

Dec. 8, 1942.

F. E. WIRTZ ET AL

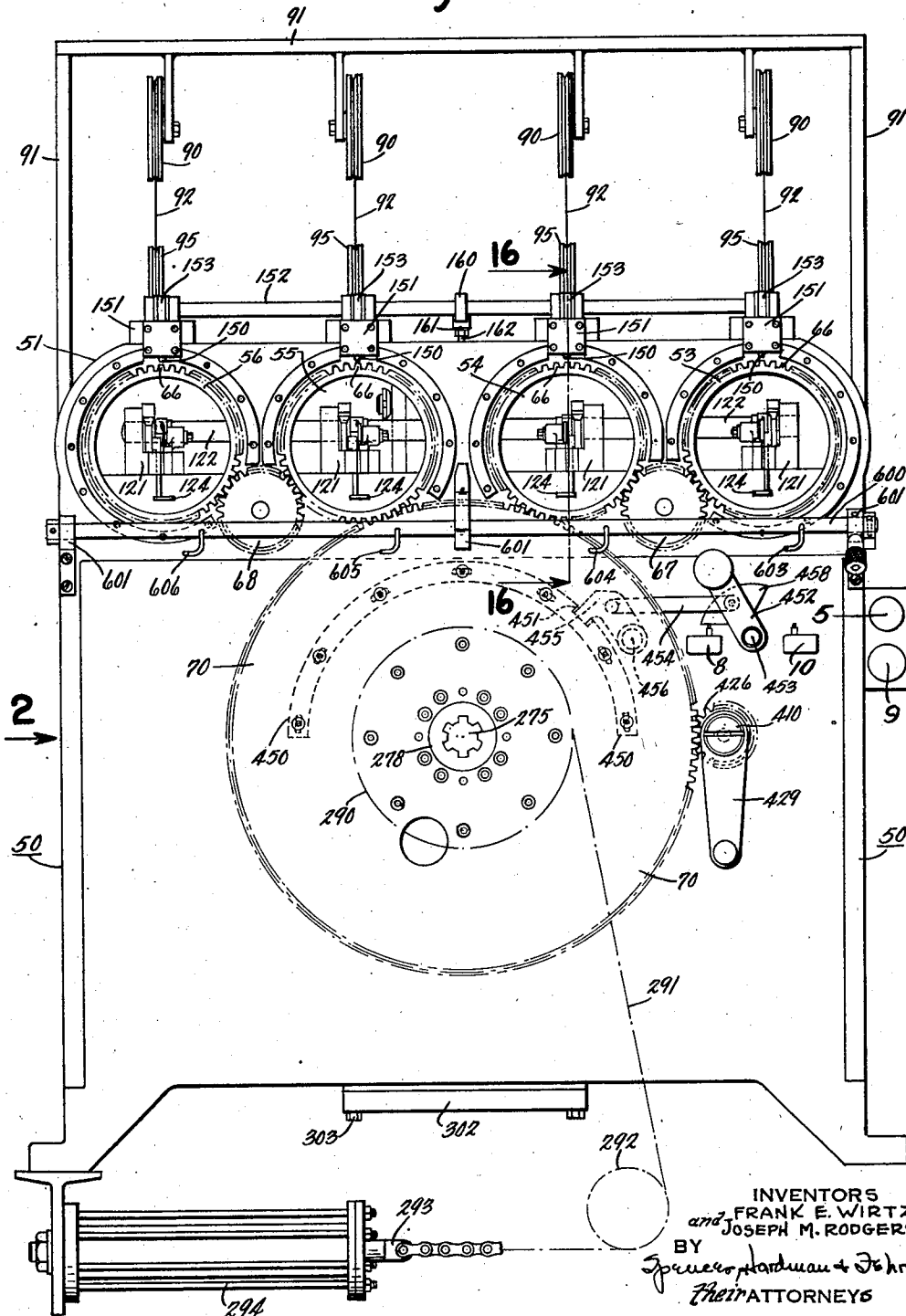
2,304,520

WINDING MACHINE

Filed Sept. 27, 1940

18 Sheets-Sheet 1

Fig. 1



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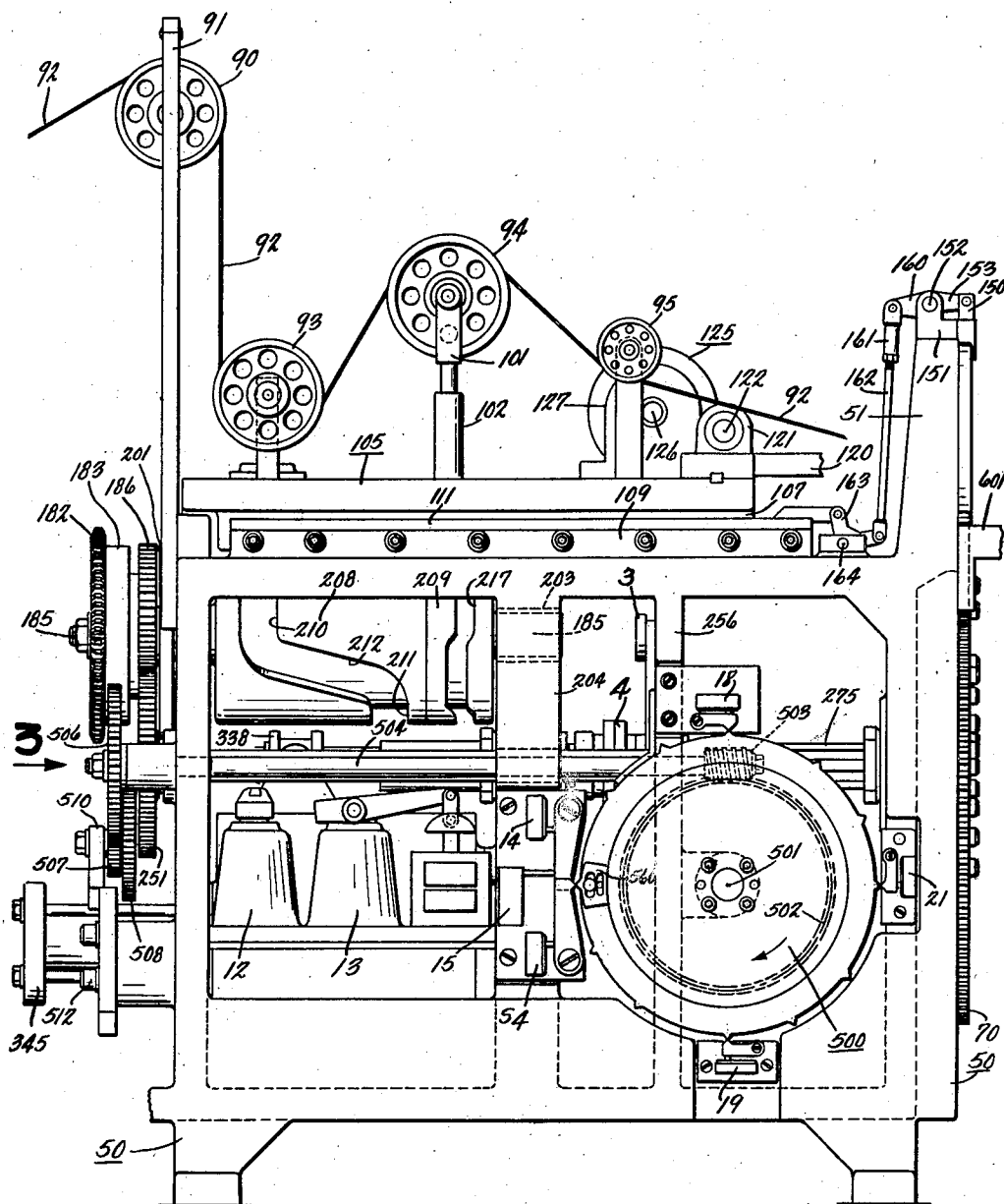


Fig. 2

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WINDING MACHINE

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18 Sheets-Sheet 3

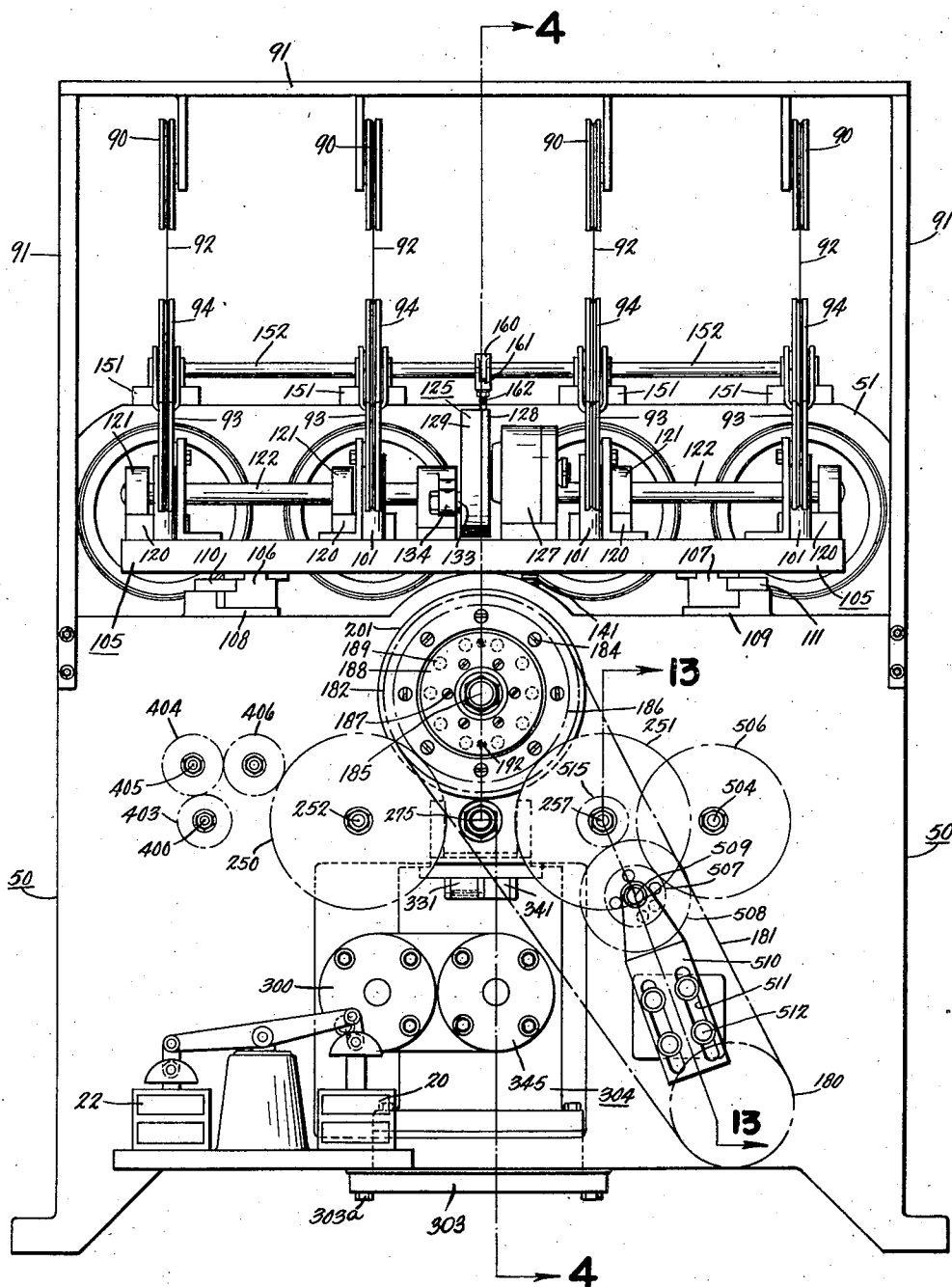


Fig. 3

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Fig. 5

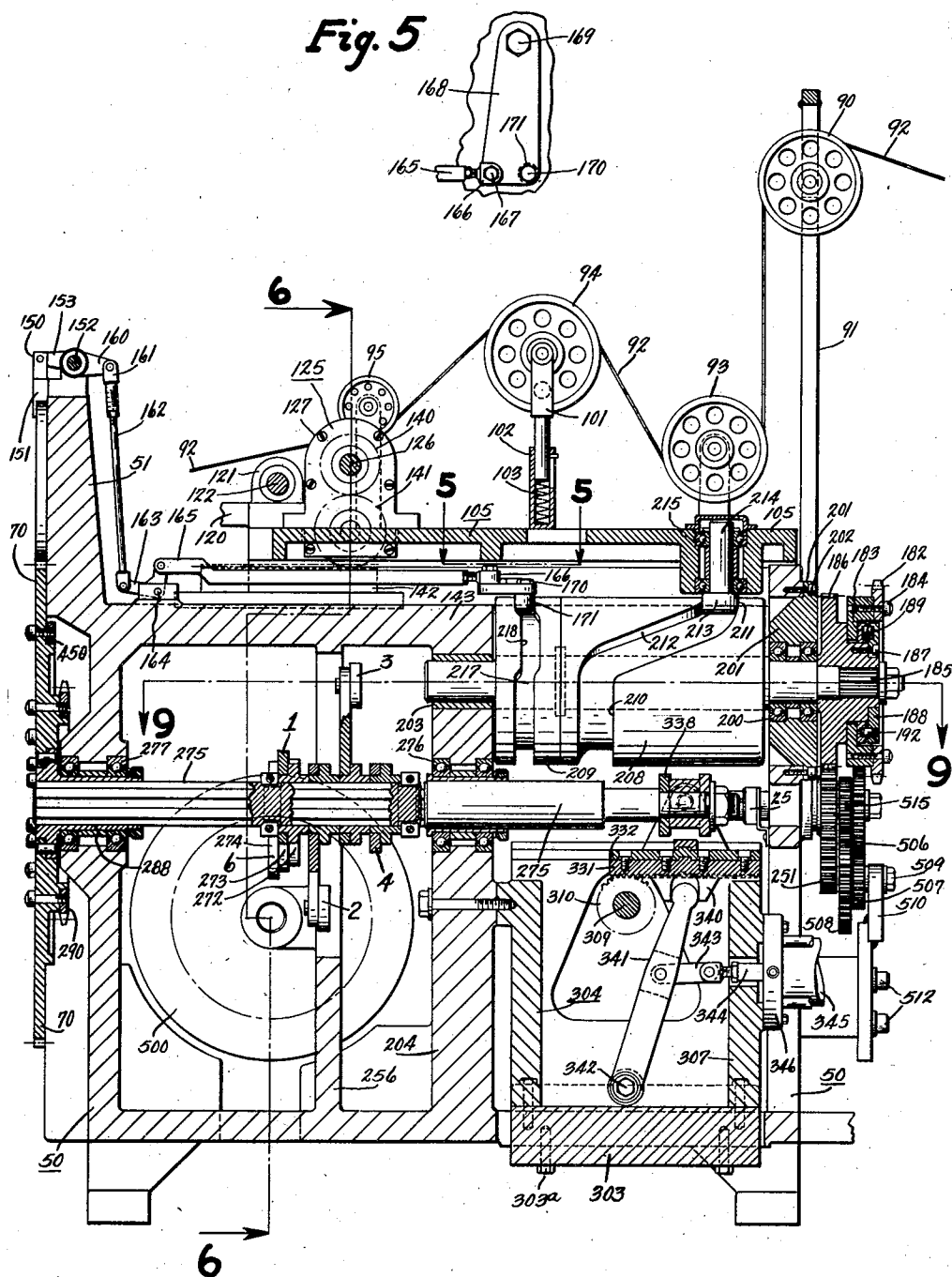


Fig. 4

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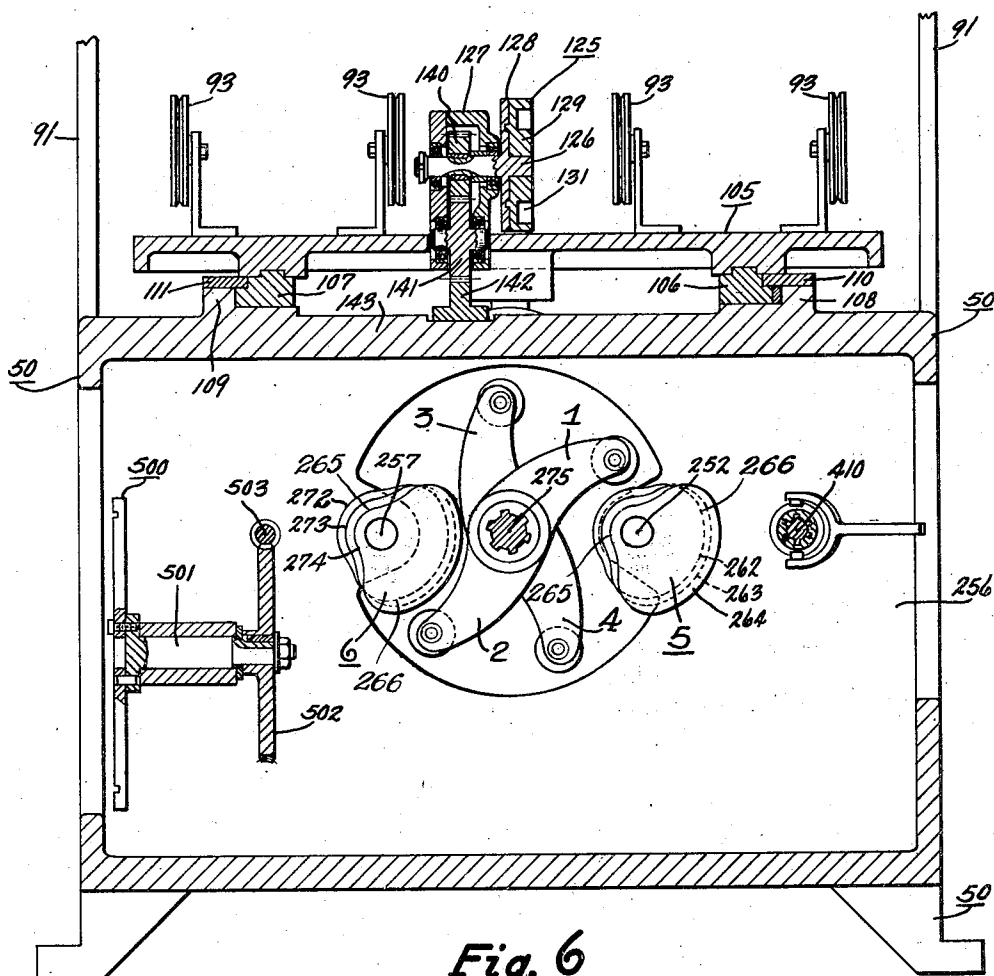


Fig. 6

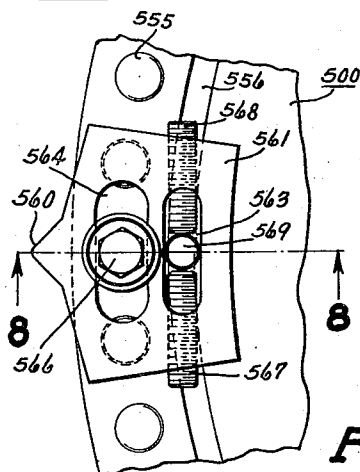


Fig. 7

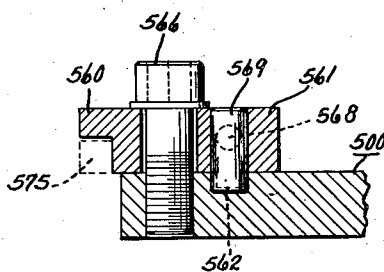


Fig. 8

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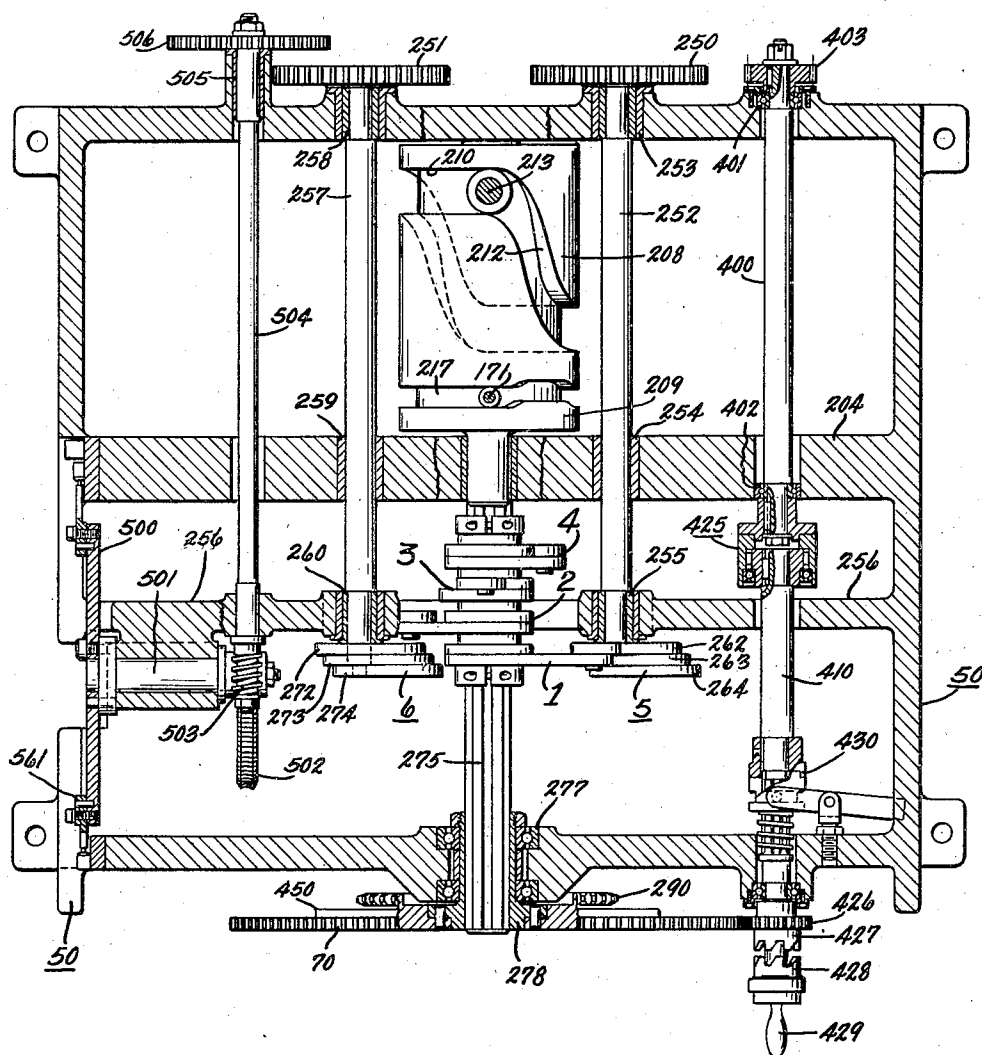


Fig. 9

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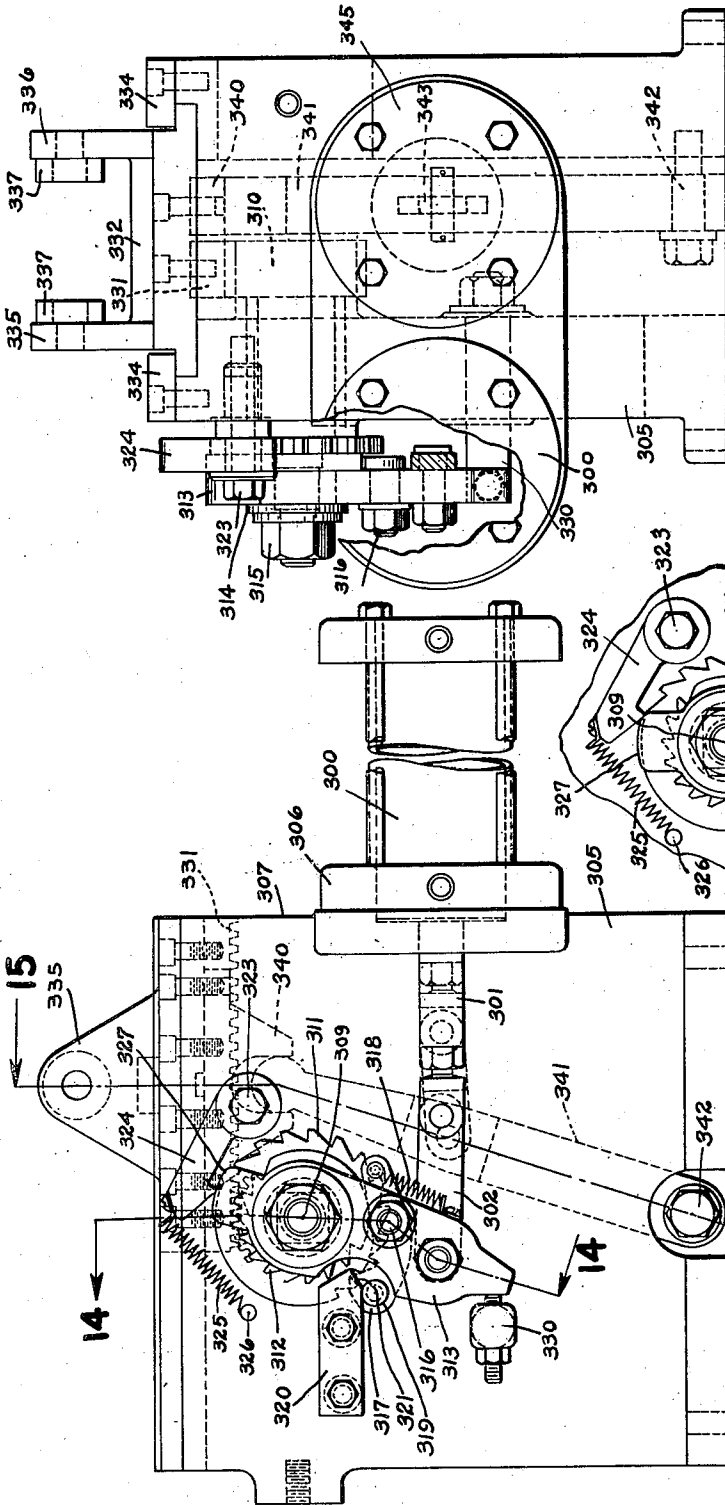


Fig. 12

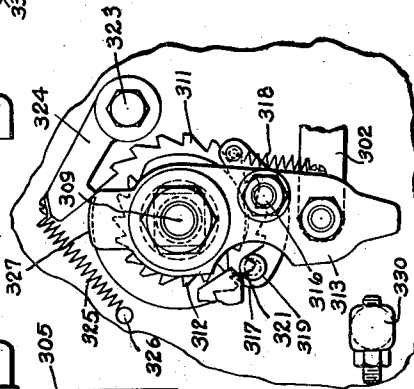


Fig. 11

Fig. 10

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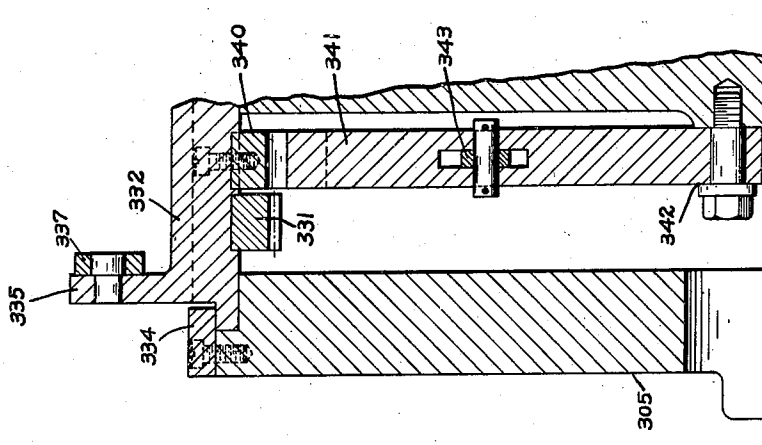


Fig. 15

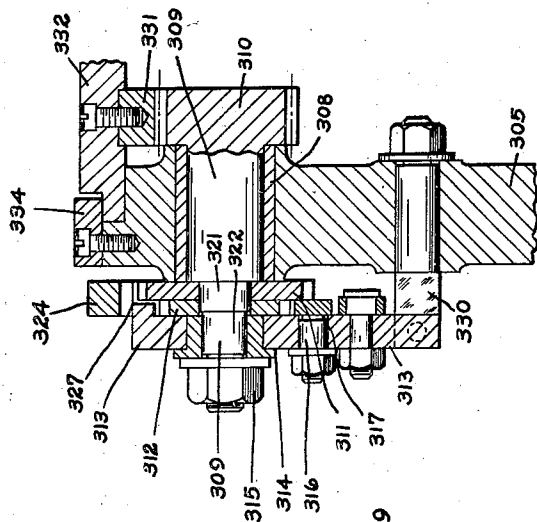


Fig. 14

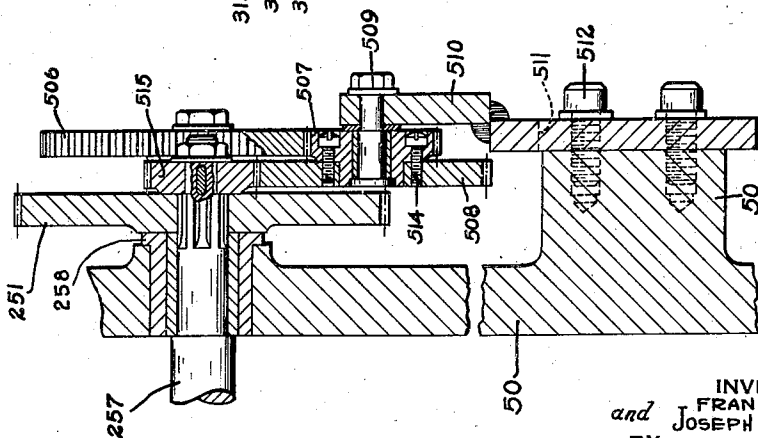


Fig. 13

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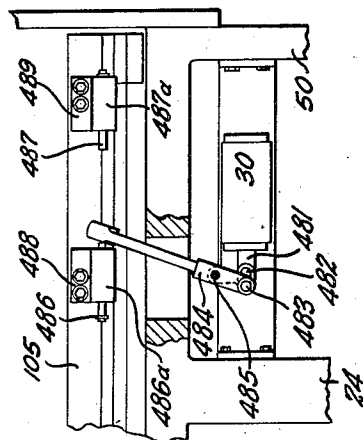


Fig. 18

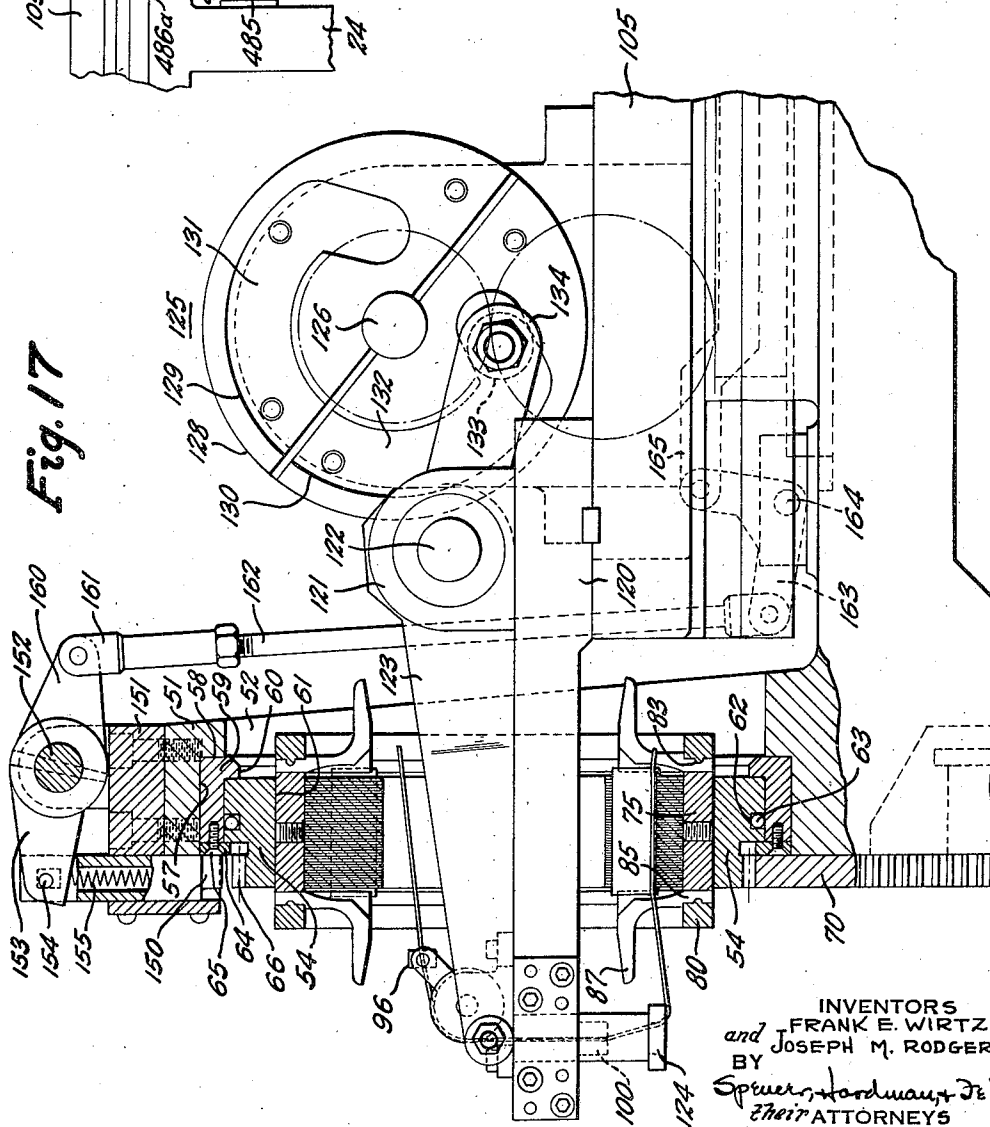


Fig. 17

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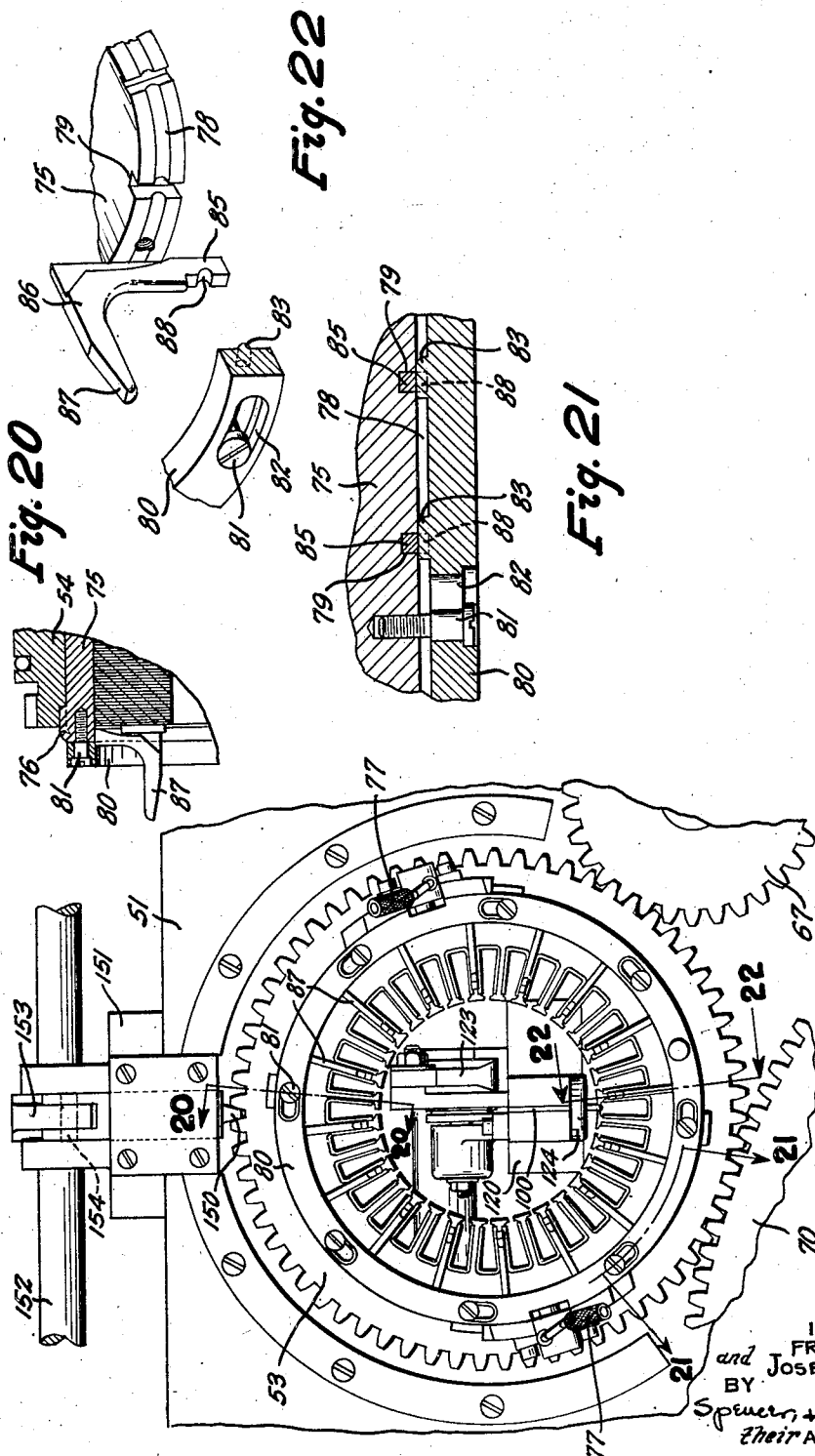
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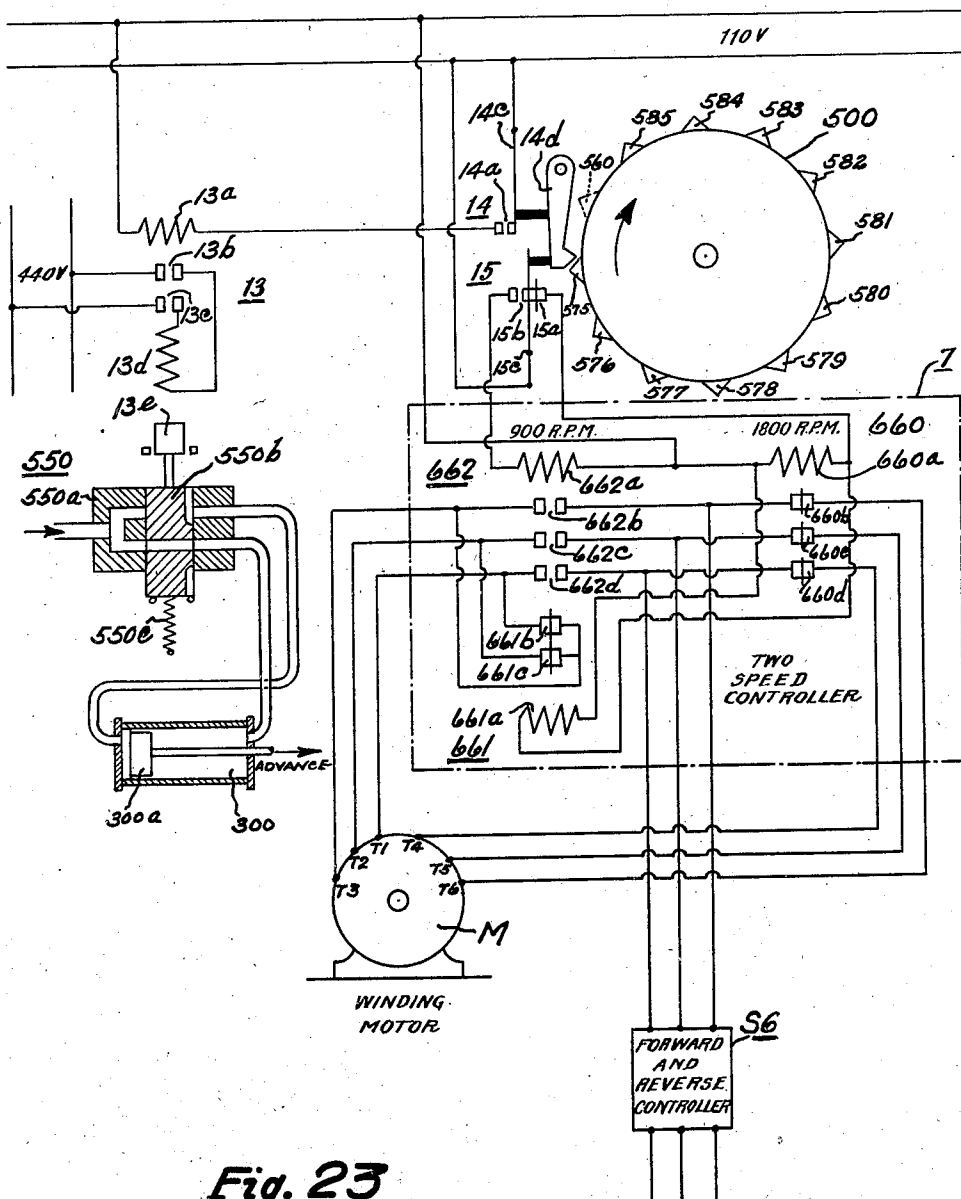
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WINDING MACHINE

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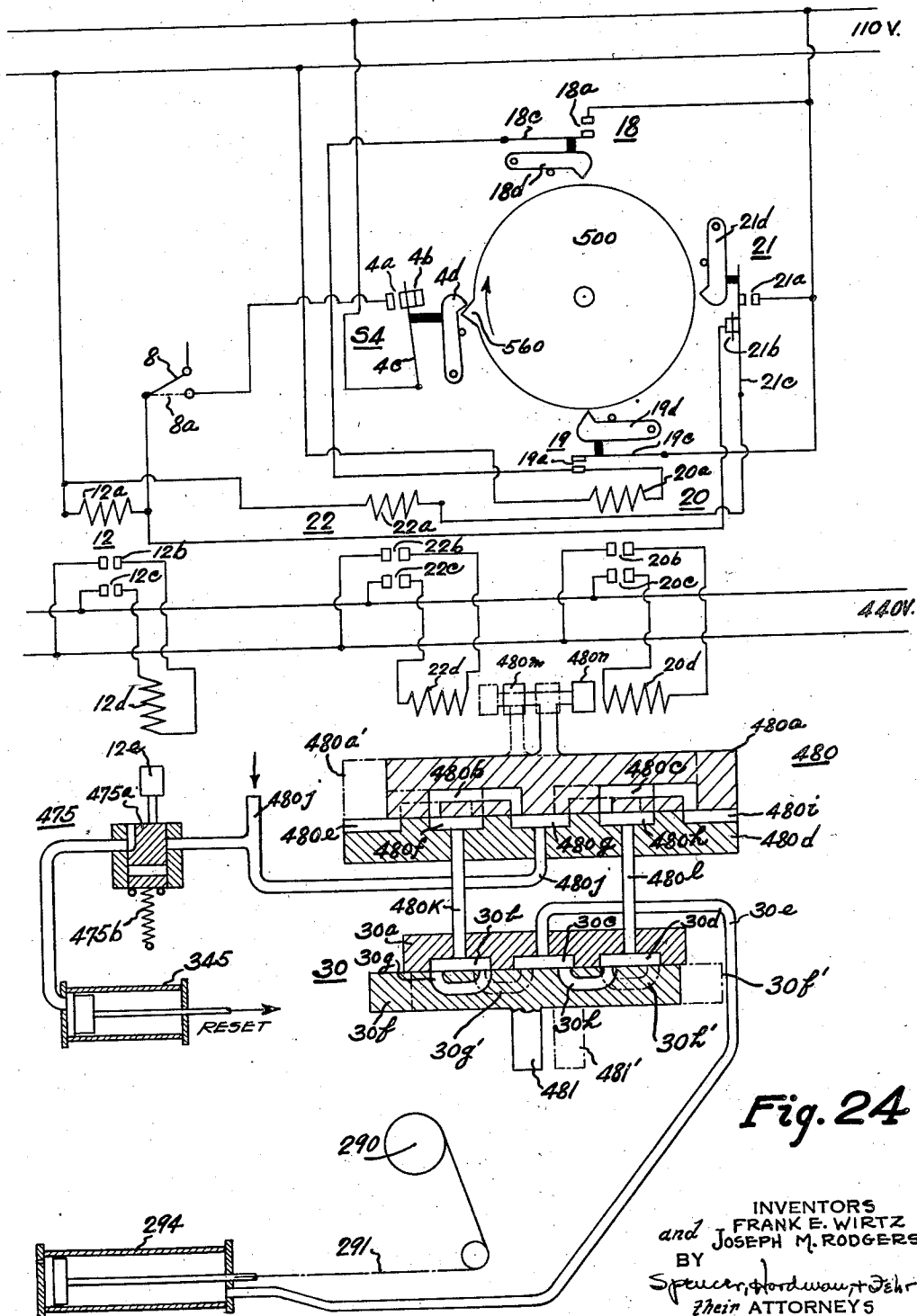
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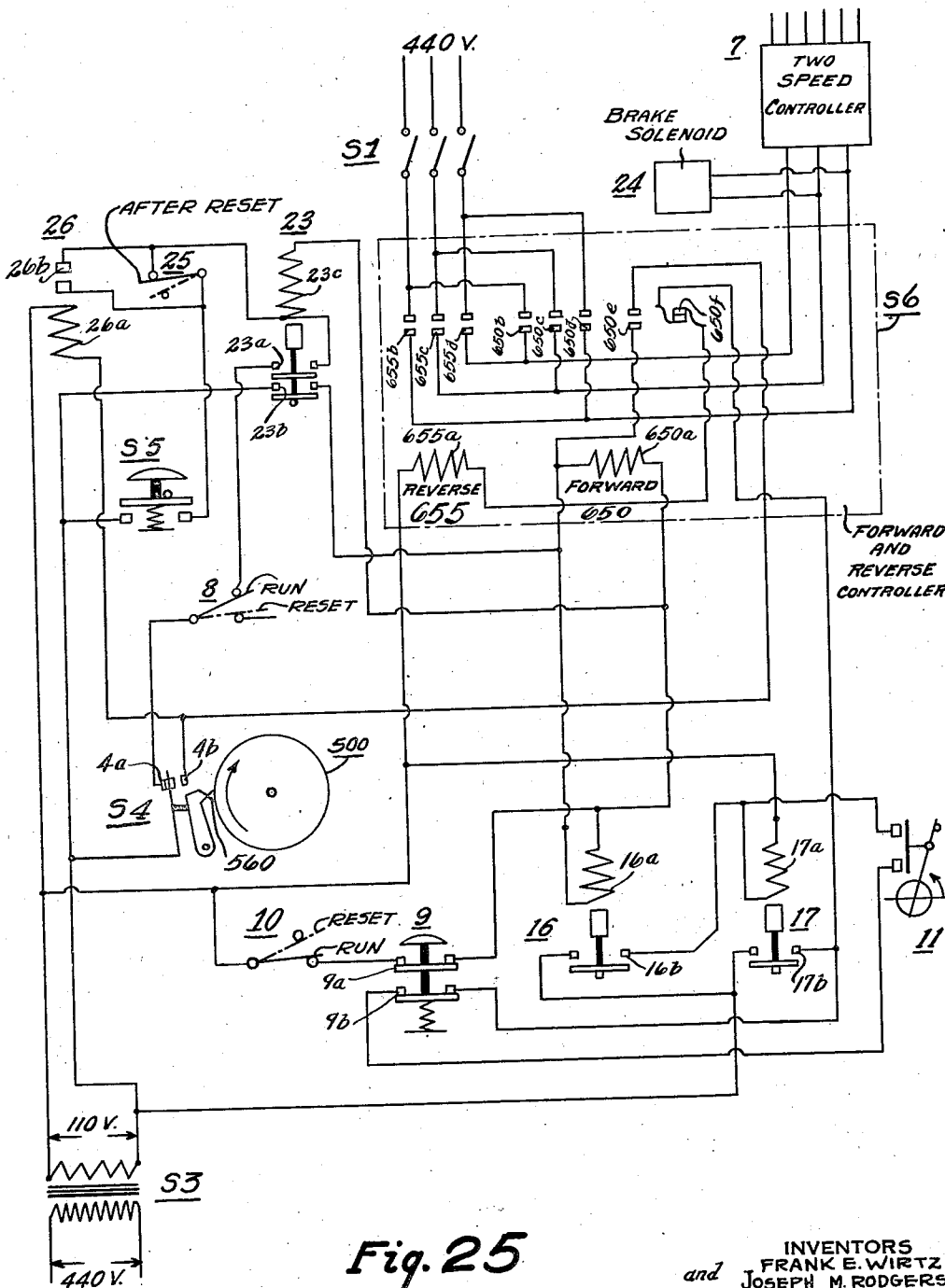
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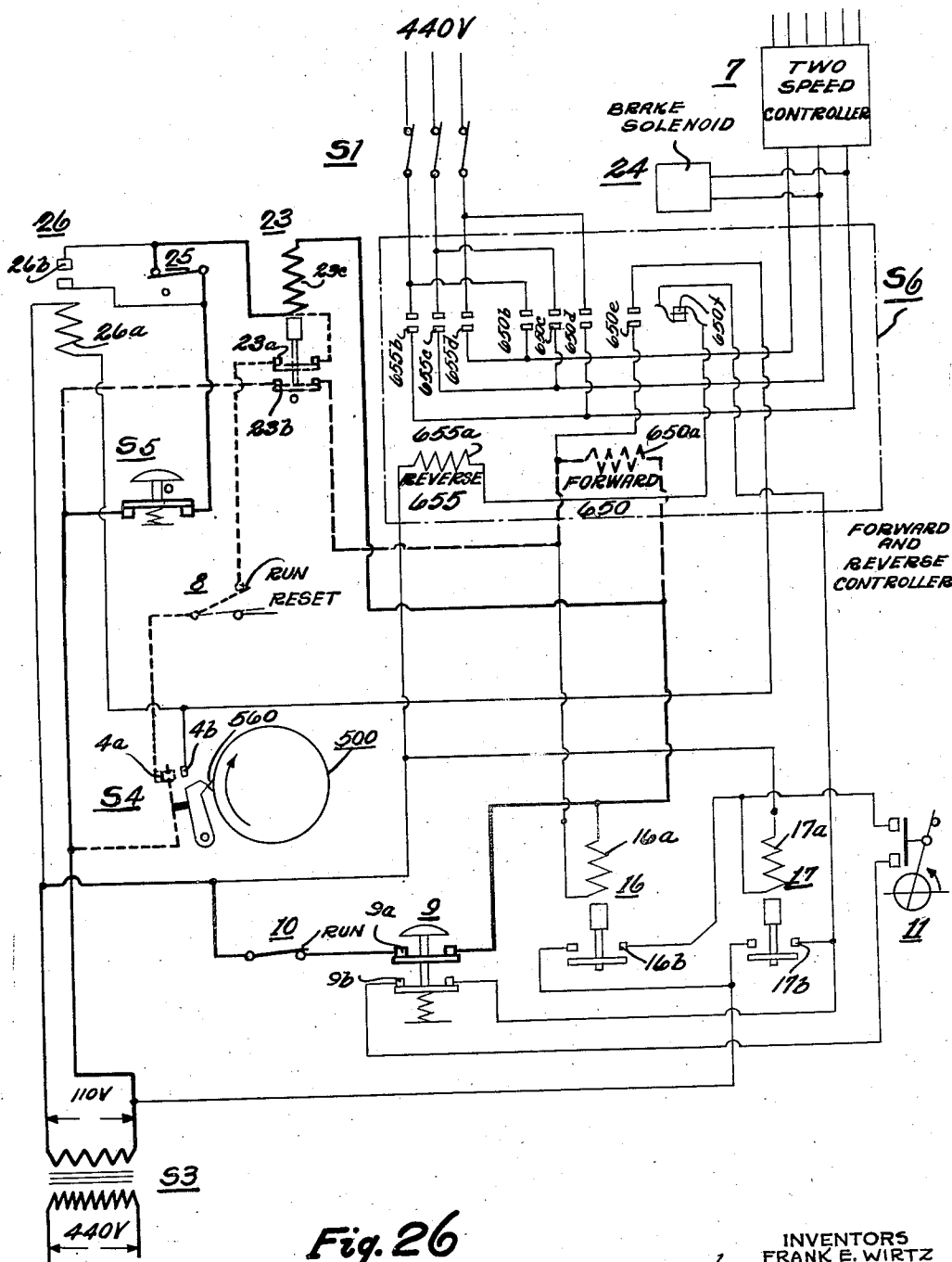
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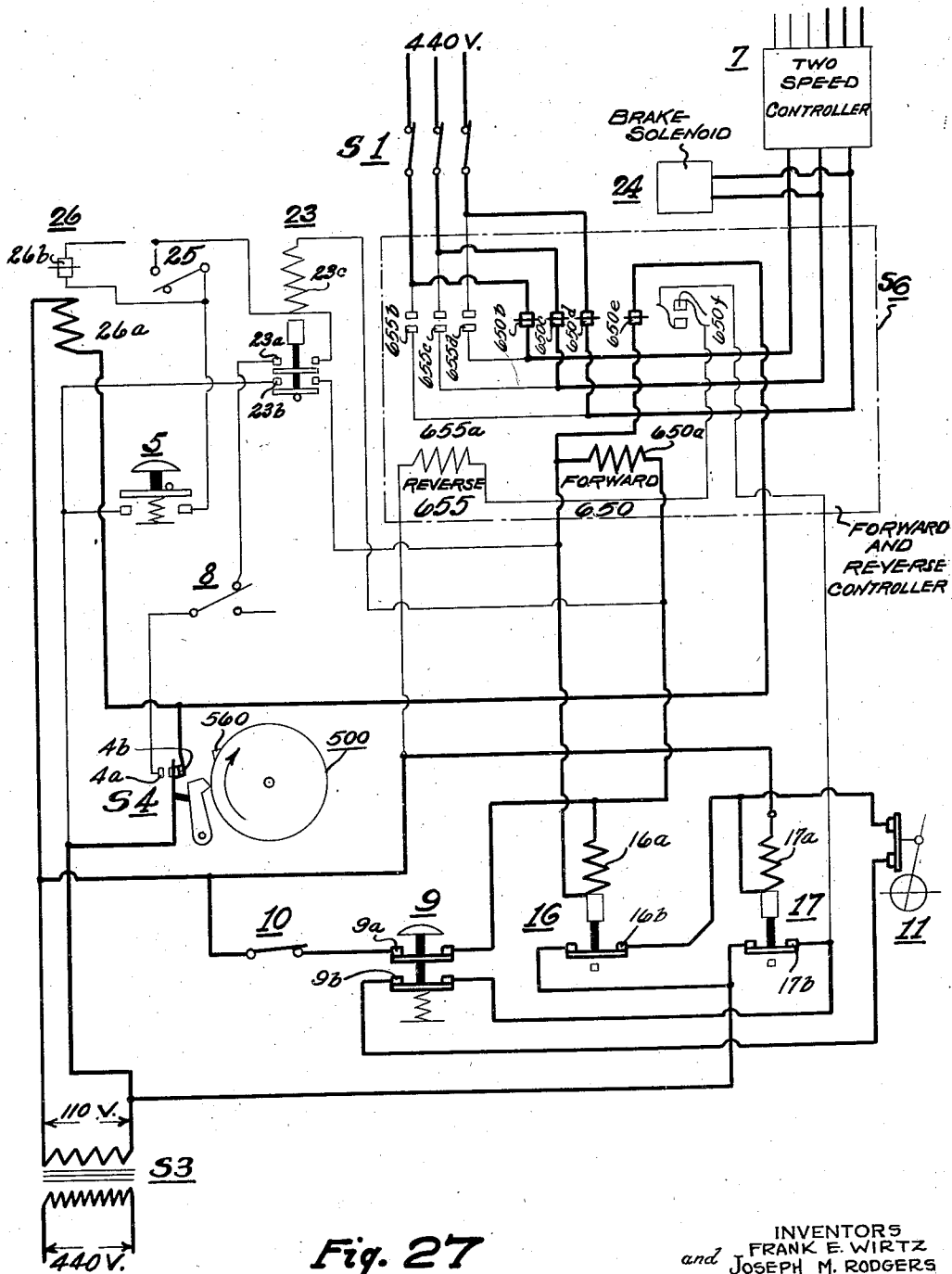


Fig. 27

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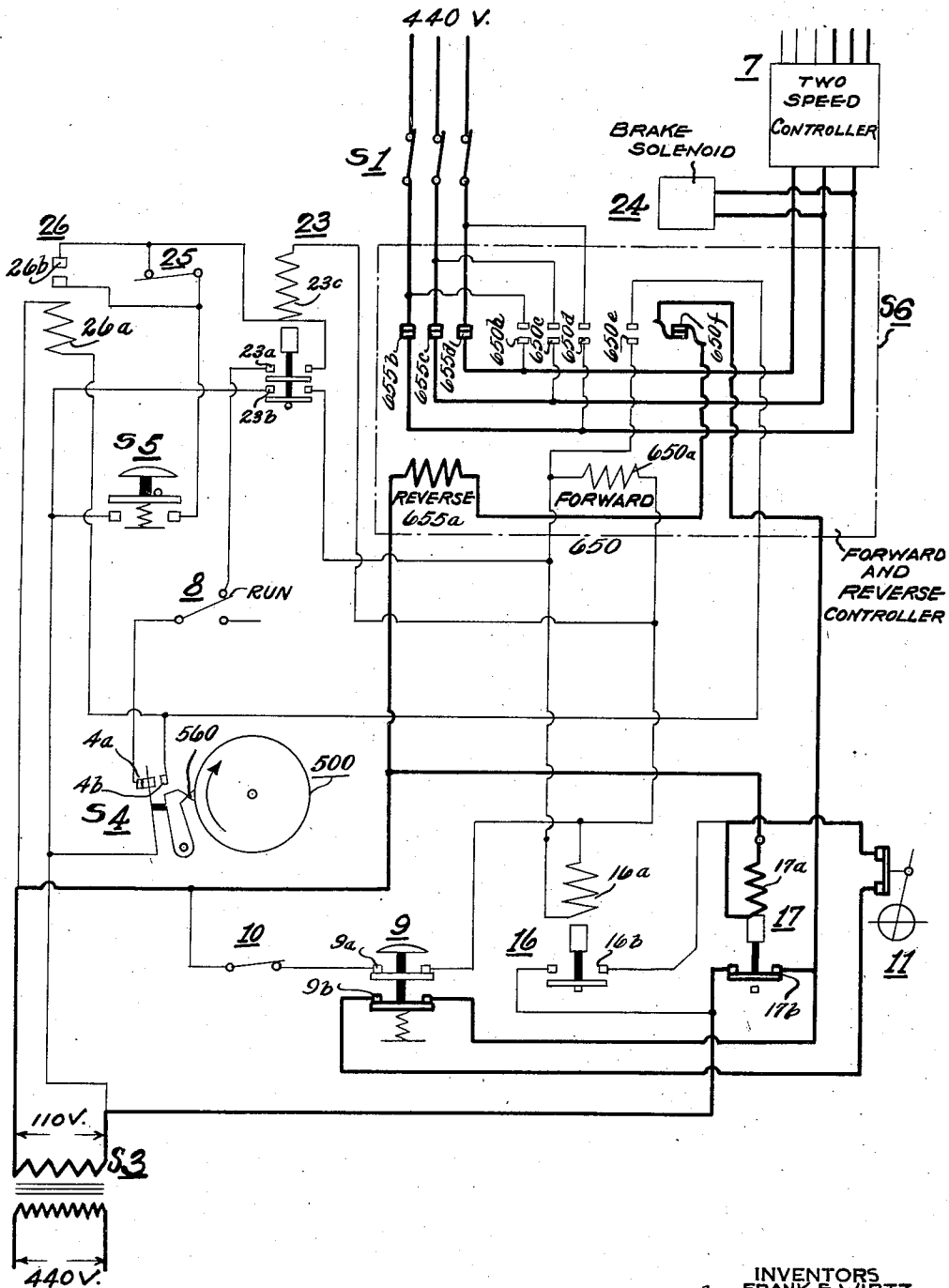


Fig. 28

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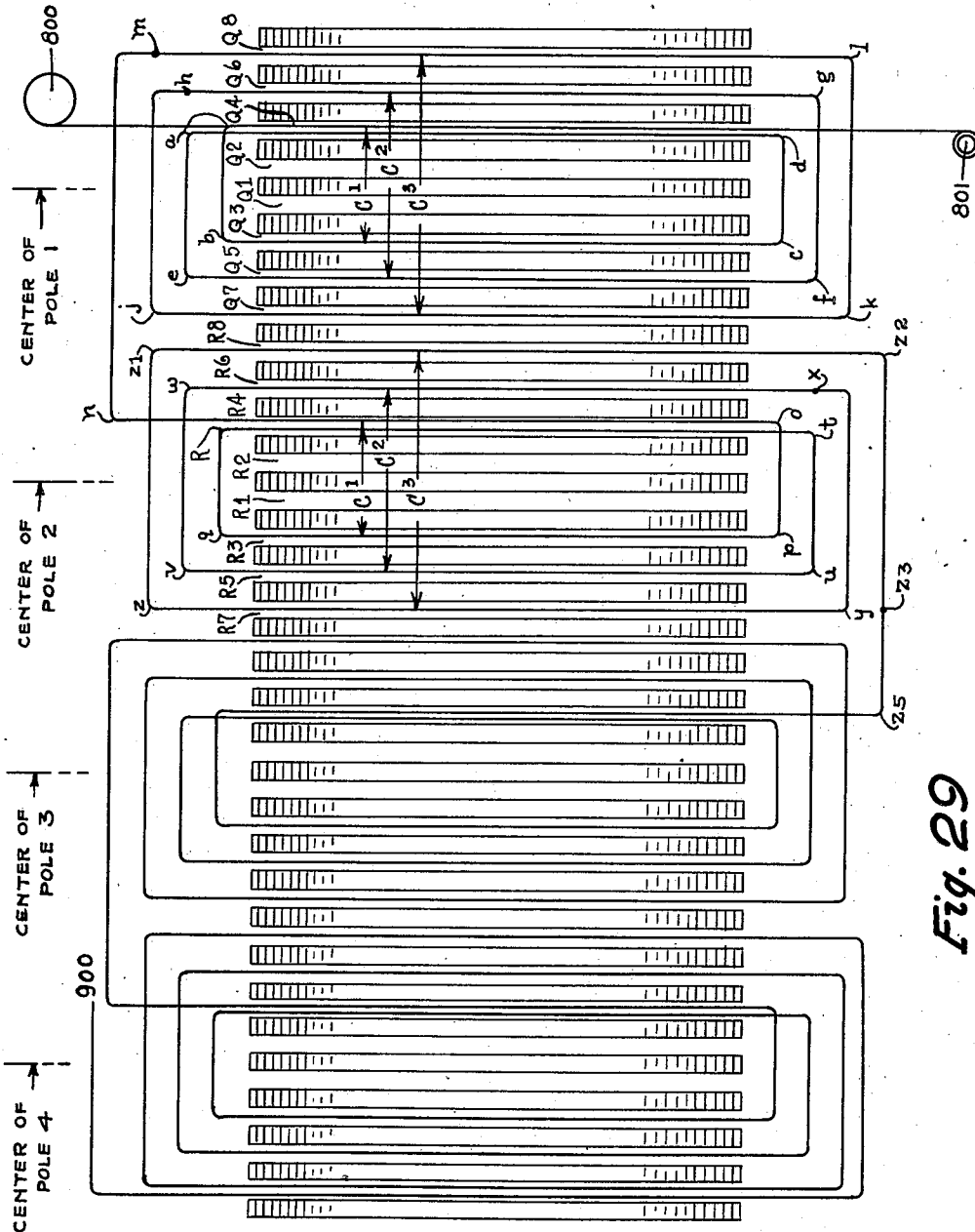


Fig. 29

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UNITED STATES PATENT OFFICE

2,304,520

WINDING MACHINE

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Application September 27, 1940, Serial No. 358,721

41 Claims. (Cl. 242—1)

This invention relates to machines for winding coils in the slotted cores of electrical apparatus and particularly of stators for dynamoelectric machines.

It is among the objects of the present invention to provide a machine adapted automatically to wind a plurality of concentric coils at each pole position of a stator, each succeeding set of concentric coils being wound in a direction opposite to the preceding set and all of the sets of coils of the stator being wound by the machine from a continuous length of wire or wires.

For carrying out the above mentioned object, the machine is provided with a rotatable stator supporting cage and a reciprocable wire guiding and laying needle and means for oscillating the said cage in one direction or the other at a time when the mechanism adapted to reciprocate the needle is inactive. The means for oscillating the stator carrying cage in one direction or the other comprises cam follower arms which are oscillated clockwise and counterclockwise by operatively engaging the working surfaces of the groups of cams, each group comprising a plurality of predeterminedly arranged cams in juxtaposition. A cam follower arm, operatively engaging the cams of one group in proper succession will oscillate the stator carrying cage through successively longer arcs of movement for the purpose of bringing the more widely separated slots of the successively wound concentric coils of one stator pole in proper operating alignment with the reciprocating wire laying needle. Reversal of the winding direction of the machine for the set of concentric coils at the next succeeding pole position of the stator is obtained by the shifting of the previously acting cam follower arm out of operating alignment with the one group of cams and the subsequent alignment of the second cam follower arm, with the second group of cams with which said second arm co-operates to wind the second set of pole coils in a manner similar to that just described in connection with the first follower and first group of cams. The means for reciprocating the wire guiding and laying needle comprises a cam so designed that it will maintain the needle at each end of its reciprocative movement for a period of time sufficient to permit oscillation of the stator carrying cage for the purpose of bringing the other slot of the respective stator coil into proper operating alignment with the needle and incidentally forcing the one end loop or cross-over of the respective coil. The two groups of cams just described are driven by the same power

means that operates other parts of the machine. This power means is preferably an electric motor and may be referred to hereinafter as the "primary power means." Due to friction and inertia, the cam follower arms can only be actuated counterclockwise by the cams, for in this direction the cam follower arms are moving "uphill" from a lower dwell of the cam to a higher one. Friction and inertia of the machine, however, will prevent the follower arm from riding "down-hill" on the cam, that is, from the higher to the lower dwell, thus necessitating the application of a separate power means directly to the cam follower arm and in a clockwise direction.

In order to obtain smooth operation of the machine and to avoid the simultaneous application of opposing driving forces to the cam follower arms, it is another object of the present invention to provide the machine with two separate and distinct power means one of which, although constantly available, is capable of rotating the oscillatable cam follower arms in one direction only, the other power means being applied to rotate said arms in the other direction and being active only during the period in which the first power means is incapable of oscillating the arms. In this connection, it is a further object of the present invention to provide the machine with controlling means adapted to render the second power means sequentially active and inactive at proper stages in the winding of each convolution of a stator coil. This object is attained by providing a control device which is actuated by the reciprocating needle mechanism adjacent its one end of travel, to render said second power means active for oscillating the stator carrying cage in one direction and adjacent its opposite end of travel is adapted to render the said second power means inactive, thereby effecting oscillation of the stator carrying cage in the opposite direction by means of the first power driven cams.

In the foregoing it has been stated that each succeeding set of pole coils are wound in a direction reversed by the set of coils at the preceding pole position of the stator. It has also been stated that the control device which effects oscillation of the stator carrying cage in opposite directions sequentially, renders the second power means active and inactive for each convolution of said set of coils. Therefore it is a still further object of the present invention to provide the winding machine with a timed control mechanism which will change the sequence of operation of the control device for the second power means at the proper instant between the completion of

one set of coils at one pole position of the stator and the beginning of the set of coils at the next adjacent pole position of the stator.

Thus, in a machine as shown which is adapted to wind a stator of four poles, the machine timed control mechanism will be effective in the first half of a complete cycle of the machine, first to change the sequence of operation of the second power means control device so that said second power means will be active to oscillate the cage at both the back and front positions of the needle mechanism when completing the last end-loop of the first set of coils and the first end-loop of the second following set of coils, reversely wound to the first set. The machine timed control mechanism will next be effective to actuate the control device of the second power means so that said power means will be inactive while the cams, driven by the first power means, successively oscillate the cage to form the last end-loop of the second set of coils and the first end-loop of the third set of coils. The operation will be repeated for the second half of the machine cycle of operation during which time sets of coils for pole positions three and four are wound.

In the present machine the second power means comprises an air pressure cylinder, the piston of which is actuated by air pressure to rotate the cam follower arms clockwise. Uncontrolled movement of the cam follower arm under the influence of the air cylinder causes clashing engagement of said follower arms with the respective cams. Consequently it is a further object of the present invention to provide a controlling means adapted to prevent excessively fast rotation of the cam follower arms toward their respective cams under the influence of the air cylinder. This control is of a dual character, the first comprising means for reducing the speed of the primary power means at the time a cam follower arm is to be shifted, the second comprising a one-way, speed limiting clutch operatively connected between one member driven by the primary power means and another member driven by the mechanism for rotating the cam follower arms. This clutch is so constructed and arranged that the cam followers may be rotated by the air cylinder no faster than the predetermined speed of rotation of that part of the clutch connected to the primary power means. In fact, while the machine is at rest, said clutch actually prevents movement of the cam follower arms by the air cylinder even after said air cylinder has been activated by the manual resetting of certain parts of the machine preliminary to its winding cycle. Starting of the machine by the primary power means permits the air cylinder to become active and move the follower arm in accordance with the speed of machine operation.

When the complete stator has been wound, the machine will automatically stop due to the breaking of the main circuit to the electric motor which forms the primary power means. A machine of this type will not stop immediately upon the sudden breaking of the circuit to the driving motor, but will tend to coast due to its inertia. Such coasting is not desirable especially because it is necessary to start the machine from a predetermined home position. It is therefore another object of the present invention to provide the winding machine with control means rendered effective to oppose the running of the machine and bring it to a definite stop within a minimum time after its completion of the wind-

ing of a stator. This object is attained by providing means actuated by the machine when a stator is completely wound, not only open the circuit to the electric motor which drives the machine, but also simultaneously close a reverse circuit through said motor which energizes the motor to effect its reverse operation. This energy in reverse, opposes the normal forward coasting tendency, quickly bringing the motor and its connected machine to a full stop. The electric motor has a switch closing the main circuit through the motor only as long as the motor rotates in the normal forward direction. As soon as the motor stops, and attempts to go in reverse, this switch will automatically open the main circuit and consequently the reversing energy to the motor will be discontinued. Breaking of the motor circuit releases a spring actuated brake which is applied to the motor as long as the circuit thereto is broken.

A still further object is to provide power means for resetting or returning the cam followers to initial position, said power means becoming operative in response to rotating the cam followers so that they will clear the cam.

Since the air cylinder which effects rotation of the cam followers in one direction is inactive at the end of the winding cycle and must be active at the instant of the start of the next winding cycle, the present machine includes means for establishing a change in the sequential operation of the control for the air cylinder while the machine is at rest. It is an object of the invention to effect this change in sequential operation concurrently with the resetting function.

Another object of the invention is to render the machine incapable of being started until the resetting operation has been fully completed. In carrying out this object the shaft carrying the cam follower arms is adapted to actuate a switch to close one gap in the circuit of the primary power means only when said shaft has been moved to restore the cam follower arms to their reset positions preliminary to the starting of another winding cycle. Other gaps in the circuit of the primary power means such as relay switches and the like are energized to complete and maintain the entire power circuit in response to the momentary closing of the main starting button switch by the operator.

A further object is to provide for the facile adaptation of the machine to wind stators differing with respect to total number of turns per pole and also differing with respect to the number of turns in each pole winding. This object is accomplished by providing for quickly changing the gearing between the main drive and the timer disc shaft, and for adjusting the lugs on the timer disc or for quickly substituting one timer disc for another.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings, wherein a preferred form of the invention is clearly shown.

In the drawings:

Figs. 1 to 22, inclusive, all illustrate the mechanical construction of the machine and may be detailedly described as follows:

Fig. 1 is a front elevation of the machine which in the present instance is adapted to wind four separate stators simultaneously.

Fig. 2 is a side elevation of the machine taken in the direction of the arrow 2 in Fig. 1.

Fig. 3 is a rear elevation of the machine as viewed in the direction of the arrow 3 of Fig. 2.

Fig. 4 is a vertical sectional view taken along the line 4—4 of Fig. 3. In this view, however, certain parts of the machine are shown in elevation for the sake of clarity.

Fig. 5 is an enlarged fragmentary plan view of certain of the cooperating members taken along the line 5—5 of Fig. 4.

Fig. 6 is a sectional view taken along the line 6—6 of Fig. 4.

Fig. 7 is a fragmentary view of the timing disc and one of its adjustable switch actuators.

Fig. 8 is a section taken along the line 8—8 of Fig. 7.

Fig. 9 is a part sectional view taken along the line 9—9 of Fig. 4.

Fig. 10 is a side elevation of the advance mechanism of the machine.

Fig. 11 is a detail view of several of the cooperating members of the apparatus shown in Fig. 10.

Fig. 12 is a rear elevation of the apparatus shown in Fig. 10.

Fig. 13 is a sectional view taken along the line 13—13 of Fig. 3.

Fig. 14 is a similar view taken along the line 14—14 of Fig. 10.

Fig. 15 is a cross-sectional view taken along the line 15—15 of Fig. 10.

Fig. 16 is a sectional view taken along the line 16—16 of Fig. 1. Some parts of this view illustrate cooperating parts of the machine in elevation.

Fig. 17 is a view similar to Fig. 16 showing certain parts in different operating positions, however.

Fig. 18 is a detail view of one of the controlling elements of the machine.

Fig. 19 is a detail view of a stator supporting mechanism and its cooperating parts of the machine.

Fig. 20 is a fragmentary sectional view of the mechanism shown in Fig. 19. This view is taken along the line 20—20 of Fig. 19.

Fig. 21 is a fragmentary view taken along the line 21—21 of Fig. 19.

Fig. 22 is a disassembled view in perspective of the parts of the machine along the line 22—22 of Fig. 19.

Fig. 23 is a diagrammatic view illustrating the various air and electrical devices and their circuits rendered effective for the periodical changes of operating speeds of the machine.

Fig. 24 is a diagrammatic view illustrating certain air and electrically operated control devices and their circuit connections for the purpose of resetting the entire machine preparatory to its winding cycle.

Fig. 25 is a wiring diagram of certain electrical control elements of the machine, these elements being shown in non-operating status.

Fig. 26 is a wiring diagram similar to Fig. 25, various circuits of which are established for the purpose of starting the machine.

Fig. 27 is a wiring diagram similar to Figs. 25 and 26 and shows in heavy lines all of the circuits established during the running of the machine.

Fig. 28 is a circuit diagram identical with Figs. 25, 26 and 27 and shows in heavy lines the circuits established for bringing all operating parts of the machine to an instantaneous stop and thereby preventing coasting of the machine beyond a predetermined stopping range.

Fig. 29 is a chart illustrating the path and direction of placing wire in a stator.

The work-holder cages

The machine comprises a frame 50 (Fig. 1) of rectangular construction providing four side walls and a top. At its top and front the machine has an upwardly extending wall 51 provided with four circular openings 52 in which oscillatable cages 53, 54, 55 and 56 are supported. Inasmuch as the construction of these oscillatable cages and their workpieces are all identical, only one will be described detailedly, reference being had to the oscillatable cage 54 through which the section figures 14 and 15 have been taken.

Concentric with the opening 52 (Fig. 16) the front surface of wall 51 is counterbored to provide the recess 57 having a shoulder 58 at its inner end. This recess 57 receives a ring 59 provided with an inwardly extending flange 60 at its inner end. Ring 59 is press-fitted into the counterbored recess 57 of wall 51 of the machine and is therefore fixed therein. This ring 59 provides the outer bearing member for the oscillatable cage 54 which is also of circular formation, being bored out as at 61 to receive the workholder ring, to be described hereinafter. An annular groove 62 is formed in the outer annular surface of the cage 54, providing a retainer race for the ball bearings 63 which engage both the inner surface of the annular groove 62 and the inner surface of the non-rotatable ring 59. To retain cage 54 within the ring 59 a circular plate 64 is secured to the outer edge of ring 59 by screws 65, this plate extending beyond the confines of the inner wall of ring 59. The cage 54 has a reduced diameter portion extending through and beyond the retainer ring 64, the outer peripheral edge of said smaller diameter portion of the cage being provided with gear teeth 66.

By referring to Fig. 1, it will be seen that the gear teeth of the cage 53 mesh with an idler gear 67, rotatable on a stud carried by the frame of the machine. This idler also meshes with the gear teeth 66 of cage 54. A similar idler gear 68 has its teeth operatively engaging the teeth of the cages 56 and 55. The teeth of cages 54 and 55 also engage a common oscillating gear 70 whose function will be detailedly described hereinafter. From this it may be seen that any rotation of the gear 70 will be transmitted to the cage 54, and from cage 54 through the idler 67 to the cage 53. Likewise, rotation of gear 70 will be transmitted to the cage 55 and through the idler gear 68 to the cage 56. Thus cages 53, 54, 55 and 56 will be actuated in one direction or the other concurrently in accordance with rotation of the gear 70.

The work-holder

The work-piece operated upon by the present machine is a stator for an electric motor or generator, the stator comprising a stack of metallic laminations provided with inwardly opening slots for receiving the windings. The stator is supported in the work-holder, detailedly shown in Figs. 16 to 22 inclusive. The work-holder comprises a ring 75 adapted to be received by the oscillatable cage 54. In order properly to locate the work-holder ring 75 in the cage 54, the cage has a notch adapted to receive a lug 76 on the ring 75 so that the ring must at all times be placed in the proper position in ring 54 and so that said work-holder will slip into ring 54 at a predetermined distance. Clamping screws 77 are actuated to secure the work-holder ring 75 in the cage 54, when placed in proper position therein.

Referring particularly to Figs. 21 and 22, ring

75 has an annular groove 78 in its outer peripheral surface. This ring also has a plurality of equally spaced notches 79 transversely in its outer peripheral surface. These notches 79 are so arranged so that each notch is located centrally between every alternate slot in the stator when the stator is in proper position in the work-holder. A ring 80 fits about the outer annular surface of the work-holder ring 75, the ring 80 being secured to ring 75 by a plurality of screws 81 extending through elongated slots in the ring 80 and threadedly engaging the work-holder ring 75. These slots are designated by the numeral 82. The surface of ring 80 engaging the outer periphery of ring 75 has a plurality of spaced ridges 83 adapted to ride in the annular groove 78 of ring 75. An extension 83 is provided adjacent each notch 79 in ring 75. These notches 79 are provided to receive the ends 85 of wire retaining fingers 86 which have extensions 87 substantially at right angles to the arm portion 85 previously referred to. The edge of arm 85, adjacent the inner surface of ring 80 when the retainer 86 is in position, has a notch 88 which coincides with the annular groove 78 in the ring 75. When the ring 80 is rotated on ring 75 so that the screw 81 is at one end of slot 82, the projection 83 will lie in the groove 78 so as not to engage or enter into the notch 88 of arm 85, thereby permitting removal of the wire retaining member 86 from the notch 79. However, after the retaining member 86 is placed in notch 79 and the ring 80 is rotated so that the screw head 81 is at the other end of its slot 82 then the ridge 83 on ring 80 will be moved into locking engagement with the notch 88 of arm portion 85 of the wire retaining member, thus securely locking said member in proper position on the ring 75. It will, of course, be understood that each finger opposite each alternate slot in the stator is simultaneously locked on the ring 75 by the operation of the ring into one position and likewise is simultaneously unlocked and releasable for removal when said ring 80 is actuated into the other position.

The wire guiding or laying mechanism

As mentioned in the statement of the objects of the invention, the present machine is adapted to wind the various coils of the stator for an electric motor or generator from an unbroken supply of conductor wire or wires. This wire is on a supply spool, not shown, leading from said supply spool to a guide pulley 90 rotatably supported on a standard 91 carried by the frame of the machine. The wire designated by the numeral 92 extends from pulley 90 across a pulley 93 carried by a reciprocating part of the machine to a pulley 94 also carried by said reciprocating part of the machine, then to a pulley 95, thence through the stationary guide block 96 to the needle or wire-laying element 100 shown in dotted lines in Fig. 17. As shown in Fig. 2, pulley 94 is supported upon a yoke member 101 resiliently supported in a sleeve 102 by a shock absorbing spring 103. This spring not only maintains a proper tension upon the wire 92 passing from pulley 93 to pulley 95 over the pulley 94, but it also acts as a yieldable member adapted to absorb any undue stresses placed upon the wire under any circumstances.

It has been said that pulleys 93, 94 and 95 are carried by a reciprocating member. This reciprocating member, as shown in Fig. 6, comprises a platform or table 105 having tracks 106 and 107 attached to its bottom surface in any

suitable manner. These tracks slidably rest upon the upper surfaces of the slideway members 108 and 109 respectively, said slideway members being provided on the upper plate of the frame 50 of the machine. In order to maintain the tracks upon the slide members 108 and 109 these slide members are provided with retaining plates 110 and 111 respectively. The reciprocating table or platform acts as a movable carrier for the wire laying members of the machine. Inasmuch as all wire laying members of the machine are identical, only one will be described detailedly, reference being had particularly to Figs. 16 and 17. The numeral 120 designates the rigid arm of the wire laying mechanism secured to the reciprocable table 105 in any suitable manner. This arm 120 has an upwardly extending integral ear 121 carrying a shaft 122 which pivotally supports a reciprocating arm 123. Here it may be said that shaft 122 extends through all of the similar ears or lugs 121 of the four wire laying mechanisms of this machine, providing a common pivotal support for the reciprocating arms 123 of the respective wire laying mechanisms of the machine. The wire laying needle or guide is rigidly secured to the outer end of the rigid arm 120 and extends downwardly from the outer end of arm 120 a predetermined distance so that when said arm 120 is reciprocated back and forth through the stator held in the work-holder ring, said needle is adapted to transverse the slot of the stator in alignment with the path of travel of the wire laying guide or needle. Cooperating with the needle is a shuttle 124 in vertical alignment and surrounding the needle, this being slidably supported in a guide way provided by the outer end of the arm 120 and being pivotally secured to the outer end of the reciprocating arm 123 so that as said arm 123 is raised or lowered by a clockwise or counterclockwise reciprocating arm 123 about its pivotal shaft 122, shuttle 124 will be slid upwardly and downwardly about the needle 100 through the guideway provided by the rigid arm 120. This shuttle tends to draw wire through the needle to provide a slack wire for the purpose of crossing over from one slot of the stator to another. It also acts as a rigid tension member taking a load off the more fragile needle or wire guide during such cross-over operation, as will be described later.

The rotation of the pivotal shaft 122 clockwise or counterclockwise to reciprocate the various arms 123 of the various wire laying mechanisms of the machine is obtained by a single cam mechanism designated as a whole by the numeral 125. This mechanism comprises a shaft 126 supported transversely in a housing 127 which in turn is carried by the reciprocating table. Referring particularly to Fig. 17, shaft 126 has an annular disc portion 128 to which are attached two segments 129 and 130 recessed as at 131 and 132 to provide a cam way for the roller 133. This roller is supported upon an arm 134 rigidly secured to an intermediate portion of the oscillating pivotal shaft 122 of the various wire laying mechanisms of the machine. The guideways 131 and 132 are so arranged that the arms 123 are properly oscillated to raise or lower the shuttle mechanism 124 of the various needles at the proper time, or particularly when the reciprocating table 105 is at the desired or proper positions in its travel back and forth. It will, of course, be understood that the shuttle 124 must be moved downwardly when it is beyond the con-

lines of the workpiece at one side thereof and must be raised again to permit movement of the shuttle, needle, and reciprocating arm 120 through the workpiece or stator.

Within the housing 127, shaft 126 has a pinion gear 140 secured thereto. This pinion gear operatively engages a cooperating pinion gear 141 carried on a stub shaft rotatably supported by the housing. The lower portion of the pinion gear 141 extends beyond the confines of the housing 127 and operatively engages a rack 142 rigidly attached to the top plate of frame 50, this top plate being designated by the numeral 143. From this it may be seen that reciprocation of table 105 on its guide-ways 108 and 109 will cause the pinion gear 141 to rotate as it moves longitudinally over the rack 142, its rotation being transmitted to the pinion gear 140, thereby rotating the cam comprising segments 130 and 131 in one direction or the other, dependent upon the direction in which the pinion 141 is moving over the rack 142.

Cage-locking mechanism

During the winding operation it is desirable to lock the workpiece supporting cage in proper position so that the slot of the stator into which wire is being laid will remain in proper alignment with the wiring laying needle as it traverses said slot. The mechanism for locking this cage comprises a detent 150 in the form of a wedge adapted to be inserted between adjacent teeth provided on the cage ring. For purposes of description Figs. 1, 4, 16, 17 and 19 will be particularly referred to, which figures particularly illustrate the winding mechanism comprising the cage 54 which is the winding mechanism second from the right on Fig. 1. This detent or wedge 150 is an integral part of a block slidable in a guideway provided by the member 151 secured to the upper flat surface of the wall 51 in any suitable manner. This member 151 has an upwardly extending lug which is apertured to receive the rocking shaft 152. This shaft is adapted to be oscillated in the lug of the member 151 and has attached thereto a rocker lever 153 which extends outwardly and over the guideway in the member 151. A cross-pin 154 is secured to this outer end of rocker lever, which end of the rocker lever fits into the yoke provided on the outer end of the detent block. The openings in said yoke member for receiving the ends of the cross pin 154 are rectangular in shape so that a lost motion connection is provided at this point between the lever 153 and the detent block 150. As the rocker lever moves counterclockwise, its pin 154 will move to engage the bottom surface of the rectangular opening in the yoke portion of the detent block, thus moving said block downwardly while compressing the shock absorbing spring 155 interposed between the detent block and the arm 153. The downward movement of the block will urge its detent portion 150 into locking engagement with the space between two adjacent gear teeth provided on the cage ring 54, thus securely holding the cage ring against rotation. When the lever 153 is moved clockwise, the pin 154 will have a free movement until it engages the upper surface of the rectangular opening in the yoke portion of the detent block with a hammer blow effect, thus tending to release the detent from engagement with the gear teeth even though considerable friction has been set up between those two parts during the winding operation.

The machine having four winding heads 53, 54, 55 and 56, as aforesaid, will require four of the locking arrangements as just described. Therefore, the wall 51 supports four blocks 151 and its associated parts, these blocks each being located substantially axially of the center of the respective cage. Consequently, the upstanding ears or lugs of each block 151 are adapted to support a single shaft designated by the numeral 152 and heretofore referred to and to which the various levers or arms 153 of the separate locking devices are attached. However, only one actuating mechanism for rocking the shaft 152 is provided. Referring particularly to Fig. 4, the shaft 152 has an arm 160 secured thereto, the end of which has a bifurcated clevis attached. The clevis is screw threaded to one end of the rod 162, the other end of the rod having a clevis secured to a rocker arm 163 pivotally carried by a stub shaft 164 secured to the top of the machine, said top being designated by the numeral 143. The rocker arm 163 has another arm portion to which one end of the rod 165 is anchored. Referring to Figs. 4 and 5, the other end of this rod has a clevis 166 providing an eye for receiving a screw stud 167 adapted to be screwed into one corner of a triangular shaped lever 168 which is pivoted to the machine by a screw stud 169. Adjacent the screw stud 167 this triangular shaped lever 168 has another screw stud 170 which supports a cam follower roller 171 adjacent the lower surface of said plate lever as shown in Fig. 4.

The driving mechanism as applied to the reciprocating table

Certain portions of the machine are driven by an electric motor. The motor itself is only shown diagrammatically on the sheets of drawings of the electric circuits. It may be said, however, that this motor may be of any suitable type, its driving shaft being connected with the sprocket 180 shown in Fig. 3 through any suitable type connections or gear reductions. The sprocket 180 has a chain drive connection 181 with the sprocket 182 shown also in Figs. 2, 3, 4 and 9.

Referring particularly to the drawing Fig. 4, the sprocket 182 is illustrated as having a clutch shell 183 secured to its rear surface by screw studs 184. It will be seen in Fig. 4 that the sprocket itself is ring-shaped, its inner annular edge coinciding with the inner annular edge of the ring shell 183. This ring shell forms the outer ring of an overload clutch mechanism connecting the sprocket 182 with the shaft 185. Shaft 185 has a gear 186 splined thereto, this gear having an extending hub portion bored to receive the annular flange portion of the ring shell 183 so that the outer surface of the ring shell engages the one surface of the hub as shown in Fig. 4. Screwed to a smaller diameter portion of the hub of gear 186 by bolts 187 is an abutment disc 188. This abutment disc has a circular row of recesses 189 for receiving spiral springs 190. These spiral springs also seat into corresponding recesses formed in a friction plate 191 surrounding the hub portions of gear 186 and interposed between the abutment plate 188 and the inwardly extending annular flange on the ring shell 183. The friction plate 191 is well as the abutment disc 188 has aligned openings for receiving driving pins 192 which drivingly connect the abutment plate.

From the foregoing it may be seen that as

the motor rotates the sprocket 180 and through its chain connection 181 rotates the sprocket 182, this rotation is transmitted from sprocket 182 to its attached ring plate 183 thence through the friction plate 191 through shear pins 192 to the abutment plate 188 thence to the gear 186 to which said abutment plate is bolted. Rotation of the gear 186 will rotate shaft 185 inasmuch as this gear is splined to the shaft. A bearing of any suitable kind shown as a ball bearing 200 in the present instance supports the shaft 185 in a block 201 which in turn is secured to the frame of the machine by bolts 202. The shaft 185 has another portion thereof journaled in the bearing 203 carried by a partition member 204 in the interior of the machine. On this shaft 185 are provided the driving mechanisms for both the reciprocating table 105 and the locking mechanisms for the winding cages. This driving mechanism comprises two barrel cams 208 and 209, the first cam 208 being secured directly to the shaft 185, the second cam 209 being free of the shaft, but keyed to the first cam 208.

The drum cam 208 has a cam groove, a portion 210 being circumferential of the outer surface of the barrel cam, another portion 211 being also partially circumferential of the drum cam while connecting portions of the groove which connect these partially circumferential portions thereof are angularly displaced relatively thereto. This tortuous groove comprising portions 210, 211 and 212 forms the cam surface receiving the roller 213 which is secured to the reciprocating table 105 by a stud 214. This stud 214 is supported in the table by any suitable anti-friction bearing 215. Thus as the drum cam rotates, the roller 213 is carried from one partially circumferential portion of the camming groove through an angular portion 212 to the outer partially circumferential portion 210 at the opposite ends of the drum cam whereby the reciprocating table 105 will be moved from the position as shown in Fig. 4, which is the rear-most position, to the position as shown in Fig. 17, which is the most forward position of the reciprocating table and vice versa.

The cam 209 has a circular cam groove 217 provided with offset portions 218. This groove receives the roller 171 on the triangular shaped lever 168. As the roller 171 moves through the cam groove comprising annular groove 217 and its offset portion 218, the triangular lever 168 is oscillated clockwise and counter-clockwise about its pivotal stud 169, thus moving the lever or arm 165 backwards and forwards which in turn through its connections with the arm 160 on shaft 152 will oscillate said shaft 152 whereby the locking detent is inserted and retracted from the space in the gear teeth of the winding cage.

As the table is moved from its rear-most position to its front position, the pinion gear 141 is rotated clockwise, resulting in a counter-clockwise movement of the pinion gear 140. Upon the return of the table from its foremost to its rear-most position, this rotation of said pinion gears 140 and 141 will be reversed when such movements of the pinion gears 141 and 140 result in a counter-clockwise and clockwise rotation of the cam comprising cam sectors 130 and 131, thus resulting in a rocking up and down of the arm 123 which actuates the shuttle 124 surrounding the needle.

From the foregoing it may be seen that the shuttle 124 is reciprocated by and in accordance with the reciprocation of the table 105, the timing

of said shuttle movement being controlled by the position of the camming discs 130 and 131.

The machine of the present invention is adapted to wind a coil or coils in the stator or field coil member of a motor or generator. Each coil comprises a complete convolution of wire consisting of two parallel active coil sides and two cross-overs to complete the loop. As the table 105 of the machine moves forwardly, the wire for one parallel side of the coil is laid, then the work-piece carrier or cage is oscillated to provide the cross-over at one end of the coil following which the table is oscillated in the opposite direction to lay the second coil side after which the work-piece is again oscillated in the opposite direction, however, to provide the cross-over or loop at the other end of the coil.

The wire laying mechanism of the machine has been described as comprising the table 105, which is moved from its rearmost position as shown in Fig. 4 to its extreme front position as shown in Fig. 17 during which time the wire will have been laid or guided into the one slot of the stator. After this, the shuttle is moved downwardly to provide the slack for the cross-over of the coil at its one end, this shuttle at the same time taking from the needle the strain of pulling the wire during the cross-over. After this the table 105 is moved from its foremost position as shown in Fig. 17 to its rearmost position as shown in Fig. 4, at which time the wire is introduced in the next slot of the stator, following which the cage is again oscillated in a direction opposite its first oscillation however to provide the cross-over in the same manner at the opposite end of the coil or more particularly on the opposite side of the stator. It has also been shown how the stator carrying cage is securely locked against oscillation while the table reciprocates, to lay the wire in the slot of the stator and how such locking arrangement is released to permit oscillation of the cage during the cross-over period.

By this description it will be seen that oscillation of the cage is necessary in order to bring the two wire receiving slots of the stator into proper alignment with wire-laying or guiding needle so that said needle may enter the proper slot, one as it moves forwardly, the other as the table moves rearwardly.

Cage oscillating mechanism

The mechanism for oscillating the stator carrying cages of the machine to provide the cross-over portions of the coils as they are being wound is clearly shown in Figs. 1 to 6. Referring to Fig. 3, the clutch driven gear 186 is the main gear which drives two associated gears 250 and 251. Gear 250 is secured to the shaft 252 which as shown in Fig. 9 is journaled in aligned bearings 253, 254 and 255, the first supported in the rear wall of the frame 50, the second in the partition wall 204 of the frame, and the third in another partition wall 256 of the frame. Similarly gear 251 is secured to the end of the shaft 257 journaled in bearings 258, 259 and 260 supported in the housing. These shafts 252 and 257 may be termed the cam shafts. As clearly shown in Figs. 6 and 9, cams are carried by shafts 252 and 257 at their ends opposite gears 250 and 251 and adjacent the partition 256. Each cam assembly is identical, therefore only one will be described detailedly.

The cam assembly of shaft 252 includes three adjacent single-acting cam discs designated by

the numerals 262, 263 and 264. The inner cam 262 nearest the partition 256 is the smallest of these cams, the shape of said cam being shown in Fig. 6. It will be seen that each cam has one dwell portion 265 substantially concentric of the shaft 25, and a larger dwell portion 266 also substantially concentric of the shaft 252, these concentric dwell portions being connected by the working edge surfaces. The cams 263 and 264 are similarly constructed except the dwells have different radial dimensions. The smaller dwell portion of the cam 262 is a greater distance from the center of the shaft 252 than the smaller dwell portion of the intermediate cam 263; and the dwell portions of the outer cam 264 is still a lesser distance from the center of shaft 252 than either the smaller dwell portion of the intermediate cam 263 or cam 262. On the contrary the larger dwell portion of cam 262 is spaced a lesser distance from the center of shaft 252 than the similar cam portion of the intermediate cam 263 and the same cam portion of the outer cam 264 is still a greater distance from the center of the shaft 252 than the similar cam portions of the other two cams. The cam assembly of shaft 257 has the same characteristics. Here the inner cam 272 has its smaller dwell portions a greater distance from the center of the cam shaft 257 than the similar cam portion of cam 273 and this dwell portion of cam 273 is also a greater distance from the center of the shaft than the smaller dwell portion of the cam 274. Like the opposite cam assembly, cam 272 has a larger dwell portion a lesser distance from the center of the cam shaft than the similar portion of cam 273, while the larger dwell portion of cam 274 is still further spaced from the center of the cam shaft 257 than similar portions of the other two cams 272 and 273.

From the foregoing it may be seen that a cam follower, moving from either of cams 262 or 272 to cams 263 or 273, would be shifted at the time it rides upon the smaller dwell portions thereof, the cam follower moving inwardly toward the center of the cam shaft as it moves from the dwell portion of the inner cam to the similar smaller dwell portion of the intermediate cam. Similarly such movement will result as the cam follower would move from the smaller dwell portion of the intermediate cams 263 and 273 to the similar portions of the outer cams 264 or 274. It must be remembered that such movement of a follower from one cam to another in each set of cams must take place when the cam follower is riding upon the smallest diameter dwell portion of each cam, for the cam follower in the present machine is moved progressively during the operation of the machine from the rearmost cam to the intermediate cam then to the outer cam or the one closest the front of the machine.

The rotating movement of the two sets of cams is translated into reciprocatory movement for purposes of reciprocating the work carrying cages of the machine clockwise and counter-clockwise. To obtain such reciprocatory movement, arms are provided, each arm carrying a cam following roller. For purposes of description, the cam group including cams 262, 263 and 264 will be referred to as a whole by the numeral 5, and the group of cams including those designated by the numerals 272, 273 and 274 by the numeral 6. The follower arms will be referred to by the numerals 1, 2, 3 and 4. The rollers on cam arms 1 and 3 are adapted to engage the cams of group 5 while the rollers of follower

arms 2 and 4 are adapted to engage the cams of group 6. These four arms are splined to a shaft 275 journaled in an anti-friction bearing 276 provided in the partition 204, and a similar bearing 277 carried in the front wall of the frame 50 of the machine. The bearing journal in the frame is of such a character that the shaft 275 may slide longitudinally therethrough. The rotating bearing portion oscillatably supported by the anti-friction bearing 277 and in which the shaft 275 is reciprocally supported has a flange 278 formed thereon outside the confines of the bearing and in front of the front wall of the casing 50. To this flange is bolted the main oscillating gear 70 illustrated in Figs. 1, 4 and 9. A sprocket wheel 290 is bolted to the rear face of the gear 70, this sprocket wheel having a sprocket chain 291 attached thereto and engaging its teeth, said sprocket chain passing over an idler sprocket wheel 292 carried by the machine in any suitable position and being secured to the piston shaft 293 of an air cylinder 294.

Figs. 4 and 9 clearly show that the cam follower arms 1, 2, 3 and 4 are arranged in different planes on the splined shaft 275. The cam follower arm 1 is closest the front end of the machine then spaced therefrom and further back is the next arm 2, then spaced from arm 2 and further back is the arm 3, and finally spaced from arm 3 and closest the rear end of the machine is the cam follower arm 4. Any suitable means on the shaft maintain these arms in the proper spaced relation and position upon said shaft and also that said arms will translate oscillatory movements to the shaft but not move longitudinally relatively thereto. Assuming the roller of arm 1 is in contact with cam 262 of group 5 as this cam rotates clockwise the follower arm 1 will be lifted, thus transmitting a counter-clockwise rotation to the shaft 275. This counter-clockwise rotation of shaft 275 will rotate the main oscillating gear 70 in a similar counter-clockwise direction. Such rotation of gear 70 will result in a clockwise rotation of the various workholder cages. As has been said before the workholder cages are oscillated to bring the proper slots of the stator into alignment with the reciprocating wire-laying needle in order that the proper slot will receive the wire conductor. Clockwise rotation of the cages as has been mentioned will move the stator so the slot next to receive the wire conductor is properly aligned with the needle. As the cam continues to rotate and follower 1 is caused to follow the cam follower 1 will be moved from the high dwell to the low dwell, resulting in a reverse movement of arm 1 or more specifically a clockwise movement thereof. This results in a clockwise movement of the gear 70 and consequently a counter-clockwise movement of the work carrying cages 53 to 56 inclusive. Now the other slot to receive the wire conductor is brought into alignment with the needle. Thus the clockwise and counter-clockwise movements of the cam follower arm 1 moves the two wire receiving slots of the particular pole coil being wound into the proper aligned position with the needle. The cam follower arm and its roller will remain in operating engagement with cam 262 until the desired number of convolutions are wound in the two stator slots. After the desired number of convolutions are wound in these two slots and if a second coil is to be wound at this pole position, the cage supporting the work-piece must be oscillated through a greater range of movement so that

slots next adjacent the ones already wound will be brought into proper alignment with the wire laying needle. In order to give this greater range of oscillation the cam follower arm is brought into engagement with the cam which due to its characteristics will oscillate said follower arm and consequently the main gear 70 and the cages driven thereby through a comparatively greater range of oscillatory movement. To move said cam follower arm from one cam to the other, or more specifically from the cam 262 to the larger intermediate cam 263, the shaft 275 carrying the arm 1 is shifted longitudinally a distance equal to the thickness of a cam. By shifting the shaft 275 forwardly the thickness of the cam, the roller of cam arm 1 will be moved to engage the surface of the cam 263, such shifting as has been described heretofore taking place when the roller of cam follower arm 1 is in contact with the smaller concentric dwell of the respective cams. Cam follower arm 1 will remain in operative engagement with cam 263 until the desired number of convolutions are wound upon the second coil of this one stator pole position, at which time if a third coil is to be wound at this position the cam follower arm 1 will be moved into engagement with the outer cam 264, thereby again increasing the degree of oscillation of the cam arm 1, the main driving gear 70 and the various work carrying cages 53 to 56 inclusive. This increase in the degree of oscillation is necessary because new slots further spaced than the intermediate or first wound slots must now be brought into proper operating alignment with the wire-laying needle.

Clockwise rotation of the cam assembly 5 with the follower of arm 1 in engagement therewith will move said arm counterclockwise while the follower thereof rides the cam surfaces from the smaller substantially concentric dwell portion to the higher substantially concentric dwell portion. Friction of the mechanism including the various gears and the cage will hold the cam follower of arm 1 in engagement with the cam during this process. However, when the cam passes through its range of movement during which the cam follower engages the cam surface from the greater dwell portion toward the lesser dwell portion, means must be provided to maintain the follower of arm 1 in engagement with the cam surface, or more specifically means must be provided to rotate said arm clockwise so that such engagement will be maintained. In the present machine there is provided an air cylinder 294 enclosing a piston which, when air pressure is directed thereto, will exert a pull through a sprocket chain 291 urging the sprocket 290 attached to the main oscillating gear 70 clockwise and consequently rotating the shaft 271 upon which said gear is mounted and also upon which the cam arms 1, 2, 3 and 4 are mounted in a similar clockwise direction. One of the main features of the present invention is the provision of means whereby this force for rotating the arms carrying shaft 275 clockwise is rendered ineffective, while the electric motor is driving the machine to rotate this same shaft 275 counterclockwise. This means is properly timed by suitable mechanism driven by the machine to be described hereinafter. The air pressure in cylinder 294 for rotating the shaft 275 clockwise is cut off at a certain time so that the electric motor drives the shaft 275 counterclockwise through the cam assemblies 5 and 6 will be relieved of extra work of opposing the air pressure in cylinder 294 in a clockwise direction. Thus

it may be said that the present machine provides work-carrying cages which are oscillated in one direction only by a first power means, namely an electric motor, and which are oscillated in an opposite direction by a second means, namely under the pressure of an air cylinder 294. The cam assemblies 5 and 6, however, which are constantly rotated by the first power means or electric motor, may be said to act as timing driving members to obtain one direction of oscillation of the cage, and to act merely as a timing mechanism and not as a driving mechanism while the said cage is oscillated in the opposite direction by the second power means or air pressure.

The foregoing description clearly shows how the machine operates to wind the several concentric coils of predetermined convolutions for one pole of the stator.

The stator to be wound in the present machine has a plurality of such poles angularly spaced 90°. The present machine, as has been stated, is adapted to wind the various coil groups for the different poles of the stator from an unbroken or continuous wire supply. Therefore, after one set of pole windings is completed said stator must be oscillated the distance necessary to bring the other pole slots into proper operating alignment with the wire-laying needle. The windings of the second pole of the stator are wound in a direction reverse to the windings in the first pole. Thus, this machine must be automatically set to reverse the wire laying operation so that the convolutions in the second coil are wound reversely to those of the first coil. This reversal of the windings of the convolutions is attained by bringing into action the cam follower 2 so that during the winding of the second coil the roller of cam follower 2 will engage with the camming surfaces of cam assembly 6. This is effected by longitudinal shifting of the shaft 275 forwardly in the machine since cam follower arm 2 lies a properly spaced distance on shaft 275 rearwardly of cam follower arm 1. Thus, as the cam shaft 275 is moved longitudinally forward properly to position the cam follower arm 2 so that its roller will engage with the cam 272 of cam assembly 6, cam follower arm 1 will be moved forwardly so as to be entirely free of any cam assembly and thus this cam follower arm 1 is rendered entirely ineffective. Cam follower arm 2 in engaging cam 272 will affect oscillation of the work piece carrying cages in a manner similar to the actuation effected by the cam follower arm 1 engaging cam assembly 5. As the roller of the cam follower arm 2 moves from the lowest dwell of the cam 272 toward the highest dwell thereof the cam follower arm 2 will be moved counterclockwise and likewise shaft 275 and gear 70. Counterclockwise rotation of the gear 70 results in clockwise oscillation of the cages 53 to 56 inclusive. The air cylinder is automatically brought into effect to maintain the roller of the cam follower arm 2 in engagement with cam 272 to cause it to pass over the cam surface from its highest dwell to its lowest dwell, thereby resulting in a clockwise directional rotation of arm 2, shaft 275 and gear 70 and a resultant counterclockwise oscillation of the work-carrying cages 53 to 56 inclusive. Like cam assembly 5 and arm 1, this cam assembly 6 and arm 2 will effect operation of the machine, or more specifically will effect oscillations of the work holding cages resulting in the winding of the coils at the second pole of the stator.

The two additional poles 3 and 4 of the stator

are wound in a like manner. Pole 3 is wound oppositely to pole 2 and pole 4 oppositely to pole 3. Thus for pole 3, arm 3 cooperates with cam group 5 and for pole 4, arm 4 cooperates with cam group 6. When all of the coils of the stator will have been wound all four cam follower arms will have cooperated with their proper cam groups and at the conclusion of the winding operation the follower shaft 275 will have been shifted forwardly its full travel at which time cam followers 1, 2 and 3 will have been shifted forwardly beyond the plane of the two cam assemblies 5 and 6.

Mechanism for shifting cam follower arm progressively forward

As has been mentioned heretofore, the cam follower shaft 275 upon which the cam follower arms 1, 2, 3 and 4 are mounted, is shifted progressively from a rear position to a forward position in recurrent steps. When the cam follower shaft 275 is in its rearmost position, the cam follower 1 is in a position to operatively engage cam 262. After the work of the cam 262 is completed, shaft 275 is moved forwardly substantially the thickness of a cam so that the roller on cam follower arm 1 will be in operating alignment with the cam 263.

The mechanism for so moving the shaft 275 is fully illustrated in Figs. 4 and 10 to 14. The source of power for moving the shaft comprises an air cylinder 300 connected with any suitable source of air pressure. The piston within said cylinder has a rod 301 which is connected with a link 302 in any suitable manner, preferably by some adjustable linkage. A hole in the bottom of the machine receives a plate 303, said plate being anchored to the base of the machine by bolts 303a. To this plate 303 is attached a housing 304, said housing having a side wall 305. This wall 305 supports the work cylinder 300 by a flange 306 which is secured to the rear wall 307 of the housing 304.

A bearing sleeve 308 is secured in an opening of wall 305 of the housing. This bearing sleeve rotatably supports the stub shaft 309 of a pinion gear 310. The opposite end of the stub shaft has reduced diameter portions 321 and 322, the portion 321 being preferably of rectangular cross section while the portion 322 is of cylindrical cross section. On the rectangular portion 321 of the shaft 309, are mounted two ratchet wheels 311 and 312, the larger ratchet wheel 311 being closest to the pinion 310. These ratchet wheels, due to the rectangular portion of the shaft upon which they are mounted must rotate with said shaft. The cylindrical portion 322 of the shaft rotatably supports a bearing sleeve 314 which in turn carries an actuator 313. A nut 315 threaded upon the outer end of the shaft urges and maintains the ratchet wheels and the actuator and its bearing in proper position upon the shaft and prevents their removal.

The actuator 313 has a screw stud 316 upon which a pawl 317 is pivotally mounted. A spring 318 interposed between the pawl and actuator yieldably urges said pawl clockwise about its pivot pin. A detent plate 320 secured to the housing wall 305 has its lower edge normally engaged by a roller 319 carried at the toothed end of the pawl 317. Counterclockwise rotation of the actuator 313 about the shaft 309 will cause the roller 319 of the pawl to pass from the bottom edge of the detent plate 320 across an angular edge 321 of said plate to permit clockwise movement of the pawl 317 by the spring 318 for purposes of en-

gaging the toothed end of said pawl with a notch of the ratchet wheel 312 whereby continued counterclockwise rotation of the actuator 313 will result in a similar counterclockwise rotation of the pawl 312.

The wall 305 has a screw stud 323 pivotally supporting a ratchet pawl 324 urged in a counterclockwise direction by a spring 325 interposed between the pawl 324 and an anchor pin 326 in the wall 305 of the housing. Normally the toothed portion of the larger pawl 324 engages a lug extension 327 of the actuator 313. However, upon counterclockwise rotation of said actuator as formerly described, this lug 327 will be moved from underneath the toothed portion of the ratchet pawl 324, permitting the spring 325 to become effective to actuate said ratchet pawl so that its toothed portion will engage a notch of the ratchet 311. These notches in the ratchet 311 are so arranged that the ratchet pawl 324 will permit the ratchet wheel 311 to move counterclockwise a predetermined distance, engagement of the ratchet pawl 324 with the radial edge of a tooth terminating positively this counterclockwise rotation of said ratchet wheel. An adjustable stop member 330 on the wall 305 of the housing is normally engaged by one end of the actuator 313 as shown in Fig. 10. However, when the air cylinder 300 is energized to draw its piston rod 301 into the cylinder, the actuator 313 will rotate counterclockwise. As the actuator 313 is moved counterclockwise, shaft 309 will likewise be rotated counterclockwise, this rotation being limited by the ratchet pawl 324. Rotation of the pinion 310 (a part of shaft 309) through a measured range of rotation will actuate a rack 331 with which it meshes. Rack 331 is secured to a sliding member 332 supported in the housing 304 and retained by plate 334 (Figs. 14 and 15). The plate 332 supporting the rack 331 has an upwardly extending saddle member comprising spaced parallel arms 335 and 336, each arm carrying a roller 337. This saddle member encompasses a spool-shaped member 338 secured to the end of the cam shaft 275. Thus the roller of one arm 335 of the saddle member will extend into one side of the spool-shaped member 338, while the roller 337 of the arm 336 of the saddle member will extend in the diametrically opposite side of the spool-shaped member 338 whereby the cam follower shaft 275 is mechanically connected to the sliding member 332.

From the foregoing it may be seen that each measured increment of counterclockwise rotation of the ratchet 311 by the air cylinder 300 determined by the ratchet 324 engaging notches of said ratchet wheel 311 will be translated into reciprocatory movement through the gear 310 and its rack 331 to the sliding member 332 and consequently through the saddle connections to the shaft 275. The rotation of the ratchet wheel 311 measured by the ratchet pawl 324 will be sufficient for each increment of movement to move shaft 275 a distance substantially equal to the thickness of a cam 262, 263, 264 or the cams 272, 273 and 274 of the other cam group.

During the complete winding of an entire stator there will be 11 equal increments of movement of shaft 275 from its rearward toward its foremost position.

Mechanism for returning cam follower shaft to initial position

The sliding member 332 which supports rack 331 also has a depending yoke portion 340 which

receives the ball-shaped end of a lever 341 pivoted on the pin 342 secured in the bottom of housing 304. This lever 341 has a link 343 secured to it substantially intermediate its ends, this link 343 in turn being secured to the piston rod 344 of an air cylinder 345 carried on the housing wall 307 by a flange 346 of said cylinder. In Fig. 4 it will be seen that the piston rod 344 of cylinder 345 extends through an opening in the wall 307 of housing 304.

After the machine has completed its winding operation on a stator during which operation the cam follower shaft 275 has been moved to its front-most position, control mechanism to be described hereinafter will become effective to cause energization of the air cylinder 345 which will actuate the lever 341 clockwise about its pivotal pin 342, thus moving the sliding member 332 connected with the shaft 275 through the yoke and saddle connection 335 and 338 rearwardly to return the cam followers on said shaft 275 to their home position preparatory to the winding another stator.

Overrunning clutch mechanism

Referring particularly in Figs. 1, 3, 6 and 9, the machine as shown has a shaft 400 rotatably supported in aligned bearings 401 and 402 carried in the rear wall of the machine and in the partition 204 of the machine respectively. This shaft 400 extends beyond the confines of the rear wall of the machine and has the pinion gear 403 secured thereto. Pinion gear 403 operatively engages an idler gear 404 carried by a stub shaft 405 on the machine frame. Idler gear meshes with a pinion gear 406 which is in driving engagement with the cam shaft gear 250. The relative sizes of the gears 406, 404 and 403 are such that shaft 400 is driven at a predetermined greater speed than the shaft 252 upon which the gear 250 is mounted. The direction of rotation of the shaft 252 and its gear 250 is clockwise as regards the front of the machine thus making the rotation of the shaft 400 counterclockwise when viewed from the same side of the machine.

In coaxial alignment with shaft 400 there is provided a shaft 410, one end of which is supported in the bearing 412 carried by the front wall of the housing, the other end having one member of an overrunning clutch 425 attached thereto which has a bearing in and cooperates with another member of the clutch secured to the shaft 400. Clutch 425 may be of any standard construction; however, its characteristics must be such that shaft 410 may be rotated clockwise or in a direction opposite the rotation of shaft 400 at any time. However, shaft 410 in view of the characteristics of the overrunning clutch 425 may never be operated in a counterclockwise direction, or more specifically in the direction of rotation of the shaft 400 at a speed greater than the actual rotation of said shaft 400 in this counterclockwise direction.

A pinion 426 secured to the outer end of shaft 410 is constantly in mesh with the main oscillating gear 70. This pinion has a hub 427 provided with a ratchet with which a corresponding ratchet 428, provided on the hub of a hand crank 429, may be moved into driving relation whereby the gear 426 with its shaft 410 may be manually rotated, in a clockwise direction at any speed. Of course, it will be understood that if the shaft 400 is not rotating, then the shaft 410 can not be rotated counterclockwise for, as has been said, shaft 410 can not be rotated counterclockwise at

any greater rotating speed than shaft 400. In case of an abnormal manual displacement of the main oscillating gear 70 a result of the actuation of the hand lever or crank 428 by an inexperienced operator, readjustment would be necessary thus requiring the attention of an expert. To avoid this a releasable clutch has been provided in the shaft 410 whereby said shaft 410 may be divided thus separating the portion thereof attached to gear 426 from the portion thereof attached to clutch 425, thereby permitting free movement in either direction of the hand crank lever 428 when the machine is at rest for the purpose of moving or returning the oscillating gear 72 to the desired position. Ordinarily this clutch mechanism designated as a whole by the numeral 430 is not essential, at least not essential to the operation of the machine and as has been said is merely introduced for the purpose of avoiding much unnecessary disassembling of the machine if any inexperienced operator should actuate the hand lever beyond its ordinary resetting range of movement, as will be described later. The shaft 400 does not drive the shaft 410 through clutch 425 due to the nature of this clutch. Thus while the machine is being operated to wind a stator, shaft 400 is rotating at a speed predeterminedly higher than the cam shafts 252 or 257 while shaft 410 is merely being oscillated in one direction or the other, dependent upon the oscillation of the main oscillating gear 70. As the main oscillating gear 70 oscillates clockwise the pinion gear 426 of shaft 410 will cause a counterclockwise oscillation of said shaft 410 at a speed less than the speed of the shaft 400.

In connection with the operation of the cam follower arms by the cam groups 5 and 6, it has been stated that the cam follower arms are always moved counterclockwise by the motor applied power through the cam groups while the clockwise rotation of said cam follower is effected by the air pressure in cylinder 294 operating through a sprocket chain 291 attached to sprocket wheel 290 on the oscillating gear 70 (Fig. 1). It has also been said that the oscillation of the cam arms 1, 2, 3 and 4 results in oscillations of the workpiece-carrying cages. Thus, when cam follower arm 1 moves from the smallest cam 262 to the intermediate cam 263, the range of oscillatory movement of the workpiece is increased in order to bring into alignment with the wire-laying needle the two proper slots receiving the windings of the second coil of the same pole. To wind the third coil, the cam follower arm 1 cooperates with the largest cam 264 in order to increase again the range of oscillatory movement of the cage in order to bring into alignment with the needle the two outer slots receiving convolutions of the third coil of the same pole. Following this the coils are wound for a second pole spaced 90° from the first pole. Now a still greater travel of oscillation of the workpiece cage is necessary. Following the completion of the third coil of the first stator pole, the roller of the cam follower arm 1 is approximately at the end of the larger dwell portion of the cam 264 and is ready to descend to the smaller dwell portion under the influence of air pressure. However, at the end of the third coil of the first pole it is necessary to prepare the machine for winding the narrowest coil of the second pole in the opposite direction thereby requiring the engagement of the roller of the cam follower arm 2 with the smallest cam 272 of the cam group 6. The distance through which the work-holding cage is

required to oscillate in order to bring in the proper slot of the second pole piece winding into operative alignment with the needle is greater than the angular travel provided by arm 1 when cooperating with cam 264. In order to provide for this increased oscillation of the workholding cage the mechanism for axially shifting the cam follower shaft 275 is so timed that movement thereof forwardly will take place substantially as soon as the roller of the cam follower arm 1 approaches the surface of the cam 264 leading from the high dwell to the low dwell. When the cam roller of arm 1 is shifted beyond the plane of the cam 264 of group 5 the air pressure in the cylinder 294 acting through chain 291 will have a tendency suddenly to rotate the entire cam follower arm assembly including shaft 275 clockwise until arm 2 strikes cam 272 of cam group 6. However, the shaft 400 operates through clutch 425 to limit the speed of shaft 410, thereby preventing rotation of shaft 275 at such speed as would allow the arm 2 to bang against cam 272. More specifically, the tendency of the air cylinder to rotate sprocket 290 and gear 70 at an excessive speed not only results in an excessively fast rotation of the cam follower arms clockwise, but also an excessive rotation of the pinion gear 426 counterclockwise. The shaft 410 will likewise be moved counterclockwise at an excessive speed. However, as we have said before the clutch 425 will at no time permit shaft 410 to rotate at a speed exceeding the rotating speed of shaft 400. The speed of shaft 400 is such that rotation of the shaft 410 at the same speed will so control the rotation of the pinion 426 and oscillating gear 70 so that the rotative effect of said gear by the air cylinder 294 will be held within a safe limit thereby entirely avoiding the banging of the cam follower 2 into engagement with the smallest cam 272 of the cam group 6. Therefore, clutch 425 acts as a brake automatically brought into effect to control rotative movement of the cam follower arms by the air cylinder when free from any other operating mechanism of the machine. In other words, the clutch 425 comprises a means under the control of a first power device (electric motor driving gear 180 in Fig. 3) for controlling the movement of the cam follower arm shaft by the second power means (air pressure in cylinder 294).

Resetting the machine after completely winding a stator

After a stator is completely wound, the machine is automatically stopped, at which time the cam follower shaft 275 has been moved to its extreme foremost position so that the followers 1, 2 and 3 are in planes ahead of the cam groups 5 and 6, while only the cam follower arm 4 has its roller in engagement with cam 274 of the group 6. Under these circumstances cam follower arms 1, 2 and 3 would engage cam groups 5 or 6 if the shaft 275 were moved toward its rearmost position required for resetting the machine. Before the cam follower arms can be moved by shaft 275 to their initial positions, these arms must be rotated into positions in which they will entirely clear the two cam groups.

Referring to Fig. 1, the main oscillating gear 70 carries an arcuate member 450 adjustably attached to its inner face and concentric with the axis thereof. This ring member has a notch 451 in its outer peripheral face. A reset lever 452 is pivotally supported by a pin 453, and is connected by a link 454 to a dog lever 455 pivoted

on the pin 456. This dog 455 may enter the notch 451 in ring-member 450 under certain conditions. In order to rotate the cam follower arms 1 to 4, inclusive, into the position as shown in Fig. 6, in which all cam follower arms are clear of the cams of groups 5 and 6, the operator actuates the hand lever 429 (Fig. 9) longitudinally of shaft 410 so that its ratchet teeth 428 will operatively engage the ratchet teeth on the hub 427 of gear 426. Then the operator moves the reset lever 452 counter-clockwise about its pivot pin 453 to bring the dog 455 into engagement with the ring member 450. Then the operator rotates the crank 429 clockwise thus rotating the gear 70 counter-clockwise and consequently rotating the shaft 275 and its cam followers 1, 2, 3 and 4 in the same direction to clear them with respect to the cam groups 5 and 6. When the followers are clear, the notch 451 is in position to receive the dog 455. Dog 455 gravitates into notch 451 thus causing segment 458 attached to lever 452 to actuate electric switch 8 to close circuits which render the cylinders 294 and 345 effective. The air cylinder 294 is the cam shaft actuating cylinder and the cylinder 345 is the cam shaft returning cylinder. Immediately upon the cylinder 294 becoming effective, it will exert a pull upon the sprocket 290 secured to gear 70 in a clockwise direction tending to rotate the cam shaft 275 and its followers in that direction. As air cylinder 294 tends to rotate gear 70 clockwise, gear 70 will tend to rotate the pinion gear 426 and the shaft 410 counterclockwise. However, the overrunning clutch 425 becomes effective because shaft 410 cannot rotate counter-clockwise at any speed in excess of speed of counter-clockwise rotation of the shaft 400. Since the machine is inoperative and shaft 400 not rotating, shaft 410 cannot move, thus preventing any movement at this time of the pinion gear 426, the main oscillating gear 70 and cam follower shaft 275 under air pressure in cylinder 294.

The closing of circuits by switch 8 causes air pressure to enter cam follower reset cylinder 345 and to cause the cam follower shaft 275 quickly to return to its initial position preliminary to machine operation, in which position all of the arms with the exception of cam follower arm 1 will lie in planes to the rear of the cam groups 5 and 6. The cam follower arm 1 is so located that its roller will lie in the plane of the working surface of cam 262 and will engage said cam when the cam follower shaft 275 is next rotated in a clockwise direction.

The roller of cam follower arm 1 is brought into engagement with the working surface of cam 262 in the following manner: After completion of the resetting operation as has just been described, the operator places a stator assembly together with the workpiece supporting ring within the cage of the machine. At this time, the wire-laying needle 100 will be in a position to the rear of the workpiece or at the extreme end of the stroke opposite to that shown in the Fig. 17. The cage, by the resetting operation, has been brought into such position that, when the workpiece carrying ring is placed in said cage located therein by the locating lug 76 on said ring as shown in Fig. 20, the proper slot will be in alignment with the needle. The operator then draws the wire from the needle and into the aligned slot and secures the end of the wire to any suitable anchoring position on the front surface of the stator carrying ring. Now the one side of

the convolution of the first coil lies in the stator slot; and the next step is to form the rear loop end of this winding. The machine is now set into operation by the closing of a proper circuit through the electric motor. As soon as the machine starts to operate, shaft 400 will rotate counter-clockwise at its predetermined speed which, as has been mentioned heretofore, is faster than the rotation of the cam shafts 252 and 257. The air cylinder rendered effective by the resetting of the machine and particularly by the closing of the circuit at switch 8, but being prevented by the clutch 425 to rotate the cam shaft oscillating gear 70 while the shaft 400 was non-rotating, is now rendered effective to oscillate the gear 70 because shaft 410 may now be rotated counter-clockwise by said gear 70. It has previously been described how shaft 410 may rotate counter-clockwise just as fast, but no faster than the shaft 400 due to the provision of the clutch 425 between said shafts.

As soon as the machine is rendered operative, all of its parts are driven. Barrel cam 208 and the cam groups 5 and 6 rotate continuously at the same speed. As stated before, immediately after resetting and before the machine is rendered operative by the motor, the cam follower arms are returned to their initial position preliminary to winding, at which time the roller of cam follower arm 1 is in alignment with, but spaced from the working surface of the cam 262 with which it will cooperate for the winding of the first coil. If the follower of cam arm 1 were already in engagement with the smaller dwell portion of the cam 262, it would traverse this dwell portion of the cam, while the roller 213 engaging the barrel cam 208 is moving through the angular portion 212 of the cam track of said barrel cam to shift the table forwardly for the purpose of laying a wire in the second slot of the stator coil. However, as has been said heretofore, the rear cross-over or loop section of the coil must be complete before such wire-laying operation by the reciprocating table is started, thus the cam follower arm 1 must be moved clockwise from its home position to its cam-engaging position before the barrel cam becomes effective to move the table. The air in cylinder 294 which moves the cam follower 1 clockwise is capable of moving this arm 1 substantially instantaneously. However, if the speed of shaft 400 were equal to the rotating speed of the cam shaft 252, such quick movement could not be obtained on account of the control by clutch 425 between shaft 400 and shaft 410 drivingly connected with the oscillating gear 70. However, since shaft 400 rotates considerably faster than cam shaft 252, shaft 410 may be operated at this increased speed during this interval by the air cylinder, resulting in the quick counterclockwise shifting of the shaft 275 which carries the cam follower arm 1.

To summarize, the shaft 400 drives no part of the machine but merely rotates at a predetermined speed to function as a rotation limiting member for controlling the speed of the shaft 410. When shaft 400 is stationary, shaft 410 and shaft 275 cannot operate. When shaft 400 turns, clutch 425 applies a braking force to reduce the speed of shifting of the cam follower arms by the air cylinder from one cam group to another, thereby preventing the engagement of a cam follower roller with the first cam of the group at an excessive or damaging rate of speed.

Control of air cylinder 294

The admission of air pressure to the front end of cylinder 294, Fig. 24, is controlled by a valve 30 actuated in response to movement of the table 105 and a valve 480 actuated by electrical means rendered effective at certain stages of the operation of the machine. Valve 30 comprises a stationary part 30a having ports 30b, 30c and 30d and a movable part 30f having ports 30g and 30h. Valve 480 has a movable part 480a provided with ports 480b and 480c and a stationary part 480d having ports 480e, 480f, 480g, 480h and 480i. Pipe 480j connects a source of compressed air with port 480g. Pipe 480k connects port 480f of valve 480 with port 30b of valve 30. Pipe 480l connects port 480h of valve 480 with port 30d of valve 30. Pipe 30e connects port 30c of valve 30 with the right end of cylinder 294. Movable valve part 480a is connected with solenoid armatures 480m and 480n.

The mechanism for operating valve member 30f is responsive to movements of the table 105. Referring to Fig. 18 the movable valve part 30f is connected with a rod 481 having a slot 482 for receiving a pin 483 in the end of a lever 484 pivoted at 485 and having its upper end located in the path of movement of plungers 486 and 487 supported, respectively, by brackets 488 and 489 attached to table 105 in the required spaced relation. The plungers 486 and 487 are supported by their respective brackets for limited sliding movement horizontally. Plunger 486 is urged by a spring in its cylinder 486a toward the right and plunger 487 is urged toward the left by a spring in its cylinder 487a. When the table is in the back position as shown in Fig. 18, plunger 486 engages lever 484 to move the same clockwise in order to move rod 481 toward the left and hence locate the movable valve part 30f in the position shown in full lines in Fig. 24. When the valve 480 is in the position shown in Fig. 24 in full lines the supply of air to the cylinder 294 is cut off by valve 480 and by valve 30 and these valves cooperate to provide a vent for the front end of cylinder 294 through the passages comprising pipe 30e, port 30c, port 30h, port 30d, pipe 480j, port 480h, port 480c, port 480i. Therefore, the air cylinder 294 is inoperative to move the cam follower arms clockwise. This is the condition which would exist at the time when one of the cams of either group 5 or group 6 is operating to move a cam follower in a counterclockwise direction. Under these conditions the power source including the electric motor is operating to oscillate the work holder cage in one direction. Since the resistance to the turning of these cages provides a reaction which keeps the cam follower against the cam as it passes from a low dwell to a high dwell of the cam, it is not necessary that the air be on in the cylinder 294. Furthermore, it would be disadvantageous to have air cylinder 294 effective while the electric motor is causing the cam followers to rotate counterclockwise because the motor would be burdened with the extra work of opposing the effect of air cylinder 294. In order to avoid loading the electric motor with the burden of opposing the air cylinder, it is necessary to render the air cylinder ineffective at this time. For the winding of poles of a certain polarity this is the condition which should obtain when the electric motor is operating the work cage for the purpose of laying an end loop at the back of the stator just prior to a movement of the wire placing device or needle

from back to front. Then the table 105 moves forward to carry the needle through the stator to the front thereof. At the end of this forward travel, the plunger 487 (Fig. 18) strikes the lever 484 to cause the rod 481 and hence valve part 30f (Fig. 24) to move toward the right (Fig. 24) thereby causing port 30g to connect ports 30b and 30c while port 30h is inactive since it is entirely in alignment with port 30d. Under these conditions air will be admitted in the cylinder 294 through pipes 480j, port 480g, port 480b, port 480f, pipe 480k, port 30b, port 30g, port 30c and pipe 30e. Then the air cylinder 294 will be effective while the needle is in the front of the stator (as viewed in Fig. 1) in order that the cam follower will be urged by air pressure against the cam while the follower is passing from a high dwell of the cam to a low dwell. Under these conditions the work cage is rotated in a direction opposite to that in which it had been rotated by the motor, in order to form the front end loop of the winding which had just been threaded through a stator slot from back to front. When the needle moves from front to back to place the other active coil side of the pole winding, the valve 330 will be moved to the position shown in Fig. 18 again in order to shut off the air supply to cylinder 294 and to vent the cylinder. Therefore, the sequence of operations of the cylinder 294 with respect to the movements of the table 105 will be as follows: table back-air off, table front-air on. Now this may be the proper sequence which would exist during the winding of certain stator poles, for example, poles 2 and 4 as will be explained later with respect to Fig. 29. But for winding poles 1 and 3 this will not be the correct sequence because the direction of windings of poles 1 and 3 is reverse of the direction of winding of poles 2 and 4.

The valve 480 and its associated control mechanism provides means for reversing the sequence relation, with respect to movement of table 105, of the sequence of alterations between the effectiveness of electric motor to oscillate the work cages in one direction and the effectiveness of the air cylinder 294 to rotate the work cages in the opposite direction. Preparatory to the winding of the first end loop of the first coil for poles 1 and 3, it is necessary that the air cylinder 294 be effective since, at that time, the cam follower which is active passes from a high cam dwell to a low cam dwell as the cam rotates. This reversal of the sequence relation is obtained by moving valve part 480a from the full line position to the dot-dash line position 480a'. For example, if the full line position in 480a is correct for the winding of poles 2 and 4, then at the end of the machine cycle after winding pole 4, the table 105 will be back and the air will be off. But the sequence table back-air off, table front-air on, is not correct for the winding of the first pole as will be shown more in detail later. The sequence should be table back-air on, table front-air off. Now this sequence can be changed to suit the winding of pole 1 and also pole 3 by moving valve 480a from the full line position to the dot dash position 480a' shown in Fig. 24.

The shifting of valve 480a in either direction is accomplished by two solenoids. Solenoid 22d cooperates with armature 480m to move valve 480a to the position 480a'. Solenoid 20d cooperates with armature 480n to move this part to the full line position 480a. At the end of the machine cycle a circuit is preconditioned for

energizing solenoid 22d, but that circuit is not completed until the operator has reset the cam followers to the home position. The circuit of solenoid 22d is controlled by contacts 22b and 22c of relay 22 having a magnet coil 22a. Magnet coil 22a is connected with a current source through normally closed contacts 21b of switch 21 and through switch 8 and through the contacts 4a of switch S4, these contacts being open except at the start and stop position of the machine. The switch S4 has a spring blade normally biasing contacts 4a open and contacts 4b closed. The machine comes to rest at the end of the cycle with the point of lug 560 of timing disc 500 engaging the point of lever 4d of switch S4 to separate contacts 4b and to close contacts 4a. But the circuit of relay coil 22a is not complete. This circuit cannot be completed until the switch 8 is moved from the full line position to position 8a. Switch 8 cannot be moved into this position until the operator has cranked the cam followers back so that they clear all of the cams at which time the dog 455 can drop into notch 451 of the segment 451 attached to the gear 70. Then switch 8 will close and the circuit of relay coil 22a will be complete and contacts 22b and 22c will close and solenoid 22d will be energized in order to move valve 480a to the position 480a', thereby reversing the sequence from back-off to back-on and from front-on to front-off, in other words, reversing the alternating effectiveness of the motor and the air cylinder from "back-motor" to "back-air cylinder" and from "front-air cylinder" to "front-motor." This is the sequence required for winding poles #1. Therefore, as soon as the machine starts the motor driven part of the one way clutch 425 will rotate and allow the cam arm 1 to move into engagement with cam 262 under the influence of air pressure in cylinder 294. This movement will place the first end loop of the first coil of pole #1.

The closing of switch 8 also effects the reset operation since magnet coil 12a of relay 12 is connected with the current source thereby causing its contacts 12b and 12c to close, thereby energizing a solenoid winding 12d which lifts an armature 12e attached to a moving part 475a of valve 475 against the action of a spring 475b. This causes air to be admitted to the left end of cylinder 345 in order to cause the cam arm carrying shaft 285 to move to the back of the machine. Downward movement of switch 8 to position 8a for effecting the reset operation cannot take place until the cam followers have been manually turned so as to clear all of the cams. The operator cranks the follower arms to "clear" position, at which time the dog 455 enters the notch 451 to permit segment 458 of lever 452 to move switch 8 down thereby rendering the solenoid 12d effective to move air valve 475a up to apply air pressure to the cylinder 345 to cause the shaft 275 to return to home position. As the machine starts to operate, the timing disc 500 is rotated to cause lug 560 to clear lever 4d whereupon spring switch blade 4c moves to the right to open the circuit of relay 12 which opens the circuit of solenoid 12d to permit spring 475b to return valve part 475a to lower position and thus cut off the air supply to cylinder 345 and vent the piston end of this cylinder. It is necessary to vent cylinder 345 because its piston is mechanically connected with the piston 300a of advance cylinder 300. The machine is fool proof with respect to resetting because switch 8 can-

not be moved to down position after the machine starts since notch 451 is out of alignment with dog 455; and contacts 4a of switch 4 cannot close again until the end of the winding cycle.

As the timing disc 500 turns from start position, lug 560 will release lever 4d of switch S4 permitting switch S4 to return to normal position. Circuit coils 22a and 12a have previously been deenergized by the movement of lever 452 into its clockwise or run position previous to starting the cycle so that valve 475 returns to normal while valve 480a remains in the position 480a' shown in dot-dash lines.

As the machine continues to operate, the timing disc 500 rotates clockwise and will bring its lug 560 into engagement with lever 18d of switch 18 thereby causing its normally open contacts (biased open by spring blade 18c) to close, thereby energizing coil 20a of relay 20 thereby causing contacts 20b and 20c to close and thereby energizing solenoid 20d. Solenoid 20d moves the valve 480a to the full line position. The time that this sequence reversal is made is just before the placing of the first end loop at the front of the stator of the first winding of the coil group for pole #2, as will be explained in detail later with respect to Fig. 29. The sequence will be reversed to motor driving the cage at table-back and air driving cage at table front position. This is the correct sequence for pole #2.

As the machine continues to operate, the lug 560 will leave the lever 18d and switch 18 will open, thereby deenergizing solenoid 20d but the valve remains in position 480a. Just before it is time to place the first end loop of the first coil for pole #3 the lug 560 engages lever 21d of switch 21 thereby opening its contacts 21b and closing its contacts 21a (biased open by spring blade 21c). Then magnet coil 22a of relay 22 will be energized without energizing magnet coil 12a of relay 12, since the circuit which parallels 12a and 22a has been broken by separating contacts 21b. Then relay 22 is operative to cause solenoid 22d to be energized; and the valve 480a will move to the dot-dash-line position 480a' to cause another reversal of sequence relation. The reversal of sequence relation is such that the sequence will be table back-cylinder operative, table front-motor operative. This is the sequence required for winding pole #3.

As the machine continues to operate the lug 560 will move away from lever 21d to allow switch 21 to return to normal condition under the action of spring blade 21c and solenoid 22 will be deenergized but valve 480 will remain in the position 480a'. At a time just prior to the formation of the first end turn of the first coil of the coil group for pole #4, the lug 560 will engage lever 19d of switch 19 to close its normally open contacts 19a (biased open by spring blade 19c) to close thereby connecting coil 20a of relay 20 with the current source thereby closing contacts 20b and 20c and thereby energizing solenoid 20d to cause the valve part 480a to move to the full line position thereby changing the sequence relation again to table back-motor effective, table front-air cylinder effective as required for the winding of pole #4.

As the machine continues to operate the lug 560 passes to the left from lever 19d thereby permitting blade spring 19c to open contacts 19a thereby deenergizing solenoid 20d but the valve 480a remains in the full line position shown in Fig. 24. Finally the lug 560 engages lever 4d

again to separate contacts 4b for the purpose of stopping the machine in the manner to be described later and for the purpose of closing contacts 4a for the purpose mentioned heretofore. The machine therefore stops when the sequence is table back-air off, table front-air on. Since the machine stops at the table "back," air is cut off from cylinder 294 when the machine stops automatically at the end of the cycle. The resetting of the machine is accomplished by cranking the follower arms clear of the cams and the closing of the switch 8 to cause the cam arm shaft 275 to move back. The function is accompanied by a reversal of sequence relation prior to starting the machine cycle again.

It is therefore apparent that we have provided for the effectiveness of the motor as one power source to move the work cage in one direction alternating with the effectiveness of the air cylinder 294 as a second power source to rotate the cage in the opposite direction, there being a valve controlled by reciprocating table carrying the wire placing device so as to cause the second power source, the air cylinder, to be ineffective at the time the first power source, the motor is effective. We also provide means for reversing the relation with respect to table movements of the sequence of the alternations of the effectiveness of the first and second power sources. This reversal of sequence relation is obtained automatically by a timer operated by the machine. One of the reversals of sequence relation takes place concurrently at the resetting of the cam followers preparatory to starting the machine cycle.

Timing disc control of advance cylinder and motor speed

The operation of the air cylinder 300 for purposes of advancing the cam follower shaft 275 through a predetermined range of forward travel at predetermined intervals through the actuation of the mechanism shown in Figs. 10 to 12 is controlled and timed by the timing disc 500. This disc has eleven suitable spaced lugs 575 to 585 (Figs. 23) adapted to close contacts 14a of switch 14 at predetermined intervals to close a circuit through magnet coil 13a of relay 13 to close its contacts 13b and 13c to energize solenoid 13d to lift an armature 13e attached to movable part 550a of valve 550 having stationary part 550b to render said valve 550 effective to apply air pressure to the left end of cylinder 300. Piston 300 will move to the right to cause oscillation of the actuator 313 and its associate mechanism counterclockwise, resulting in a movement of the cam follower shaft 275 forward through a predetermined increment of movement equal to the thickness of one of the cams of cam group 5 or 6. As soon as the lug of the timing disc 500, which has closed switch 14, opens said switch, the air valve 550a will return to its normal position under the action of spring 550c. Then piston 300a will move to the left and relocate actuator 313 preparatory to the next advance of the cam followers.

In the disclosed embodiment of the present invention the machine provides for winding a four pole stator, three coils per pole. Therefore, there are four cam followers each cooperating with three cams in succession. In other words, twelve cams and cam follower combinations are set up automatically during the machine cycle. Although the machine cycle requires twelve cam and follower combinations, there are only eleven shifts

of the cam followers because the cam follower shaft is not shifted beyond the extreme inner and outer cams. Therefore, the timer disc 500 is required to carry only eleven lugs numbered 575 to 585, both inclusive, for the purpose of controlling switch 14. There is a space between lug 585 and lug 575 in which the lug 560 is located for the purpose of controlling the stopping of the machine. The lug 560 does not strike switch arm 14d for the reason that the lug 560 is not in the same plane as the lugs 575 to 585. Lug 560 is only in the plane of the switch arms 4d, 18d, 21d and 19d (Fig. 24).

As stated earlier in this specification, it is desirable, when advancing the shaft 272 to bring a cam follower arm into alignment with a new cam toward which the arm is urged by air pressure provided by cylinder 294, to retard the movement of the follower arm under the influence of air pressure so that it will not too forcibly strike the cam. Therefore, we provide means operable concurrently with the follower shaft advancing function for decreasing the speed of the motor. In other words, at the time when a cam follower should be brought into engagement with the new cam, the status of the machine is such that the electric motor is inactive to turn the workholder cage, whereas the air pressure means is active concurrently with advancing the follower shaft to bring an arm into an operative alignment with a new cam. The air cylinder 294 is effective to swing the cam follower into engagement with the new cam but at that time the motor, which is then effective only to rotate the cam, is caused to operate at a reduced speed thereby operating through the one-way clutch 425 to retard the movement of the follower arm into engagement with the new cam under the force exerted by the air cylinder 294.

The electric motor M (Fig. 23) which rotates the cams of the machine is a two-speed motor. It is provided with taps T1, T2 and T3 for low speed operation and taps T4, T5 and T6 for high speed operation. Taps T4, T5 and T6 are connected with contacts 660b, 660c and 660d of relay switch 660 having a magnet coil 660a. When relay 660 is closed the high speed taps T4, T5 and T6 are connected with a line through a forward and reverse controller S6. At the time relay 660 is energized a relay 661 is also energized to close contacts 660b and 660c which bridge across line wires leading to low speed taps T1, T2 and T3. These line wires are connected with switch S6 by relay 662 having magnet coil 662a and contacts 662b, 662c and 662d.

Unless one of the lugs 575 to 585 engages switch lever 14d, contact 15a of switch 15 will be closed and contact 15b will be open. Therefore, the windings 660a and 661a of relays 660 and 661 will be connected with a current source thereby closing contacts 660b, 660c and 660d, and closing contacts 661b and 661c. The low speed taps T1, T2 and T3 will be shorted together and the high speed taps T4, T5 and T6 will be connected with line through the switch S6 thereby causing the motor M to rotate at a normal high speed, for example 1800 R. P. M. But, when one of the figures 575 engages switch arm 14d to cause it to close contacts 14a of switch 14, to close contact 15b of switch 15 and to open contact 15a, relay windings 660a and 661a are disconnected from a current source and relays 660 and 661 open, and relay coil 662a will be connected with a current source and relay 662 will close. This results in the connecting of low speed taps T1, T2 and T3 through the

controller S6 with the line. Then the motor will operate at a reduced speed thereby effecting through the one-way clutch 425 a positive speed limiting effect upon the movement of a cam follower arm into engagement with the new cam under the pressure provided by the energized air cylinder 294.

As the timer disc 500 continues to rotate, a lug (575 to 585) will move away from the switch lever 14d to permit switch 14 to open under the biasing action of spring 14c and switch contacts 15b to open and 15a to close under the biasing action of spring 15c. This causes the advance piston 300a to move to retracted position 300a and causes relay 662 to open and relays 660 and 661 to close again, whereupon the speed of motor M is increased to normal operating speed.

Timing disc drive

Referring particularly to Figs. 2, 3 and 6 to 9, the timing disc 500 is mounted upon a stub shaft 501 carried in a lug provided on the partition 256 of the housing. At the end of said stub shaft 501 opposite the timing gear there is provided a worm gear 502 meshing with the worm 503 secured to shaft 504. This shaft 504 is journaled in a bearing provided in a partition 256 at its one end and at its other end in a bearing sleeve 505 in the back wall of the machine casing. The end of the shaft 504 extending to the rear of the machine has a gear 506 secured thereto in any suitable manner.

Referring now to Fig. 3 in particular, gear 506 meshes with a pinion gear 507 connected to gear 508 and journaled on a stub shaft 509 rigidly secured to a bracket 510 attached to the rear wall of the housing 50. Bracket 510 has elongated slots 511 for receiving the studs 512 which secure the brackets to the back wall of the housing. This method of securing the bracket to the wall provides for the removal of this bracket in order to apply different size gears 507 and 508, to change the operating characteristics of the machine, particularly as regards the number of turns to be wound at each stator position. Fig. 13 illustrates the particular construction of gears 507 and 508. It will be seen that gear 507 is directly rotatably supported upon the stud 509 while gear 508 is directly secured upon a hub extension of gear 507 by studs 514. Gear 508 operatively engages a pinion gear 515 which is keyed to the cam shaft 257, previously referred to. From this it may be seen that the timing disc shaft 504 is rotated in timed relation to the cam shaft 257.

Timing disc construction

The timing disc 500, secured to the shaft 501, has a circular row of threaded holes 555 (Fig. 7). There are 60 holes spaced 6° apart. Disc 500 has an annular groove 556. All of the lugs 560 and 575 to 585 for actuating the various control switches of the machine are adjustably attached to disc 500. For purposes of description, the adjustment of lug 560 will be described. Lug 560 projects from a block 561, one side of which has an arcuate ledge 562 of the same radial dimension as the annular groove 556 of disc 500 so that said ledge may slidably seat in said groove. Block 561 has an elongated slot 563 the center line of which is tangent to the center line of groove 556. Block 561 has an arcuate slot 564 the center line of which aligns with the center line of the circularly arranged openings 555. A screw 566 extends through the elongated slot 564

of the block 561 and is received by tapped opening 555 of the disc. When block 561 is positioned substantially in its proper place on the disc 500, a hole is bored into the disc 500 substantially coaxial of the slot 563 and intermediate its ends. A pin 569 is then pressed into this opening thus providing an abutment pin for micrometer adjustment by means of screws 567 and 568 threadedly received in openings at the opposite ends of the elongated slot 563. It will be seen that when one screw 567 is screwed out of the block 561 and the other screw 568 screwed into the block, said block will be moved slidably along the groove 556 to adjust the position of the lug 560 on said disc. Tightening the screw 566 secures the block 561 in properly adjusted position.

Besides the block 561, disc 500 has eleven similar blocks providing lugs 575 to 585 all of which lie in a plane different from the plane of lug 560; otherwise these blocks are identical. In Fig. 8 the plane position of the lug 560 is shown in a full line section. The plane position of the lugs 575 to 585 is shown by dotted lines.

Front cross-over retainer

With reference to Fig. 1, numeral 600 designates a shaft journaled in bearings 601. At the one end of this shaft there is provided an operating handle 602. Adjacent each winding head, shaft 600 has hooks 603, 604, 605 and 606 respectively adjacent heads 53, 54, 55 and 56. This apparatus is shown in the normal inoperative position in Fig. 1; however, at one time during the operation of the machine for purposes of guiding the wire conductor during a certain cross-over or loop formation the operator actuates the handle 602 upwardly as regards Fig. 1 to bring the hooks 603 to 606 inclusive into a predetermined position in which its hooks will properly guide the wire during its cross-over pull while the cages are being oscillated to provide such cross-over.

Starting the machine from beginning of cycle

When the machine is at rest and in its normal or home condition preparatory to the winding of a stator, the electrical devices and circuits are in a condition as shown in the Fig. 25. The switch 25 will have been closed as shown, due to the resetting of the cam follower shaft 275 into its initial position from which it moves forwardly as the coils are being wound. The switch 10 is closed by the operator actuating the lever 452 clockwise to engage the switch 10 and actuate it into closing position. At the same time switch 8 moves to the upper position.

To start the machine the operator first closes the main circuit completing switch S—1 which connects the entire machine with the source of current supply, then the switch S—5 is closed as shown in Fig. 25. This completes a circuit from the transformer S—3 through switches S—5 and 25 and the normally closed stop switch 9 and the switch 10 to energize relay switch 23 as indicated by the circuit in solid heavy lines in Fig. 26. Relay switch 23 closes contacts to complete the dotted line circuit across the contacts 4—a of the switch S—4 now closed by the timer disc 500, through the switch 8 (then up), across one set of contacts 23a of the start relay switch 23, then through the winding 23c of said switch. It will be seen that as soon as the electromagnetic switch 23 is energized so as to close its contacts 23a and 23b, switch S—5 may be released, for the closing

of the contacts 23a will establish a circuit through the magnetic winding 23c of said switch 23 via the dotted line circuit. The operator is not required to hold the switch S5 closed. The closing of the contacts 23b of the relay switch 23 completes a circuit (indicated by dash lines) through the magnet winding 650a of a relay switch 650, which switch may be termed the forward switch since the motor runs forward when this switch is closed. The closing of switch 650 closes the contacts 650b, 650c, 650d and 650e while opening the contacts 650f. As soon as contacts 650 b—c—d are closed the electric motor will start to rotate in its normal forward direction and thus will rotate the disc 500 so that its lug 560 will be moved out of engagement with the actuating lever of the switch S—4, thereby permitting the switch S—4 to break its contacts 4a and to reengage its contacts 4b, as illustrated in Fig. 27 which shows the running circuit of the motor.

Before contacts 4a of switch S4 open and contacts 4b close, relay coil 650a is energized through contacts 23b of switch 23 (Fig. 26). After contacts 4a open and 4b close, the circuit of relay coil 650 is connected through closed contacts 650e of relay 650 and 4b of switch S4. During the shifting of blade 4c of S4 to the right from the position shown in Fig. 26 to that shown in Fig. 27, the coil 650a will be maintained effective during this shifting moment by the circuit 23b of start relay 23. Contact 4b will close before the circuit 23b is opened.

The closing of the contacts 4b of the switch S4 completed a circuit through the magnet coil 26a of relay 26 so that its contacts 26b may close to by-pass contacts of switch 25 which open after the first advancing movement of shaft 275. As will be shown later, it is necessary, when restarting before the end of the machine cycle, to be able to energize relay 23 altho switch 25 may then be open.

During the forward running of the motor the relay winding 650a is connected with transformer S3 through contacts 4b of switch S4, contacts 650e of relay 650 stop switch S9 and switch S10. Magnet winding 16a of relay 16 parallels coils 650a so that contacts 16b are closed. The closing of contacts 16b energizes coil 17a of relay 17 to cause its contacts 17b to close thereby establishing a circuit between transformer S3 and magnet coil 17a independent of the relay contacts 16b. This independent circuit includes contacts 17b of switch 17 contacts 9b of switch S9 and rotation responsive switch (plugging switch) 11 whose contacts have been closed by the forward operation of the electric motor.

Automatic stopping of motor

In Fig. 28 the circuits for stopping the motor are shown in heavy black lines. The lug 560 having separated the contacts 4b and engaged contacts 4a of switch S4 at the completion of the winding cycle, the circuit through the forward winding 650a will be interrupted, thereby causing its deenergization and the opening of the contacts 650b, 650c, 650d and 650e and the closing of contacts 650f. Closing the contact 650e establishing a circuit through the motor reversing relay winding 655a thereby closing contacts 655b, 655c, 655d. Deenergization of magnet winding 650 is accompanied by deenergization of magnet winding 16a of relay 16 and the separation of its contacts 16b. However, relay 17 remains closed until the motor starts to reverse. At this time a reverse current is being applied to the motor tend-

ing quickly to bring the motor to a complete stop and then to cause it to reverse operation. At the instant the motor starts to reverse, the plugging switch 17 opens the circuit of the relay magnet coil 17a and contacts 17b open and the circuit of relay coil 655a is broken thereby causing contacts 655—a—b—c to open and severing all connection between switch S1 and the motor. Then a brake comes into action to stop the motor dead. The brake is associated and works upon a coupling connected to the motor and the braking force is applied by a spring which is effective only when no voltage is being applied to the motor. When voltage is applied to the motor, brake solenoid 24 is energized to prevent the application of braking pressure by the spring. Therefore, when the current to the motor is shut off after attempted reversal, the solenoid 24 is de-energized thus permitting the spring to become effective to apply a mechanical brake to stop the motor "dead." In this way "coasting" is prevented, and contacts 4a of switch S4 remain closed when the motor stops.

Stopping and starting during winding cycle

The stop button 9 is provided in order to permit the operator to stop the machine at any time. If, during the winding of the stator, the operator wishes to leave the machine he will be able to continue the interrupted operation when he returns. This is possible because the circuit through the winding 26a of relay 26 is maintained through the contact 4b of the switch S4 throughout the operation of the winding cycle, until it is broken at the end of the winding operation. Energization of the electromagnet relay 26 to close contact 26b by-passes switch 25 which is opened after the cam follower shaft has once been moved forward through an increment of its forward movements. When the operator has stopped the machine by opening switch 9, it will again be necessary to press the starting button 5 which again establishes the starting circuit through the contacts 26b, in this instance, instead of through the contacts of switch 25, as described in connection with Fig. 26.

The machine now having completed its winding operation on one stator must be reset, for, as has been described, the cam follower arms are now forward out of the plane of the cam groups 5 and 6 excepting, however, the rearmost cam follower 4 remains in alignment with cam 274 of cam group 6 at the end of the winding cycle. As has been previously described, to reset the machine the operator moves the lever 452 counterclockwise. Then he rotates crank 429 clockwise in order that the various cam follower arms axially clear the groups of cams. When such clearance is attained the shaft, upon which the followers are mounted will be shifted rearward to place the followers in their proper starting positions. At the end of the winding operation and before switch 8 has been closed the air pressure supply to the cam follower actuating air cylinder 294 is shut off. This makes turning of crank 429 by hand easier for it removes the load of the air cylinder 294 upon the gear 70. If the air pressure were to be turned on in cylinder 294, it would be practically impossible for the operator to rotate the gear 70 by the crank 429.

Wiring chart of the stator

The chart, Fig. 29, is a wiring or winding diagram of the complete stator. As shown, the stator has four poles designed by the pole center

lines 1, 2, 3 and 4. At each pole the present machine is adapted to wind three separate and distinct concentric coils designated C1, C2 and C3. It will be remembered that this machine winds the three separate windings at four different poles on the stator from an unbroken source of wire conductor supply. This source of wire supply is a spool designated in the present instance by the numeral 800.

After the machine has been reset by the operation of the reset lever 452 counterclockwise into the position, as shown in Fig. 1, and by the rotation clockwise of the hand crank lever 49, the switch 8 will have been moved to a circuit closing position due to the entrance of dog 455 in the notch 451 of the main gear 70. This rotation of the gear 70 counterclockwise simultaneously oscillates the cages 53 to 56 clockwise into their proper positions so that the workpiece carrier received by each cage will be in the proper starting position. The resetting operation has adjusted the various parts of the machine including switch 8 so that the air cylinder 294 has air pressure applied thereto tending to rotate the gear 70 and the work-carrying cages counterclockwise. However, movement of the gear 70 by the charged air cylinder 294 will not be permitted due to the fact that the machine is not in motion, the over-running clutch then preventing rotation of the shaft 410. Thus, although the air cylinder is exerting a clockwise turning effort on the gear 70, it will remain immovable until the machine is actually driven by the motor to cause the shaft 400 to rotate.

After the resetting operation the operator places four stator supporting rings in the four respective winding head cages 53 to 56 inclusive, locking said rings into position, as has been described. Now the slot Q4 (Fig. 29) of the stator is in alignment with the wire-guiding needle 100 of the machine. The operator draws the wire from the spool through the needle and through the slot Q4 and secures its end to a post 801 provided upon the work carrying ring. From this it may be seen that the first of the two parallel sides of coil C1 has been properly inserted. Now the operator presses the button 5 of the switch 85 so as to close its contact to start the machine. As soon as the machine starts to rotate, shaft 400 will rotate counterclockwise thus permitting shaft 410 to rotate in the same direction at least at an equal speed as shaft 400. This then permits the air cylinder 294 to become immediately effective to rotate the gear 70 in a clockwise direction resulting in counterclockwise rotation of the cages 53 to 56. As each cage is rotated counterclockwise the slot Q4 will be moved out of operating alignment being represented by the line running between spool 800 and lug 801 on Fig. 29 bringing the slot Q3 into alignment with the needle. Counterclockwise rotation of the stator carrying cage forms the one end cross-over loop extending from point a to point b. The action of the air cylinder 294 is such that this cross-over is made before the table can move forwardly from its rearmost position. When the table does move forwardly from its rearmost position to its forwardmost position, the wire-laying needle will guide the wire from point b to point c forming the second parallel side of the coil C1. As the table moves forward to lay wire from point b to c in slot Q3, the air cylinder 294 is cut off from its source of air pressure due to the actuation of the valve 30 by said table on its forward stroke. Now the stator carrying cage must be rotated clock-

wise in order to lay the end-loop from point *c* to point *d* at the other end of coil C1. Clockwise rotation of the cage is effected by the electric motor operating through cam 262 and arm 1 to effect counterclockwise rotation of gear 70. After making the cross over *c* to *d*, the table moves from its extreme forward position to its extreme rearward position drawing the needle through the slot Q4 thus completing the first convolution of the coil C1. It will, of course, be understood that as the table moves rearwardly it actuates the valve 30 again to apply air pressure to the cylinder 294 so that counterclockwise rotation of the cage will effect the laying of the second end loop *a* to *b* for the second convolution of coil C1. After winding the first coil C1 of pole #1, in slots Q4 and Q3, lug 575 engages switch lever 14 to cause the first advancing movement of cam follower shaft 275, so that the cam follower arm 1 may engage and cooperate with the cam 263. When cooperating with cam 263, arm 1 will effect an oscillating movement of the cages through a longer arc than when cooperating with cam 262.

At this time it may be mentioned that the end loops and cross-over portions of the various coils are piled upon each other at the ends of the stator, but for sake of clearness these portions are shown spaced in Fig. 29.

After the coil C1 has been completed loop *a* to *e* must be made. In making this loop the cage is rotated counterclockwise; and, due to the longer travel of this counterclockwise movement as a result of cam follower arm 1 cooperating with larger cam 263, slot Q5 will be brought into operating alignment with the wire-laying needle. The air cylinder 294 is effective to oscillate the cage counterclockwise for making loop *a* to *e*. The slot Q5 having been moved into alignment with the needle, table 105 will move forwardly to lay wire in slot Q5 so that the wire will reach the point *f*. As table 105 moves forwardly it will actuate the air valve 30 so that at point *f* in the operation the air is cut off from cylinder 294. The motor is then effected to act through cam 263 and arm 1 to rotate the cage in a clockwise direction to effect the laying of loop *f* to *g* and to bring the slot Q6 into working alignment with the wire laying needles. Now the table moves rearwardly laying the wire in slot Q6, this movement terminating at the point *h*. The table having reached its rearmost position will have actuated the air valve 30 to apply air to the air cylinder 294 which results in a counterclockwise rotation of the cage to form the end-loop of the second coil C2 at the first pole position on the stator. This operation will be repeated until the proper number of convolutions has been wound in coil C2 lying in slots S8 and S9 of the stator. The lug 576 will engage switch lever 14d to effect the advancing of cam arm shaft 275 through the second increment of its travel to bring arm #1 into alignment with cam 264. The third winding C3 of the winding group for pole #1 must lay in the slots Q7 and Q8. These slots being further apart than Q5 and Q6 will necessitate oscillation of the cage through a greater range of movement provided by the cooperation of arm 1 with cam 264 of cam group 5. The table having reached its rearmost position the air pressure will have been turned on by the actuation of valve 30 by said table permitting cylinder 294 to rotate the cage counterclockwise, thus bringing the slot Q7 into operating alignment with the wire placing needle and thus forming the rear end-loop *h* to *j*. The wire having reached the point *j*, the table

will now move forwardly to lay the wire in slot Q7 to the point *k*. As the table approaches the point *k* at its foremost position the air is turned off, and the motor is alone effective through cam 264 and arm 1 to rotate the work carrying cages clockwise to form end loop *k* to *l*. At the completion of loop *k* to *l*, slot Q8 will be in operating alignment with the wire-laying needle; and then the table moves backward to lay the wire until it reaches the point *m*. At this time the air pressure to the cylinder 294 will have been turned on thus again rendering the air cylinder effective to oscillate the cages counterclockwise to form end-loop *m* to *j*. Repetition of these operations will place the desired number of convolutions in the slots Q10 and Q11 to complete coil C3 for pole No. 1.

From the foregoing description, it will be seen that the convolutions for pole No. 1 as viewed in Fig. 29 are counterclockwise. As will be described in detail, the same is true of pole 3. The windings for poles No. 2 and No. 4 wound clockwise as viewed in Fig. 29.

The next slot to receive wire from the needle is slot R4 of pole No. 2. To form the cross-over from point *m* to point *n* the cam followers are actuated clockwise by the air cylinder which is rendered effective as the table moves from its foremost to its rearmost position or from position *l* to *m* of the wire in slot Q8 of No. 1 pole piece winding. The loop from *m* to *n* is considerably longer than any of the loops previously formed, as may be seen. This necessitates counterclockwise oscillation of the cage through a still greater range of movement than heretofore. Such greater range of movement counterclockwise by the cages is obtained as a result of the change of the effective cam follower arms. Where cam follower arm No. 1 cooperating with the cam group 5 was effective to wind the coils C1, C2 and C3 at pole No. 1, cam follower arm 2 must now cooperate with cam group 6 to wind coils C1, C2 and C3 of pole No. 2. To bring about this change in cam follower arms, upon the completion of coil C3 of pole No. 2, lug 577 engages switch lever 14d to cause shaft 275 to advance and move arm 1 away from cam group 5 and to bring arm 2 into alignment with cam 272 of group 6. The air in cylinder 294 moves arm 2 clockwise so that it engages cam 272 in order to move the cage counterclockwise so that slot R4 will be brought into working alignment with the needle. This results in the laying the cross-over *mn*. Now the table is ready to move forwardly to lay the wire in slot R4 from point *n* to point *o*. At some instant during this forward movement, lug 560 of the timing disc 500 will have closed switches 18 to energize relay 20 and solenoid 20d to cause valve part 480 to move the full line position of Fig. 24, this opening the passage of air through valve 30 to cylinder 294, since valve part 30f is then in position 30f', the table then being in forward position thus changing the sequence of the cycling of the valve 30. Therefore, where air cylinder 294 was effective during the loop formation *m* to *n* (with the table at its rearmost position) air cylinder 294 will be effective when the table reaches its foremost position to cause oscillation of the cage counterclockwise to effect the formation of the front end loop *o* to *p*. The counterclockwise rotation of the cages while making the loop *o* to *p* brings the slot R3 into alignment with the wire laying needle. Now the table moves rearwardly and lays the wire in slot R3 from point *p* to point *q* during which time

the air to the cylinder 294 will have been turned off render the air pressure means inoperative. The cam follower arm 2 is now actuated by the electric motor acting through cam 272 to rotate the cage clockwise to move the slot R4 into alignment with the needle and at the same time forming the loop q to r . Then the table is moved forwardly to lay wire in slot R4 from point r to point t . After the proper number of convolutions are completed in coil C1, coil C2 will be wound. It will be noted that the slots R5 and R6 to receive the intermediate coil C2 for pole No. 2 are wider apart than the slots of coil C1. Therefore the cage must be oscillated through a greater arc in order to bring slots R5 and R6 into working alignment with the wire laying needle. To bring this about, at the end winding coil C1 of pole No. 2, lug 578 of timer disc 500 engages switch lever 14d to effect the advancing of shaft 275 another increment in order to shift the cam follower 2 into operative alignment with the intermediate cam 273 which is larger than cam 272, with the result that cage will be oscillated through a greater range of movement.

To form the front end loop t to u , the air cylinder 294 is effective to oscillate the cage counterclockwise thus bringing the slot R5 in working alignment with the needle. The table now moves rearwardly to lay wire U—2 in slot R5. During this time the air cylinder 294 has been shut off and the electric motor will be effected through cam 273 and arm 2 to oscillate the cage clockwise to bring the slot R6 into working alignment with the needle for forming the rear end-loop v — w . As the table moves forwardly again it will lay the wire w — x in slot R6 and at the same time again turn the compressed air into the cylinder 294. The air cylinder 294 will now become effective to rotate the cage counterclockwise to form the loop x — w . This operation will be repeated until the proper number of convolutions are wound for coil C2 after which coil C3 will be wound. The loop xy is formed under the effect of air cylinder 294 to rotate the cages counterclockwise. This rotation is lengthened to bring the more widely separated slots R7 and R8 in working alignment with the needle, the slot R7 being brought into alignment with said needle as the loop xy is made. This x —7, being longer, requires an oscillation of the cage through a greater range of movement which is provided due to the fact that cam follower arm 2 will, after having been shifted forwardly by the cylinder 302 (as the result of the engagement of lug 579 with switch lever 14d), operatively engage cam 274. From point y the table moves rearwardly to lay the wire y — z in slot R7 during which time the air has been shut off. The motor is again effective through cam 274 operating on arm 2 to oscillate the cage clockwise to form the loop z — $z1$ at which time the slot R8 is brought into alignment of the needle. Forward movement of the table will turn on the air of cylinder 294 and will also lay the wire $Z1$ — $Z2$ in slot R8. From point $Z2$ to substantially point $Z3$ the front end loop is laid under the influence of air cylinder rotating the cage counterclockwise after which rearward movement of the table completes the lay of wire from point $z3$ to point z in slot R7. These operations are repeated until the desired number of convolutions are wound in the stator coil C3 at pole No. 2. Coil C3 terminates at point $z2$. To wind the coil group for pole No. 3, it will be necessary first to lay in a cross-over $z2$ — $z5$, this cross being substantially identical with and being obtained in the same manner as

the cross-over m — n between the coil groups of pole No. 1 and pole No. 2.

The entire operation as described in connection with pole No. 1 and pole No. 2 is repeated in the identical way to provide the coil group for poles No. 3 and No. 4 and therefore no further description thereof need be made. It is sufficient to state that, when at point 900 in chart 29 the machine will stop due to the fact that the finger 560 of the timing disc will have broken the circuit to the motor by opening the contacts 4b of switch S4. After this the operator must perform the resetting operations which have been described in order to bring the machine into condition for properly receiving and winding a new stator.

Slots Q1 and Q2 of pole No. 1, slots R1 and R2 of pole No. 2, and similarly located slots of poles No. 3 and No. 4 are reserved for the starting windings of the motor, to be prewound and assembled manually with the stator.

While the embodiments of the present invention as herein disclosed, constitute a preferred form, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow.

What is claimed is as follows:

1. In a winding machine the combination with a wire laying mechanism; a rotatable cage; oscillatable means for rotating the cage; a first power means for rotating the oscillatable means in one direction only; a second power means for rotating said oscillatable means in the opposite direction only; and means for rendering the second power means completely inactive while the first power means is active.

2. In a winding machine the combination with a wire laying mechanism; a rotatable cage; oscillatable means for rotating the cage; an electric motor for actuating the oscillatable means in one direction only; an air pressure motor for actuating said oscillatable means in the opposite direction; and means including an air valve for rendering the air pressure motor inactive while the electric motor is actuating the oscillatable means.

3. In a winding machine, the combination with a reciprocative wire laying mechanism; a rotatable cage; oscillatable means for rotating the cage; two separate power means for actuating the oscillatable means, each in a different direction; and control means actuated by the reciprocative wire laying mechanism for rendering one of said power means inactive while the other is active.

4. In a winding machine, the combination with a wire laying member adapted to be reciprocated from one into another extreme position; means for reciprocating said member; a rotatable cage; oscillatable means for rotating the cage; two separate power means alternately active to rotate the oscillatable means, each in a different direction; and means actuated by the wire laying member for rendering one of said power means active when said member is in one of its extreme positions and inactive when in its other extreme position.

5. In a winding machine, the combination with a rotatable cage; a reciprocative wire laying mechanism; oscillatable means for rotating the cage in either direction; means for reciprocating the wire laying mechanism from one into the other extreme positions; a power device for driving both the oscillatable and reciprocating means, the oscillatable means in one direction only, the reciprocating means in both directions; a second power device for driving the oscillatable means in the other direction only, said second

device being completely inactive while the first mentioned power device is driving the oscillatable means.

6. A machine according to claim 5 in which the second power means is actuated by air pressure and is rendered completely inactive while the first mentioned power device is acting to rotate the oscillatable member in one direction.

7. A machine according to claim 5 in which the second power means is actuated by air pressure, controlled by a valve actuated by the reciprocative wire laying mechanism adjacent each end of its travel.

8. In a winding machine, the combination with a wire laying mechanism; means for reciprocating said mechanism from one extreme position to the other; a rotatable cage; means for rotating the cage in one direction while the wire laying mechanism is at its one extreme position, and in the opposite direction while the said mechanism is at its other extreme position; a primary power means for driving the reciprocating means in both directions and the cage rotating means in one direction only; a second power means for actuating the cage rotating means in the opposite direction; and means for rendering said second power means inactive while the primary power means is active to rotate the cage.

9. A machine according to claim 8 in which the second power means is actuated by fluid pressure and in which a valve is provided, actuated by the reciprocating wire laying mechanism in its one extreme position to apply air pressure and render the said power means active, and in the other extreme position to shut off air pressure and render said power means inactive.

10. A machine for winding a slotted core comprising a rotary core support; an intermittently reciprocating device for placing wire in the core slots; means for timing movements of the core support relatively to the movements of the wire placing device; a first power means acting through the timing means to move the core support in one direction only; a second power means for moving the core support in the opposite direction; and means for controlling the operation of the first and second power means so that at no time during the operation of the machine concurrent operation of both power means is effected.

11. A machine according to claim 10 in which the timing means comprises a cam driven by the first power means and a cam follower, actuated in one direction by the cam and in the other direction by the second power means, the cam acting only to time the movement.

12. In a winding machine, the combination with a reciprocative wire placing mechanism; a rotatable cage; an electric motor for reciprocating the wire placing mechanism; a cam rotated by said motor; a cam follower operatively connected to the cage and adapted to be actuated by the cam to rotate the cage in one direction only; a compressed air actuated device connected to the cam follower and adapted to actuate it in the opposite direction under the control of the cam; and means for rendering the air actuated device inactive which the cam follower is actuated by the cam.

13. A machine as defined by the claim 12 in which the reciprocative wire placing mechanism actuates a valve for rendering the compressed air actuated device active as the said mechanism approaches one end of its travel and for render-

ing said device inactive as the mechanism approaches its other end of travel.

14. In a winding machine the combination with a reciprocative wire placing member; a rotatable cage; a cam having dwells connected by rising and falling camming surfaces; an electric motor for rotating the cam; a cam follower engaging the cam and operatively connected to the cage and adapted to rotate the cage in one direction as the follower rides over the rising camming surface; an air pressure actuated means connected to the follower and active only to rotate said follower toward the cam and to effect timed rotation of the cage in the opposite direction; means for rendering the air pressure means inactive while the follower engages the rising camming surface; and means driven by the electric motor for reciprocating the wire placing member only while the follower engages the dwells of the cam.

15. A machine for winding a set of coils at the various pole positions of a slotted core, comprising in combination, a rotary core holder; a reciprocative member for placing a continuous length of wire in the slots of the core; two groups of cams; a plurality of cam followers operatively connected to the core holder, one of said followers successively cooperating with the several cams of one group to actuate said core holder through predetermined angles of oscillation at the one pole position of the core, the other cam follower successively cooperating with the several cams of the second group to actuate said core holder through predetermined angles of oscillation at the next pole position of the core; means for shifting the followers progressively into the planes of movement of the respective cams; a first power means for actuating the cams whereby the followers will be moved to rotate the core holder in one direction only; a second power means operatively connected to the followers and adapted to rotate them toward and into engagement with the cams whereby the core holder is rotated in the opposite direction under the force of the second power means and through predetermined angles controlled by the cams; and means for preventing concurrent effect of both the first and second power means to rotate the core holder during functioning of the machine.

16. A machine for winding a set of coils at each pole position of a slotted core, comprising in combination, a reciprocative wire placing member; a rotatable core holder; means for rotating the core holder in alternate directions through predetermined angles of oscillation, said means comprising two groups of cams and a plurality of cam followers, one of which successively engages one group of cams to rotate the core holder through predetermined angles of oscillations in opposite directions to form the coils at one pole position and the other follower successively engages the other group of cams similarly to oscillate the core holder to form the coils at the next pole position; means for shifting the followers progressively into the planes of movement of the respective cams; an electric motor for rotating the cams whereby said cams will oscillate the followers in one direction through an angle of movement predetermined by the several cams; an air pressure actuated means adapted to rotate the followers in the opposite direction; the angle of said movement also being predetermined by the several cams; and means for rendering the air pressure actuated means effective to rotate a follower in

one direction, only after said follower has been moved through its complete range of movement in the opposite direction by a cam.

17. A machine in accordance with claim 16 provided, however, with means actuated by the reciprocation of the wire placing member to render the air pressure actuated means active and inactive in recurrent sequence; and a reversing air valve rendered effective at predetermined intervals in a machine cycle for periodically changing the sequence.

18. A machine in accordance with claim 15 provided, however, with means actuated by the wire placing means adjacent each end of its reciprocative travel to render the second power means active or inactive respectively in a predetermined recurrent sequence; and means rendered effective during the operation of the machine for changing said sequence for each set of coils at a pole position of the core.

19. A machine in accordance with claim 16 provided, however, with a valve actuated by the wire placing member to render the air pressure actuated means active or inactive in recurrent sequence; and means intermittently rendered effective during the operation of the machine to change said sequence at a time prior to the placing of the first end loop of a set of coils.

20. A machine for winding a slotted core comprising an oscillatable core support, an intermittently reciprocating device for placing a wire in its core slots, means for timing the oscillations of the core support relative to the reciprocations of the wire placing device, said means including groups of cams and cam followers, a first power means operating through the cams to oscillate the core in one direction only, a second power means operable, when the first power means is ineffective to oscillate the core, to urge a cam follower against a cam and thereby to cause the core to oscillate in the opposite direction; means for periodically shifting the followers successively into operating alignment with the cams, and means under the control of the first power means to limit the rate of movement of a cam follower into engagement with a cam under the influence of the second power means.

21. A machine according to claim 20 in which the means which limits the rate of movement of a cam follower into engagement with a cam comprises a one-way clutch having members connected respectively with the first and second power means.

22. A machine according to claim 20 having a rotary member the second power means of said machine being a fluid pressure device operatively connected with said rotary member transmitting motion from the cam follower to the core support and in which the means which limits the rate of movement of a cam follower into engagement with a cam comprises a one-way clutch having a part connected with said rotary member and a part connected with the first power device.

23. A machine according to claim 20 provided with means operable during the shifting of cam followers for causing the first power means to operate at reduced speed.

24. A machine according to claim 20 in which the first power means is an electric motor, in which means are provided for controlling the speed of the motor, and in which the motor drives a control device for periodically causing the concurrent operation of the cam follower shifting device and the functioning of the motor speed controller to reduce the speed of the motor.

25. A machine according to claim 20 in which the first power means is an electric motor, in which means are provided for controlling the speed of the motor, in which the cam follower shifting means is fluid pressure operated and is controlled by an electrically actuated valve, and in which the motor drives a control device for periodically effecting the actuation of said valve and the functioning of the motor speed controller to reduce the speed of the motor.

26. A machine for winding a plurality of coils at each pole position of a slotted stator, comprising in combination, a rotatable stator holder; a reciprocative wire placing mechanism; an electric motor; two groups of cams driven by the motor, each group including a plurality of contiguous cams; a shaft; a gear slidably keyed to said shaft and operatively connected to the stator holder; a plurality of cam followers secured to the shaft, each cam follower being adapted successively to engage the cams of one group and be rotated through a predetermined angle of oscillation in one direction thereby; an air pressure device connected to the gear and adapted to rotate said gear, shaft and followers in the opposite direction toward the cams, which now act as movement timing members only; means for rendering the air pressure device inactive while the followers are actuated in said one direction by the cams; an air power cylinder for shifting the shaft forwardly; means for limiting each forward shift of said shaft so that each shift of the shaft aligns a cam follower with a new, contiguous cam; and machine controlled timing means adapted to render said air power cylinder active upon completion of a stator coil.

27. A machine for winding a slotted core comprising an oscillatable core holder; a reciprocating wire placing device; means for oscillating the core holder in timed relation to reciprocations of the wire placing device, said means including cams and cam followers; two power means, one for operating the said device and cams, the second acting directly to rotate the cam followers, said second power means being inactive when the first power means is effective to actuate the cam followers; means for advancing the cam followers successively into engagement with certain cams; means for rotating the cam followers axially to clear the cams; resetting means for retracting the followers to their start positions, said means acting automatically when the cam followers have reached their cam clearing positions.

28. A machine in accordance with claim 27 in which a means is provided automatically to stop the machine at the completion of its winding cycle; and means, contingent upon the completion of the winding cycle of the machine, for retracting the followers to their start positions.

29. A machine in accordance with claim 27 in which the resetting means is controlled by a lever which has been moved toward but cannot arrive at its reset position until the cam followers reach their cam clearing positions.

30. A machine for winding sets of coils at each pole position of a slotted stator, comprising in combination, a rotatable stator holder, a reciprocative wire placing member; an electric motor; two groups of contiguous cams rotated by the motor; cam followers operatively connected to the stator holder and cooperating with the cams to rotate said stator holder back and forth through predetermined angles of oscillation; means for shifting the followers successively to

engage the respective cams; manually operable means for rotating the followers to clear both groups of cams axially; an air pressure cylinder adapted to shift the followers to their initial, pre-winding positions; means rendered effective by the arrival of the followers at their cam clearing position, to activate said air pressure cylinder; a manually operable lever for rendering said air pressure cylinder inactive and concurrently closing one gap in the running circuit of the electric motor; and a switch, closed by the return of the followers to their initial, pre-winding positions for closing one gap in the starting circuit of the electric motor.

31. A machine for winding a slotted core comprising an oscillatable core holder; a reciprocating wire placing device; two groups of cams each comprising several contiguous cams; cam followers operatively connected to the core holder; means for advancing the followers successively into operating alignment with certain cams; a first power means for driving the cams and the wire placing device, said cams rotating the followers in one direction through predetermined angles of oscillation; a second power means for actuating the followers in the opposite direction and against the cams for rotating the followers through predetermined angles of oscillation in said opposite direction; control means actuated by the reciprocating wire placing device for alternately rendering the second power means active and inactive in recurrent sequence; said second power means being inactive when the first power means is active to rotate the followers; means rendered effective during the operation of the machine for controlling said second power means to change the sequence of operation of the control means actuated by the wire placing device at predetermined stages of the winding cycle; means for rotating the cam followers into cam clearing positions after a winding cycle has been completed by the machine; resetting means for retracting the followers into their start positions; and means adapted concurrently to render the resetting means and the sequence changing means effective only when the cam followers have reached their cam clearing positions.

32. A machine for winding a slotted core comprising an oscillatable core support, a reciprocating device for placing wire in the core slots, means for timing oscillations of the core support relative to the reciprocations of the wire placing device, said means comprising groups of cams and cam followers, means for shifting the cam followers successively into engagement with certain cams, means for resetting the cam followers to start position and including a lever for controlling the resetting, a power device for operating the cams and the wire placing device, and means conditioned upon the resetting of the cam followers and upon the movement of the reset control lever out of reset position and into start position for causing the power device to operate at the start of the machine cycle.

33. A machine for winding a slotted core comprising an oscillatable core support, a reciprocating device for placing wire in the core slots, means for timing oscillations of the core support relative to the reciprocations of the wire placing device, said means comprising groups of cams and cam followers, means for shifting the cam followers successively into engagement with certain cams, electrically controlled means for resetting the cam followers and including a switch and a lever for operating the switch, an

electric motor for operating the cams and the wire placing device, and a motor control system including a starter button and a switch, closed by the reset lever when not in reset position, said system being conditioned for starting the motor from the beginning of the machine cycle by the use of the starter button, provided said switch has been closed by movement of said reset lever away from reset position, and provided said resetting means has operated.

34. A machine for winding a slotted core comprising an oscillatable core support, a reciprocating device for placing wire in the core slots, means for timing oscillations of the core support relative to the reciprocations of the wire placing device, and means including a group of cams and cam followers, means for shifting the cam followers successively into engagement with certain cams, means for resetting or returning the cam followers to start position, an electric motor operating the cams and the wire placing device, and a motor control system including a switch required to be closed by return of the cam followers to start position before the motor can be started from the beginning of the machine cycle, and a relay switch for bypassing said reset controlled switch after the machine cycle has commenced, whereby the motor may be stopped during the cycle and then be started again without requiring the resetting of the cam followers.

35. A machine for winding a slotted core comprising an oscillatable core support, a reciprocating device for placing wire in the core slots, means for timing oscillations of the core support relative to the reciprocations of the wire placing device, and means including a group of cams and cam followers, means for shifting the cam followers successively into engagement with certain cams, means for resetting or returning the cam followers to start position, an electric motor operating the cams and the wire placing device, and a motor control system responsive to completion of the machine cycle for causing the motor to stop and having provisions for preventing the coasting of the motor beyond the position for commencing the machine cycle.

36. A machine for winding a slotted core comprising an oscillatable core support, a reciprocating device for placing wire in the core slots, means for timing oscillations of the core support relative to the reciprocations of the wire placing device, and means including a group of cams and cam followers, means for shifting the cam followers successively into engagement with certain cams, means for resetting or returning the cam followers to start position, an electric motor operating the cams and the wire placing device, and a motor control system responsive to completion of the machine cycle for causing the motor to stop and having provisions for preventing the coasting of the motor beyond the position for commencing the machine cycle and conditioned by the completion of the resetting of the cam followers for starting the motor at the beginning of the machine cycle.

37. A machine for winding a slotted core comprising an oscillatable core support, a reciprocating device for placing wire in the core slots, means for timing oscillations of the core support relative to the reciprocations of the wire placing device, and means including a group of cams and cam followers, means for shifting the cam followers successively into engagement with certain cams, means for resetting or returning the cam followers to start position, an electric

motor operating the cams and the wire placing device, and a motor control system responsive to completion of the machine cycle for causing the motor to stop and having provisions for preventing the coasting of the motor beyond the position for commencing the machine cycle and conditioned by the completion of the resetting of the cam followers for starting the motor at the beginning of the machine cycle, and having provisions for stopping the motor during the machine cycle and starting again without requiring the resetting of the cam followers.

38. A machine for winding a slotted core comprising an oscillatable core support, a reciprocating device for placing wire in the core slots, means for timing oscillations of the core support relative to the reciprocations of the wire placing device, and means including a group of cams and cam followers, means for shifting the cam followers successively into engagement with certain cams, means for resetting or returning the cam followers to start position, an electric motor operating the cams and the wire placing device, and a motor control system responsive to completion of the machine cycle for reversing circuit connections to the motor to quickly bring the motor to rest by throwing it into reverse, and including means responsive to attempted reversal of the motor for disconnecting the motor from the power source, and including means responsive to disconnection of the motor from the power source for braking motion of the motor.

39. A machine for winding sets of coils at each

pole position of a slotted core, comprising a core holder; a wire placing device; power means for driving the machine; means for oscillating the core holder through a predetermined angle for each coil and for winding a successive set of coils; means for changing the speed of the driving means periodically during a winding cycle of the machine; means for stopping the machine at the end of a winding cycle; a plurality of electric switches for controlling the operation of the core holder oscillating means, the speed changing means and the stopping means; and a machine driven timer disc having means adapted to actuate all of said switches at a predetermined point in a revolution of said disc, one revolution thereof being completed during one winding cycle of the machine.

40. A machine as defined in claim 39 in which certain of the electric switches are spaced substantially 90° apart in a circular row and common plane and others in another plane, the timer disc having a single means for actuating the switches in the circular row and a plurality of means for actuating the other switches in a different plane at timed intervals in the one revolution of said disc.

41. A machine as defined in claim 39 in which the switch actuating means on the machine driven timer disc are all adjustably carried by the said disc; and a micrometer adjusting means being provided with each of said means.

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