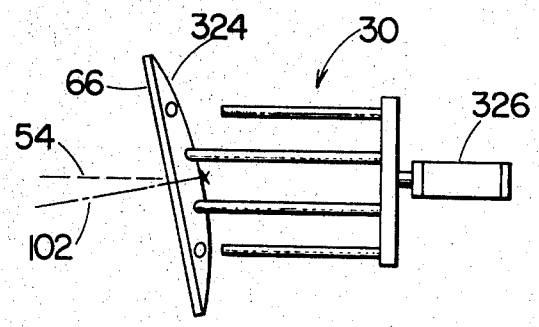


FIG. 12



INVENTOR
ROBERT J. EMINGER

BY Wood, Dalton, Irish & Lundy

ATTORNEYS

APPARATUS FOR WINDING MULTITURN, SINGLE LAYER COILS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to an apparatus for winding multiturn, single layer coils, and more particularly to an apparatus for winding concentric dynamoelectric machine coils.

2. Description of the Prior Art

In U.S. Pat. application Ser. No. 581,488 of Gene Erickson, now U.S. Pat. No. 3,415,292, and the corresponding Belgium Pat. No. 704,221, 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 coil insertion apparatus, such as that shown in U.S. Pat. No. 3,377,690 to the present inventor, and assigned to the assignee of the present application, so as to permit coils to be transferred directly from the coil forms to the blades.

In U.S. Pat. application Ser. No. 640,156 of the present inventor and Clayton L. Tyson, now U.S. Pat. No. 3,481,372, and assigned to the assignee of the present application, there is disclosed apparatus for winding a plurality of concentric, multiturn single layer dynamoelectric machine coils. That apparatus employs coil forms consisting of a plurality of spaced, parallel, elongated pins arranged in groups respectively defining concentric, coil-defining patterns with the wire being wound on a respective group of pins in a fixed plane and then pushed, as it is wound, longitudinally on the pins so that previously wound turns are likewise pushed longitudinally to form the single layer coil.

In U.S. Pat. application Ser. No. 813,798, filed Mar. 19, 1969 of the present inventor, also assigned to the assignee of the present application, there is disclosed coil-winding apparatus suitable for use with the apparatus of the type disclosed in the aforesaid Erickson application and patent in which dynamoelectric machine coils are successively wound at high speed upon the progressively smaller steps of a coil form without requiring that rotation of the flyer to be stopped between each step.

SUMMARY OF THE INVENTION

The coil winding apparatus of the type disclosed in the aforesaid U.S. Pat. application Ser. No. 640,156 required that rotation of the flyer be stopped while transferring the winding operation to the group of pins defining the next larger concentric coil. It is therefore desirable to provide coil-winding apparatus of the general type disclosed in said U.S. Pat. application Ser. No. 640,156, and incorporating certain features of the apparatus disclosed in said U.S. Pat. application Ser. No. 813,798, for winding a plurality of concentric, multiturn, single layer coils at high speed, without stopping rotation of the flyer when transferring from the winding of one coil to the next.

The present invention in its broader aspects, therefore, provides apparatus for winding a multiturn, single layer coil, including coil form means for forming a coil and which is longitudinally elongated and which has a substantially uniform, coil-defining, transverse cross-sectional configuration throughout its length, the coil form means having opposite ends and a longitudinal axis. Means are provided for rotatably winding an elongated strand upon the coil form means in a fixed plane transverse to the axis and spaced from one of the coil form means ends. Means are provided for pushing the strand, as it is wound, longitudinally on the coil form means, the pushing means having aperture means formed therein for receiving the coil form means, the pushing means surrounding the coil form means. The pushing means is inclined with respect to the axis and faces in a direction toward the one end of the coil form and toward the winding means. Means are provided for imparting a rotary wobbling motion to the pushing means with respect to the axis in synchronism with the winding means, and means are provided for restraining rotation of the pushing means with respect to the coil form means so that the strand is pushed, as it is wound, in response to the wobbling motion longitudinally on the coil form means toward the one end thereof, thereby pushing previously wound turns thereon to form the single layer coil.

It is accordingly an object of the invention to provide improved apparatus for winding multiturn, single layer coils.

Another object of the invention is to provide improved apparatus for winding a plurality of concentric, multiturn, single layer coils.

A further object of the invention is to provide improved apparatus for winding a plurality of concentric, multiturn, single layer coils without stopping the winding operation when transferring from winding one coil to the next.

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 fragmentary side view, partly in cross section, illustrating the winding and wobble plate assembly of one embodiment of the apparatus of the invention;

FIG. 2 is a top view of the apparatus of the embodiment of FIG. 1, FIG. 1 being taken generally along the line 1–1 of FIG. 2;

FIG. 3 is a side view, partly in cross section, and partly schematic, taken generally along the line 3–3 of FIG. 2;

FIG. 4 is a cross-sectional view of the pin arrangement, taken generally along the line 4–4 of FIG. 1, and further showing the relationship of the pins with the blades of coil insertion apparatus;

FIG. 5 is an end view of the wobble plate taken generally along the line 5–5 of FIG. 1;

FIGS. 6A, 6B, 6C and 6D are schematic views, partly in cross section, illustrating the mode of operation of the embodiment of FIGS. 1 through 5;

FIG. 7 is a fragmentary view, partly in cross section, showing a modification of the flyer and wobble plate assembly of FIG. 1;

FIG. 8 is a fragmentary top view, partly in cross section, illustrating another modification of the embodiment of FIGS. 1 through 5;

FIG. 9 is a fragmentary side view, partly in cross section, illustrating another embodiment of the invention;

FIG. 10 is a fragmentary side view, illustrating a further embodiment of the invention;

FIG. 11 is a cross-sectional view taken along the line 11–11 of FIG. 10;

FIG. 12 is a fragmentary, partly schematic, side view illustrating a modification of the wobble plate useful with any embodiment of the invention; and

FIG. 13 is a fragmentary view in perspective illustrating a further modification of the wobble plate useful with any embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIGS. 1 through 5 of the drawings, the coil-winding apparatus of the invention, generally indicated at 20 comprises flyer and wobble plate assembly 22, coil form assembly 24, drive assembly 26, and control system 28.

In the illustrated embodiment which is intended for winding the concentric coils forming the poles of a two-pole motor, the coil form assembly 24, includes two identical pin assemblies 30 and 32, only one of which need be described. Referring particularly to FIGS. 1 and 4, each of the pin assemblies 30 and 32 comprises a plurality of spaced, parallel, elongated pins arranged in groups respectively defining the configuration of five concentric coils collectively forming one pole of a two-pole motor. More particularly, five groups of pins 34, 36,

38, 40 and 42 are provided, each comprising six pins respectively arranged in patterns defining the configurations of the five concentric coils 44, 46, 48, 50 and 52 which collectively form one pole of the two-pole motor. The inner group of pins 34 which form the smallest of the concentric coils comprises pins 34-1, 34-2, 34-3, 34-4, 34-5 and 34-6 which define the configuration of the smallest coil 44, and it will be seen that the remaining groups of pins 36, 38, 40 and 42 are similarly arranged to define the configurations of the successively larger coils 46, 48, 50 and 52. Each of the pin assemblies 30, 32 has a longitudinally winding axis 54 with all of the pins being parallel therewith.

Each of the pins has proximal end 56 and distal end 58, the proximal end of the pins being mounted on a supporting plate 60 and extending forward therefrom. Reference to FIG. 1 will show that each of the successive groups of pins 34, 36, 38, 40 and 42 is progressively shorter in length. Thus, the distal ends of the progressively shorter groups of pins are spaced longitudinally apart by predetermined distance thereby to expose portion 62 adjacent distal ends 58 of each successively longer group of pins. It will be seen that each group of pins define a longitudinally elongated coil form having a substantially uniform, coil-defining transverse cross-sectional configuration throughout its length. Each of the pins, however, preferably has a very slight relief formed in its outer surface, as by grinding, extending forward from its proximal ends 56 approximately three-quarters of its overall length, in order to permit the coils wound thereon, as will be hereinafter described, to be more readily pushed along the pins.

Flyer and wobble plate assembly 22 comprises a conventional flyer winder 64 and wobble plate 66. Flyer 64 has hub portion 68 mounted on end 70 of hollow drive shaft 72 and secured thereto for rotation thereby in any suitable manner, as by suitable key 74. Drive shaft 72 is coaxial with axis 54 and thus the flyer 64 is rotated by drive shaft 72 about axis 54. Drive shaft 72 has external splines formed thereon, as at 76 and has coaxial center opening 78 formed therethrough through which wire 80 from a supply 82 passes, as is well known to those skilled in the art. Flyer 64 includes axially extending arm 83 having wire guides 84 and 86 thereon for guiding wire 80 to the winding location.

Referring additionally to FIG. 5, in the illustrated embodiment, wobble plate 66 is circular and has flat wire pushing surface 88 facing pin assembly 30. The other side 90 of wobble plate 66 has support plate 92 attached thereto, as by suitable screws 94. Support plate 92 is in turn secured to annular flange portion 96 of stub shaft 98, as by suitable bolts 100. The flat wire pushing surface 88 of the wobble plate 66 is normal to wobble axis 102, stub shaft 98 being coaxial with the wobble axis. Flyer 64 has a hub portion 104 secured thereto, as by suitable bolts 105. Hub portion 104 is coaxial with axis 54 and extends toward the wobble plate 66. Hub 104 has cavity 106 therein coaxial with wobble axis 102. A suitable antifriction bearing 108 is seated in cavity 106 and rotatably supports stub shaft 98.

Flat wire pushing surface 88 of wobble plate 66 has a plurality of apertures or holes 110 formed therethrough arranged in the same pattern as the pins forming pin assembly 30, 32 and respectively in axial alignment with the pins. The opening of holes 110 at flat surface 88 are slightly larger than the respective pins so as closely to receive distal ends 58 of the respective pins. Holes 110 divergently taper outwardly toward rear surface 90 of wobble plate 66, as indicated by dashed lines in FIG. 1, and as clearly shown in FIGS. 6A through 6D, in order to accommodate the wobbling motion of wobble plate 66 with the respective pins extending therethrough, as will hereinafter be described.

Referring now to FIG. 3, mounting plates 60 of the two pin assemblies 30, 32 are mounted on support assembly 112 for pivotal movement between longitudinally extending winding positions, as shown in the solid lines, and downwardly extending unloading positions, as shown in dashed lines at 30*a*, 32*a*, the pivotal movement being shown by the arrows 114. Support assembly 112 is in turn mounted upon support bracket 116 for rotation between a position in which pin assembly 30 is in cooperative winding relationship with the flyer 64 and wobble plate 66, as shown in FIG. 3, and a position in which pin assembly 32 is in cooperative winding relationship. Support assembly 112 and pin assemblies 30, 32 may be indexed between their two winding positions by means of suitable indexing gear 118 driven by suitable drive motor (not shown) mounted on the bracket 116.

A pair of spaced parallel rails 120 are provided (only one of which is shown) mounted on and extending rearwardly from drive assembly 26. Coil form assembly 24 is supported on rails 120 for movement between a winding position in which one or the other of pin assemblies 30, 32 is in cooperative relationship with flyer 64 and wobble plate 66, as shown in FIG. 3 in solid lines, and a rearward unloading position in which the distal ends of the pins of the pin assemblies are spaced away from wire pushing surface 88 of wobble plate 66. Means are also provided (not shown), as more fully illustrated and described in the aforesaid Erickson application and patent, for moving coil form assembly 24 downwardly, as shown by dashed lines 122, to a position in which pin assemblies 30, 32, in their pivoted positions 30*a*, 32*a* are respectively in intermeshing, coil-unloading relationship with fingers or blades 124 of coil insertion apparatus 126.

Referring particularly to FIG. 4, it will be seen that pins 42–3, 40–3, 38–3, 36–3, 34–3, 34–4, 36–4, 38–4, 40–4 and 42–4 are disposed on a circle, indicated by dashed line 128, having a center 130. It will likewise be seen that pins 42–5, 40–5, 38–5, 36–5, 34–5, 34–6, 38–6, 40–6 and 42–6 are disposed upon a smaller circle indicated by dashed line 132 having the same center 130. It will readily be seen that each radially aligned pair of pins on circles 128 and 132 form sections of the respective coil lying generally on radials extending outwardly from the center 130. Thus, pins 42–3 and 42–5 form section 134 of coil 52 lying generally on a radial extending outwardly from the center 130. Referring additionally to FIG. 3, when pin assemblies 30, 32 are in their pivoted coil-unloading positions 30*a*, 32*a*, the center 130 of the two circles of pins 128 and 132 is coincident with the center of the circular array of inserter blades 124, as shown in dashed lines in FIG. 4, it being seen that the circle of inserter blades is concentric with and lies between the two circles of pins 128, 132. Thus, each of the sections 134 of the respective coil extends generally radially outwardly between a respective pair of inserter blades 124 so as to permit transfer of the coils from pin assemblies 30, 32 directly to inserter blades 124, as more fully described in the aforesaid U.S. Pat. application Ser. No. 640,156.

Referring now particularly to FIGS. 2 and 3, drive assembly 26 comprises a frame having base plate 136, top plate 138 spaced above the base plate, rear end plate 140, and spaced forward end plates 142, 144. Externally splined drive shaft 72 is journaled for rotation in suitable internally splined bearings 146, 148 respectively mounted in front end plates 142, 144, thus permitting axial movement of splined shaft 72, flyer 64 and wobble plate 66, as shown by arrows 150, while permitting rotation of splined shaft 72 and flyer 64. Suitable internally splined drive pulley 152 is mounted on splined shaft 72 between end plates 142, 144 for rotating splined shaft 72 while permitting axial movement thereof. Drive pulley 152 is driven by pulley 154 and drive belt 156, pulley 154 being driven by timing shaft 158 and driving the pulley 152 in a one-to-one speed relationship. Timing shaft 158 is in turn driven by suitable variable speed drive motor 160 through pulleys 162, 164 and belt 166.

In the illustrated embodiment in which five concentric coils are successively wound on pin assemblies 30, 32, it is required that flyer and wobble plate assembly 22 be advanced in the direction shown by arrow 168 from the position shown in FIG. 3 in solid lines to the position shown in dashed lines 66*a* in four discrete steps. In order to provide this stepping movement in direction 168, and return shaft 72 and flyer assembly

22 to its initial position, block 170 is provided slidably mounted upon upper surface of top plate 138 and having portion 172 extending downwardly through longitudinally extending slot 174 in top plate 138. Portion 172 of block 170 is connected to end 176 of shaft 72 by bearing 178 which thus permits the requisite rotation of shaft 72. Portion 172 abuts shoulder 180 on shaft 72 and is secured in position by means of suitable nut 182. Thus, shaft 72 and flyer and wobble plate assembly 22 will be moved forwardly and rearwardly as shown by arrows 150 in response to movement of block 170.

Fluid power cylinder 184 is mounted on top plate 138 and has its piston rod 186 secured to flange portion 188 of block 170. Except during the return of block 170, shaft 72 and flyer and wobble plate assembly 22 to the initial position shown in FIG. 3, cylinder 184 is actuated to urge block 170, shaft 72 and flyer and wobble plate assembly 22 toward the final position shown by dashed lines 66*a*. Movement in discrete steps is provided by a pair of pivoted latching members 190 and 192 respectively disposed on opposite sides of block 170, latching member 190 cooperatively engaging stops 194, 196 and 198 and latching member 192 cooperatively engaging stops 200 and 202 formed in block 170. Latching member 190 is actuated between latched and released position by a suitable power cylinder 204, and latching member 192 is similarly actuated between latched and released positions by a suitable power cylinder 206.

Referring additionally to FIG. 1, with latching member 190 engaging stop 194, wobble plate 66 will be in its initial position as shown in solid lines. In this position, distal ends 58 of pins 34 are received in corresponding holes 110 in wobble plate 66. It will be understood that wire guide 86 on flyer 64 winds wire 80 in plane 208 normal to the axis 54. In the initial position of wobble plate 66, plane 208 intersects the exposed portions 62 of inner pins 34.

Actuation of cylinder 204 thereby to move latching member 190 to its released position, shown in dashed lines 190*a*, results in movement of block 170, shaft 72 and flyer and wobble plate assembly 22 by cylinder 184 in direction 168 until latching member 192 engages stop 200. In this position, wobble plate 66 has advanced to the position shown by dashed lines 66*b* in FIG. 1 in which distal ends 58 of the next group of pins 36 are now received within corresponding holes 110 in wobble plate 66, winding plane 208 now intersecting exposed portions 62 of pins 36. In like fashion, actuation of cylinder 206 will move latching member 192 to its released position, as shown by dashed lines 192*a*, so that cylinder 184 moves block 170, shaft 72 and flyer and wobble plate assembly 22 in direction 168 until latching member 190 engages stop 196, the wobble plate 66 now being in the position shown in dashed lines 66*c* with the distal ends of pins 38 being received in the corresponding holes and the winding plane 208 intersecting the exposed portions 62 of pins 38. In a similar manner, wobble plate 66 is moved to the position shown in dashed lines 66*d* with the distal ends of pins 40 received within the corresponding holes, and finally to the position shown in dashed lines 66*a* with the distal ends of pins 42 received in the corresponding holes.

Referring again to FIG. 3, conventional turn counter 208 is provided energized by conventional photoelectric pickup 210 in response to revolutions of timing shaft 158. Counter 208 is arranged to count the preselected number of turns in each of the five coils. Counter 208 also provides an early warning signal in output line 212, at a predetermined number of turns, such as four, in advance of completion of the preselected number of turns in each coil. This early warning signal actuates motor control 214 to reduce the speed of variable speed drive motor 160 during transferring of the winding operation to the next larger set of pins.

Assuming now that block 170, shaft 72, and flyer and wobble plate assembly 22 are in their initial position, as shown in solid lines in FIGS. 1, 2 and 3, and that counter 208 has been set to provide the desired predetermined number of turns in each of the five coils 44, 46, 48, 50 and 52, the winding operation is initiated by means of a suitable switch (not shown). At the predetermined number of turns in advance of completion of the winding of first coil 44, a signal is provided in line 212 which actuates motor control 214 to reduce the speed of variable speed drive motor 160 from its higher winding speed, such as for example 3,000 r.p.m. to a lower speed, such as 1,500 r.p.m. Upon completion of the first coil, a signal is provided in output line 215 of counter 208 which energizes a solenoid valve 216 to actuate cylinder 204 thereby to cause cylinder 184 to advance flyer and wobble plate assembly 22 to a second position 66*b* for winding second coil 46. High-speed operation of drive motor 160 is now resumed. At the predetermined number of turns in advance of completion of the second coil, the early warning signal is again provided actuating motor control 214 to reduce the speed of drive motor 160. Upon completion of the preselected number of turns of second coil 46, a signal is provided in output line 217 of the counter 208 which energizes solenoid valve 218 to actuate cylinder 206 thereby causing cylinder 184 again to advance flyer and wobble plate assembly 22 to position 66*c* for winding of third coil 48. In a similar fashion, a third coil is wound, flyer and wobble plate assembly 22 is advanced to fourth position 66*d* for winding of fourth coil 50, and finally flyer and wobble plate assembly 22 is advanced to the final position 66*a* for winding largest coil 52. Upon completion of the winding of largest coil 52, both cylinders 204 and 206 are actuated to permit return of block 170, shaft 72 and flyer and wobble plate assembly 22 to their initial positions by cylinder 184. A signal in output line 220 is provided which energizes solenoid valve 222 to actuate cylinder 184, to move block 170, shaft 72 and flyer and wobble plate assembly 22 to a position in which wobble plate 66 is located as shown by the dashed lines 66*e* in FIG. 1 so that distal ends 58 of the longest pins 34 are free of corresponding holes 110 so as to permit indexing of coil form assembly 24. The same completion signal actuates motor control 214 to reverse the direction of rotation on drive motor 160 for winding the next set of coils on pin assembly 32. Finally, indexing drive motor 224 is energized to locate the pin assembly 32 in cooperative winding relationship with flyer and wobble plate assembly 22. When the indexing operation has been completed, cylinder 204 and 206 are deactuated and the actuation of cylinder 184 is reversed thus moving block 170, shaft 72 and flyer and wobble plate assembly 22 in direction 168 until latching member 190 engages stop 194 with wobble plate 66 now returned to its initial position, as shown in solid lines, for winding the smallest coil on pins 34 of pin assembly 32.

Referring now to FIGS. 1 and 6A through 6D, it will be seen that wobble axis 102 of wobble plate 66 is inclined with respect to axis 54 which is the axis of rotation of flyer 64. Wobble axis 102 preferably intersects axis 54 at a point substantially coincident with wire pushing surface 88 of wobble plate 66, as shown at 226 in FIG. 1. It will further be seen that rotation of wobble plate 66 is restrained by reception of distal ends 58 of pins 34 in corresponding holes 110. It will thus be seen that rotation of flyer 64 about axis 54 will, through the bearing 108, cause a corresponding rotary wobbling motion of wobble plate 66 in synchronism with rotation of flyer 64, as shown by arrows 228. Thus, rotation of the arm 83 of flyer 64 from the position shown in solid lines in FIG. 1 to its position shown in dashed lines at 83*a* will cause wobble plate 66 to move, as shown by arrows 228, from its position shown in solid lines to its position shown in dashed lines at 66*f*.

Referring now to FIG. 6A, in which only pins 34–2, 34–4, 36–2, 36–4, 38–2 and 38–4 are shown, with wobble plate 66 in its initial position, it will be seen that distal ends 58 of longest pins 34–2, 34–4 are received within corresponding openings 110–1, the distal ends of the remaining pins being spaced from the wire pushing surface 88. It will further be seen that the winding plane 208 intersects axis 54 adjacent intersection 226 of axis 102 therewith, and that winding plane 208 also intersects exposed portion 62–1 of pin 34–4. In this position, free end 230 of wire 80 may be secured, as by being wrapped around pin 34–4, as shown.

Referring now to FIG. 6B, flyer 64 is shown as being rotated about axis 54 in the direction shown by arrow 232 by one-half turn. Wobble plate 66 remains in its initial position, but has been wobbled to its position 66*f*, as shown. Thus, one side 44*a* of inner coil 44 has been formed about pins 34–2 and 34–4. It will be observed that winding plane 208 now intersects exposed portion 62–2 of pin 34–2, and that the wobbling motion of wobble plate 66 has pushed starting end 230 of the wire on pin 34–4 in the direction shown by arrow 234.

Referring now to FIG. 6C in which wobble plate 66 is still shown in its initial position, it will be seen that during each one-half revolution of flyer 64 and its arm 83, wobble plate 66 by virtue of the wobbling motion imparted thereto by rotation of the flyer, is in essence pivoted about point 226 from the position shown in the FIG. 6A to its position shown in FIG. 6B, thereby continuously providing clearance for the wire to be wound upon the exposed portions of the pins and at the same time pushing the wire longitudinally on the pins in the direction shown by arrow 234 toward mounting plate 60, thereby pushing the previously wound turns longitudinally in that direction so as to form the single layer coil. Thus, each side of a coil just wound is pushed longitudinally in direction 234 while the diametrically opposite side is being wound.

Referring now to FIG. 6D, wobble plate 66 is shown advanced to its second step 66*b* in which distal ends 58 of the next shorter pins 36–2, 36–4 are now received in holes 110–2, pins 34–2 and 34–4 projecting through holes 110–1, as shown. It will now be seen that winding plane 208 intersects exposed portion 62–3 of pin 36–2 so that continued rotation of flyer 64 and the corresponding synchronist wobbling motion of wobble plate 66 will result in winding of coil 46 upon pins 36–2, 36–4, concentrically surrounding the previously wound coil 44.

Referring now to FIG. 7 in which like elements are indicated by like reference numerals, it will be seen that the throw or amount of annular travel of wobble plate 66 is much greater adjacent its outer periphery than adjacent axis 54. It will further be understood that a certain minimum amount of throw or travel, *i.e.* a distance equal to at least the diameter of the wire being wound, is required in order to move a coil side longitudinally in direction 234 sufficiently to provide space for winding the next coil side. However, in the case of long large coils, provision of the requisite throw or travel for the smaller coils may provide successive throw or travel for the larger coils. Thus, it may be desirable to provide for selective adjustment of the angle of inclination of wobble axis 102 with respect to axis 54 which, in turn, will vary the angle of inclination of wire pushing surface 88 with respect to axis 54 and thus the throw or amount of travel adjacent the outer periphery of wobble plate 66. Here, bearing 108 is mounted in a movable member 236 having arcuate surface 238 with its center at point 226. Member 236 is in turn mounted in hub portion 240 of flyer 64 which has a corresponding arcuate groove 242 formed therein. A plurality of detent notches 244 may be provided in arcuate surface 238 of member 236 which are selectively engaged by suitable set screw 246. Hub portion 240 is secured to hub portion 104 as by suitable bolts 248. It will now be readily seen that the angle of inclination of wobble axis 102 with respect to axis 54 may be readily selectively adjusted by rotation of member 236 within member 240, the desired angle being retained by means of set screw 246. It will be readily understood that adjustment of the angle may also be provided by means of a suitable worm and gear arrangement rather than by means of set screw 246.

Referring now to FIG. 8 in which like elements are indicated by like reference numerals, it will be seen that when flyer and wobble plate assembly 22 is retracted to its rearmost position 66*e* in order to permit indexing of coil form assembly 24, as above described, and also when the coil form assembly is moved from its winding position to its unloading position, the pins of one or the other of pin assemblies 30, 32 are no longer received within holes 110 in wobble plate 66, thus removing the restraint against rotation of the wobble plate. In order to insure that wobble plate 66 is at all times restrained against rotation and thus that the respective holes 110 remain in axial alignment with the pins, the arrangement now to be described may be provided.

Yoke member 250 is provided having a hub portion 252 with bearing 254 journaled on portion 256 of shaft 72. Hub portion 252 abuts hub portion 68 of flyer 64 and shoulder 258 on splined portion 76 of shaft 72 and thus, yoke 250 will be moved in the direction shown by arrows 150 along with flyer and wobble plate assembly 22 by movement of block 170 and shaft 72, while permitting rotation of the shaft and flyer and wobble plate assembly. Yoke 250 has a pair of diametrically opposite forwardly extending arms 260, 262 with flyer and wobble plate assembly 22 being disposed within the arms as shown. Arms 260, 262 respectively have bearing portions 264, 266 which are slidably journaled upon rails 268, 270 mounted on and extending forwardly from end plate 144 of drive assembly 26.

Arms 260, 262 respectively have radially inwardly extending portions 272, 274 and a pair of diametrically oppositely disposed pins 276, 278 respectively mounted on and extend rearwardly from the inner extremities of portions 272, 274, respectively parallel with axis 54. Pins 276, 278 are respectively in axial alignment with diametrically opposite holes 280, 282 adjacent the periphery of the wobble plate 66. The length of pins 276, 278 is such that one of the pins is at all times received within a hole 280, 282, while the other is spaced axially from wobble plate 66, as at 284 in order to permit wire 80 being wound to pass therebetween. It will thus be seen that wobble plate 66 is at all times restrained against rotation by one or the other of pins 276, 278, thus maintaining the pin-receiving holes 110 respectively in alignment with the pins of pin assemblies 30, 32 when the pin assembly is removed from its winding position, as shown in FIG. 8.

Referring now to FIG. 9, in the embodiment of FIGS. 1 through 8, pin assemblies 30, 32 are held in fixed relationship with respect to the frame while flyer 64 is rotated, thereby to wind a wire thereon, and wobble plate 66 is coupled to the flyer which thus imparts a rotary wobbling motion thereto about the wobble axis. In the embodiment of FIG. 9, in which like elements there again indicated by like reference numerals, the pin assembly and wobble plate are respectively mounted for rotation about axis 54 and wobble axis 102 with wire 80 thus being wound directly upon the pins by winding assembly 286 which is held in fixed relationship with respect to the frame. Thus, in the simplified form shown, in which only two pins 288, 290 of a single group of four pins forming a rectangular coil are shown, pins 288, 290 have their proximal ends mounted on mounting plate 292 which, in turn, is mounted on shaft 294 coaxial with axis 54. Shaft 294 is rotatably supported by suitable bearings 296 and frame portion 298. Shaft 98 of wobble plate 66 is again coaxial with wobble axis 102 and is rotatably supported by suitable bearings 300 mounted in frame portion 302. In the illustrated embodiment, suitable pulley 304 driven by drive belt 306 is mounted on shaft 98 and thus rotates shaft 98 and wobble plate 66, as shown by arrow 308. With the distal ends of pins 288, 290 received within holes 110 in wobble plate 66, rotation of shaft 98 and wobble plate 66 will in turn impart rotary motion to pin assembly 310 and shaft 294 in the manner of a universal joint. It will be readily apparent that shaft 294 may be driven rather than shaft 98.

The winding assembly 286 includes conventional wire source 312, such as a wire spool, and wire guide 314, shown as being a pulley, for guiding the wire to the winding plane for winding upon pins 288, 290. Wire spool 312 and wire guide 314 are mounted in fixed relationship with respect to the frame by a support, schematically shown at 316. As in the case of the previous embodiment, the winding plane intersects axis 54 adjacent the intersection of wobble axis 102 therewith, which is preferably substantially at the front surface 38 of the wobble plate. It will now be seen that rotation of pin assembly 310, as above described, will result in winding coil 318 thereon. It will further be seen that by virtue of the inclination of the wobble axis 102 with respect to the axis 54, rotation of

wobble plate 66 about axis 102 will result in the aforesaid wobbling motion of wobble plate 66 with respect to pins 288, 290 so that wire 80 is again pushed longitudinally on the pins in direction 234, as it is wound, thus pushing previously wound turns on the pins in that direction so as to form the complete single layer coil.

The embodiment shown in FIG. 9 is particularly useful where it is desired to wind several wires in parallel without imparting a twist thereto. It will be seen that two or three wires may be payed out from a corresponding number of wire spools 312 through respective wire guides 314 and wound in parallel upon the pin assembly 310 without twisting the wires.

Referring now to FIGS. 10 and 11, while the coil forms of the previous embodiments have been shown as consisting of a plurality of elongated pins disposed in a pattern to form a coil having the desired configuration, it will be readily apparent that a solid cross section coil form 320 may be employed having its distal end received within corresponding hole 322 in wobble plate 66. It will further be readily understood that the embodiment of FIGS. 10 and 11 may be employed with the rotating flyer arrangement of FIGS. 1 through 5, and also in the arrangement shown in FIG. 9.

Referring now to FIG. 12, while wire pushing surface 88 of wobble plate 66 of the previous embodiments has been shown as being substantially flat, it will be readily understood that the wire pushing surface may be convexly or concavely curved. Thus, in FIG. 12, wobble plate 66 is shown as having convexly curved wire pushing surface 324.

It will also be understood that while in the embodiment of FIGS. 1 through 5, flyer and wobble plate assembly 22 are moved axially in order to form the successively larger coils, the pin assembly 30 may alternatively be moved axially by suitable means such as hydraulic cylinder 326.

Referring now to FIG. 13, while wobble plate 66 of the previous embodiment has been shown as having an extended area wire pushing surface 88 or 324, it will be readily apparent that the wobble plate may be formed as a grid or mesh 328 with its forward surfaces 330 defined by the mesh thus forming the wire pushing surface and with pin 332 being received in the openings in the mesh, as shown.

While the coil form assembly 24 has been shown as incorporating two pin assemblies for forming the concentric coils of a two pole motor, it will be readily understood that the coil form assembly may include four- or six-pin assemblies for winding the coils of a four- or six-pole motor.

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 to the scope of the invention.

I claim:

1. An apparatus for winding a multiturn single layer coil including coil form means for forming said coil, said coil form means being longitudinally elongated and having a substantially uniform coil-defining, transverse cross-sectional configuration throughout its length, said coil form means having opposite ends and a longitudinal axis: means for rotatively winding an elongated strand on said coil form means in a fixed plane transverse to said axis and spaced from one of said ends; means for pushing said strand, as it is wound, longitudinally on said coil form means, said pushing means having aperture means formed therein for receiving said coil form means, said pushing means surrounding said coil form means and being inclined with respect to said axis, said pushing means facing in a direction toward one end of said coil form means and toward said winding means; means for imparting a rotary wobbling motion to said pushing means with respect to said axis in synchronism with said winding means; and means for restraining rotation of said pushing means with respect to said coil form means whereby said strand is pushed, as it is wound, in response to said wobbling motion longitudinally in said direction on said coil form means thereby pushing previously wound turns thereon in said direction to form said coil.

2. The apparatus of claim 1 wherein said restraining means comprises a mating configuration of said coil form means and said aperture means.

3. The apparatus of claim 2 wherein said coil form means comprises a plurality of spaced elongated pins respectively parallel with said axis, said pins being arranged in a pattern defining said configuration, said aperture means comprising an aperture for each of said pins.

4. The apparatus of claim 1 wherein said pushing means has a longitudinal wobble axis which is inclined with respect to said first-named axis.

5. The apparatus of claim 4 wherein said wobble axis intersects said first axis substantially at its intersection with said pushing means, said plane intersecting said first axis adjacent the intersection of said wobble axis therewith.

6. The apparatus of claim 4 further comprising a supporting frame, first means for mounting said coil form means in fixed relationship with respect to said frame during the winding of said coil, said wobbling motion imparting means comprising second means for mounting said pushing means for rotation of said wobble axis about said first axis.

7. The apparatus of claim 6 wherein said second mounting means is operatively coupled to said winding means and driven thereby.

8. The apparatus of claim 7 wherein said winding means comprises a flyer mounted on said frame for rotation about said first axis, said second mounting means comprising means for rotatably coupling said pushing means to said flyer.

9. The apparatus of claim 8 wherein said second mounting means includes a shaft coaxial with said wobble axis, said coupling means comprising bearing means connected to said flyer for rotatably supporting said shaft.

10. The apparatus of claim 4 further comprising a supporting frame, first means for mounting said coil form means on said frame for rotation about said first axis, said wobbling motion imparting means comprising second means for mounting said pushing means on said frame for rotation about said wobble axis, drive means coupled to one of said coil form and pushing means for rotating the same thereby rotating the other of said coil forms and pushing means through said restraining means, and means for mounting said winding means in fixed relationship with respect to said frame.

11. The apparatus of claim 1 wherein said pushing means comprises a plate member having one side thereof defining a pushing surface.

12. The apparatus of claim 11 wherein said one end of said coil form means is a proximal end and the other end is a distal end, and further comprising means for supporting said proximal ends, said one side of said plate member having said aperture means formed therein for receiving said distal end of said coil frame means.

13. The apparatus of claim 12 wherein said one side of said plate member is substantially flat, said plate member having a wobble axis which is inclined with respect to said first-named axis, said one side being normal to said wobble axis, said wobble axis intersecting said first axis substantially at its intersection with said one side, said plane intersecting said first axis adjacent the intersection of said wobble axis therewith, and further comprising a supporting frame, means for mounting said supporting means in fixed relationship with respect to said frame during the winding of said coil, said winding means comprising a flyer mounted on said frame for rotation about said first axis, means operatively connected to said flyer for rotating the same, said wobbling motion imparting means comprising bearing means for mounting said plate member on said flyer for rotation of said wobble axis about said first axis in response to rotation of said flyer and in synchronism therewith.

14. The apparatus of claim 13 wherein said wobbling motion imparting means further comprises a shaft mounted on the other side of said plate member coaxial with said wobble axis and extending outwardly therefrom in the direction opposite said first-named direction, said bearing means being connected to said flyer and rotatably supporting said shaft.

15. The apparatus of claim 1 wherein said coil form means comprises a first plurality of spaced elongated pins respectively parallel with said axis, said first pins being arranged in a first pattern defining the configuration of a first coil, a second plurality of spaced elongated pins respectively parallel with said axis, said second pins being arranged in a second pattern defining the configuration of a second coil concentric with and surrounding said first coil, said one end of said coil form means comprising proximal ends of said pins, the other ends of said pins being distal ends, and means for mounting the proximal ends of said pins, the distal ends of said first pins being spaced longitudinally outwardly from the distal ends of said second pins by a predetermined distance thereby exposing portions of said first pins, and further comprising means for longitudinally moving one of said pushing means and coil form means relative to the other parallel with said axis between first and second positions, the distal ends of said first pins being received in said aperture means in said first position with the distal ends of each second pins being spaced from said pushing means and with said plane intersecting said exposed portions of said first pins only thereby to form said first coil on said first pins, the distal ends of both said first and second pins being received in said aperture means in said second position with said plane intersecting both said first and second pins thereby to form said second coil on said second pins.

16. The apparatus of claim 15 wherein said moving means moves said pushing means between said first and second positions.

17. The apparatus of claim 16 wherein said winding means comprises a rotatable flyer, and further comprising a shaft concentric with said axis and operatively connected to said flyer for rotating the same, said wobble motion imparting means comprising means rotatably coupling said pushing means to said flyer for imparting said wobbling motion thereto in response to rotation of said flyer and in synchronism therewith, drive means for rotating said shaft, said moving means comprising means operatively coupled to said shaft for moving the same and said flyer and pushing means between said first and second positions.

18. The apparatus of claim 15 wherein said moving means comprises a member operatively coupled to said one of said pushing means and coil form means and movable therewith, means for normally urging said member and said one means to said second position, and selectively actuable latching means cooperating with said member for holding the same and said one means in said first position.

19. The apparatus of claim 1 further comprising a frame, said restraining means comprising means coupled to said frame for alternately engaging and disengaging diametrically opposite portions of said pushing means in response to said wobbling motion thereof, said restraining means and winding means being rotationally related so that said strand as it is being wound passes said restraining means when disengaged from said pushing means.

20. The apparatus of claim 19 wherein said one end of said coil form means is a proximal end and the other end is a distal end, and further comprising means for mounting said proximal end on said frame for movement between a winding position with said distal end received in said aperture means, and another position with said distal end spaced from said pushing means, said engaging means retaining said pushing means with said aperture means in longitudinal alignment with said coil form means when in said other position thereof.

21. The apparatus of claim 20 wherein said winding means comprises a rotatable flyer, a shaft coaxial with said axis and operatively connected with said flyer for rotating the same, said wobbling motion imparting means comprising means operatively coupling said pushing means to said flyer for imparting said wobbling motion in response to rotation of said flyer and in synchronism therewith, said coil form means comprising a first part for forming a first coil and a second part for forming a second coil coaxially surrounding said first coil, the distal end of said first part being spaced longitudinally outwardly from the distal end of said second part by a predetermined distance thereby exposing a portion of said first part, and further comprising means operatively coupled to said shaft for longitudinally moving the same and said flyer and pushing means between first and second positions, said distal end of said first coil form means part being received in said aperture means in said first position with said distal end of said second part being spaced from said pushing means and with said plane intersecting said exposed portion only thereby to form said first coil, the distal ends of both of said parts being received in said aperture means in said second position with said plane intersecting both of said parts thereby to form said second coil, said restraining means comprising a member having a first portion journaled on said shaft, said member being movable with said shaft between said positions thereof, said member having means coupling the same to said frame for restraining rotation of said member, said member having a yoke portion extending longitudinally toward coil form mounting means, said flyer and pushing means being disposed within said yoke portion, said engaging means comprising a pair of diametrically oppositely disposed parts mounted on said yoke member, one of said parts engaging said pushing means while the other is spaced longitudinally therefrom, said plane passing through said space between said other engaging means part and said pushing means.

22. The apparatus of claim 21 further comprising means for selectively varying the angle of inclination of said pushing means with respect to said axis.

23. The apparatus of claim 22 wherein said pushing means has a wobble axis which is inclined with respect to said first-named axis, said winding means comprising a flyer mounted for rotation about said first axis, said pushing means having a shaft coaxial with said wobble axis, said wobble motion imparting means comprising bearing means for rotatably supporting said shaft, said varying means comprising means for mounting said bearing means on said flyer for selective adjustment of the angle of inclination of said shaft with respect to said first axis.