

July 27, 1948.

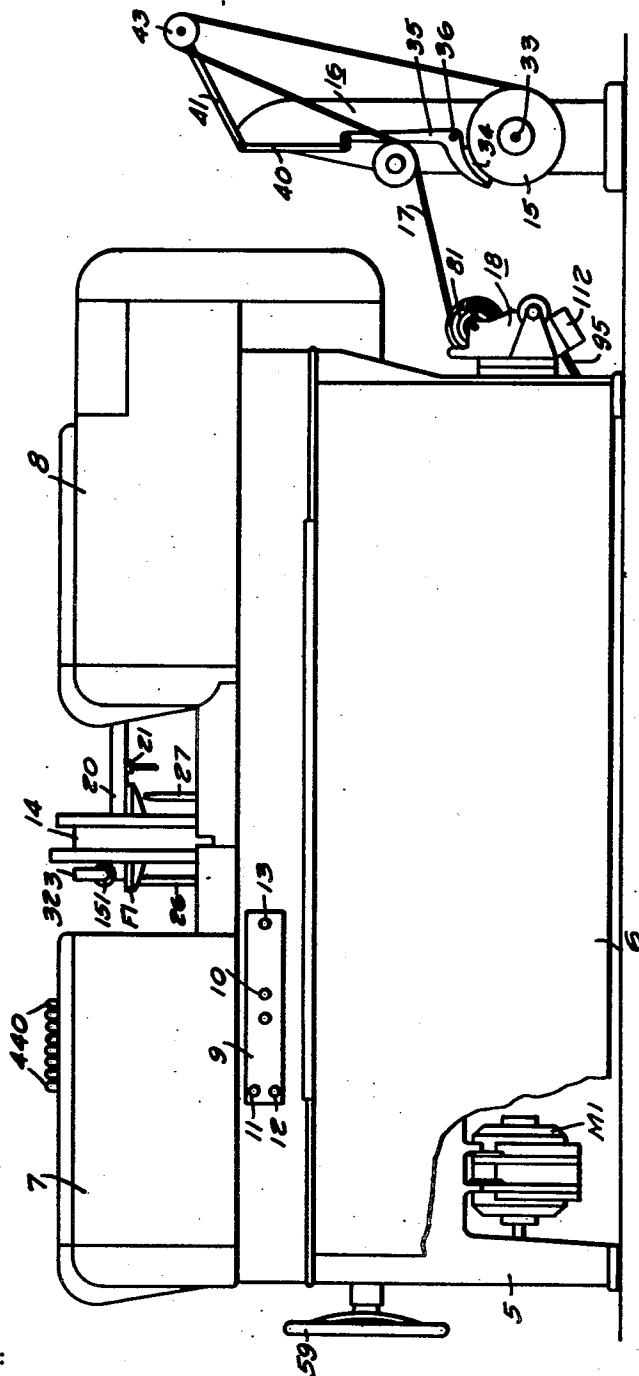
D. E. CARPENTER  
COIL WINDING MACHINE

2,445,937

Filed May 9, 1945

27 Sheets-Sheet 1

FIG. 1.



WITNESSES:

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*Carl W. Perry*

INVENTOR

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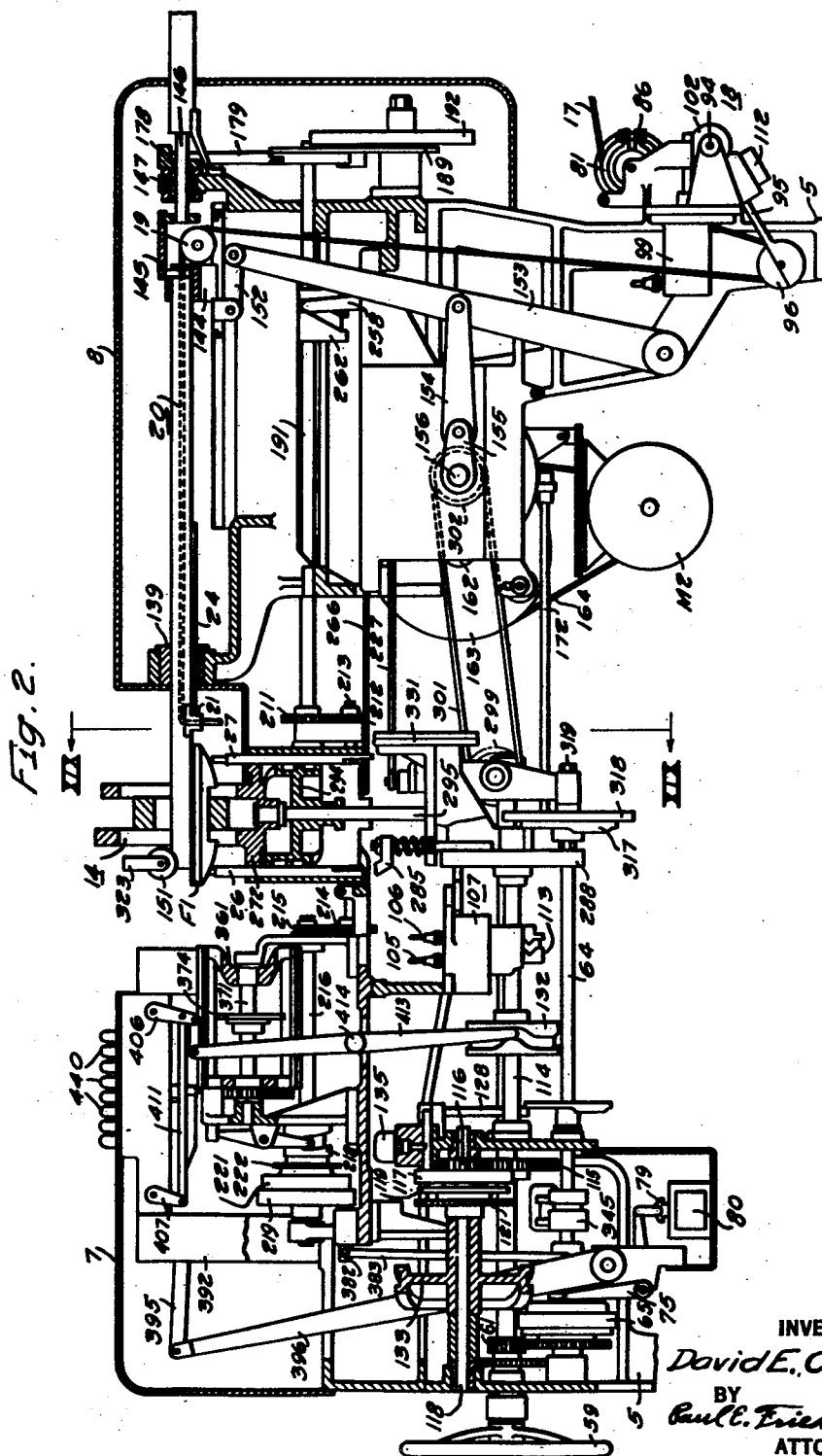
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27 Sheets-Sheet 2



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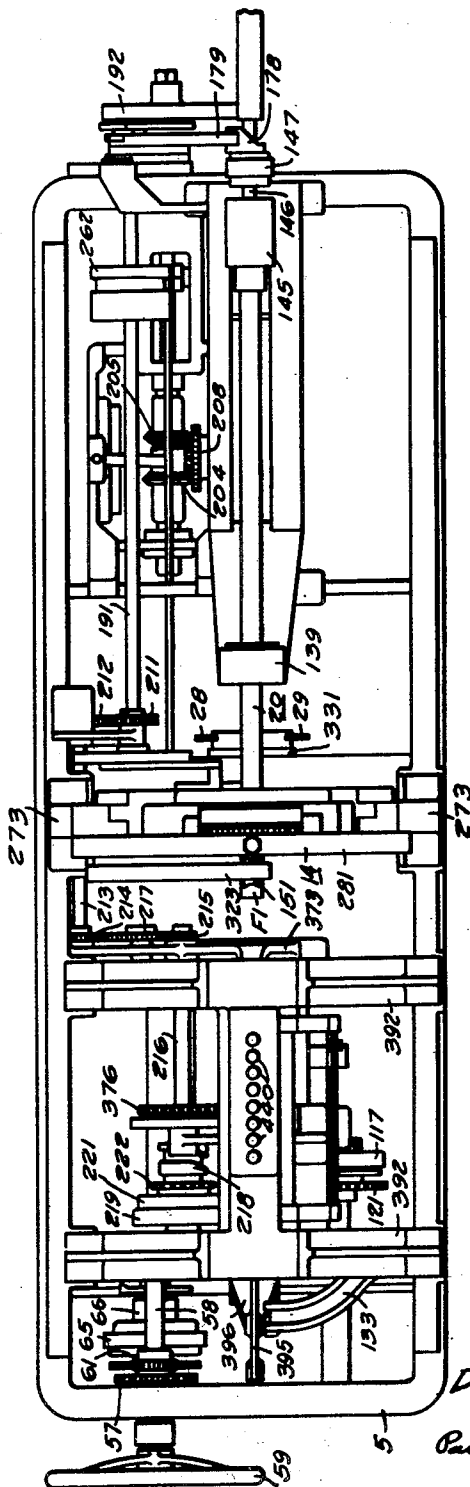
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COIL WINDING MACHINE

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27 Sheets-Sheet 3

FIG. 3.



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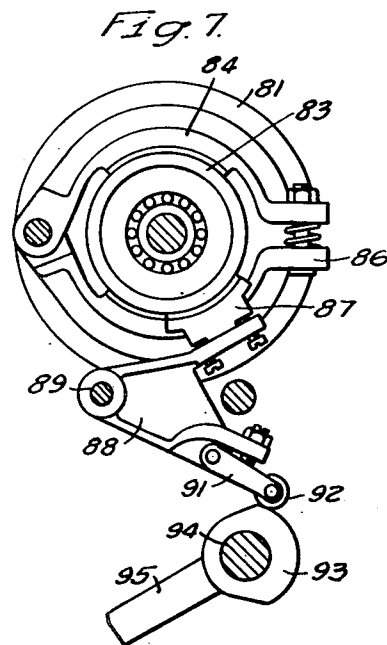
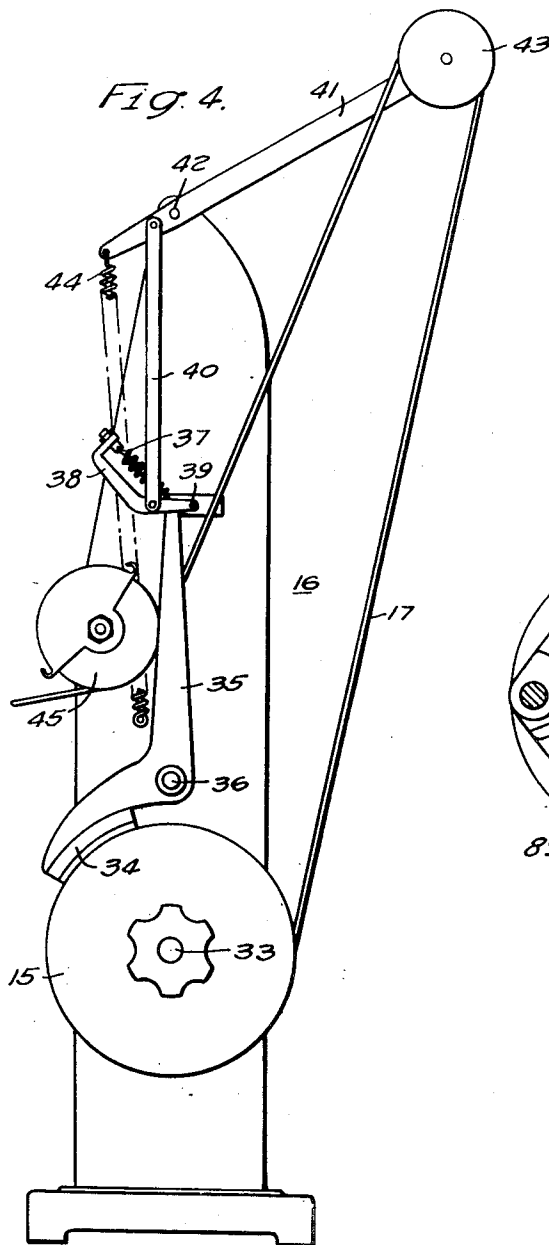
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COIL WINDING MACHINE

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27 Sheets-Sheet 4



WITNESSES:

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COIL WINDING MACHINE

Filed May 9, 1945

27 Sheets-Sheet 5

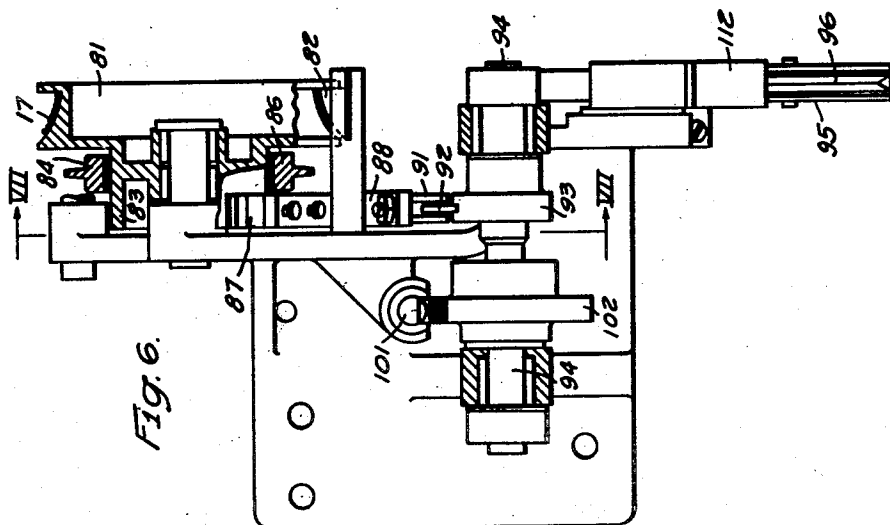


Fig. 6.

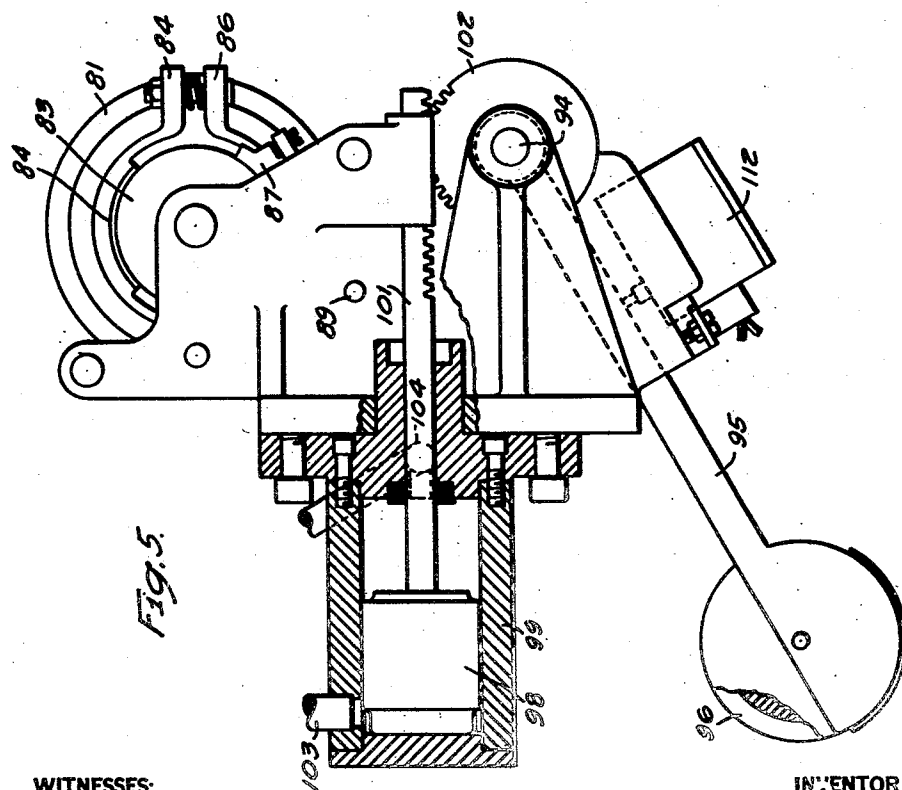


Fig. 5.

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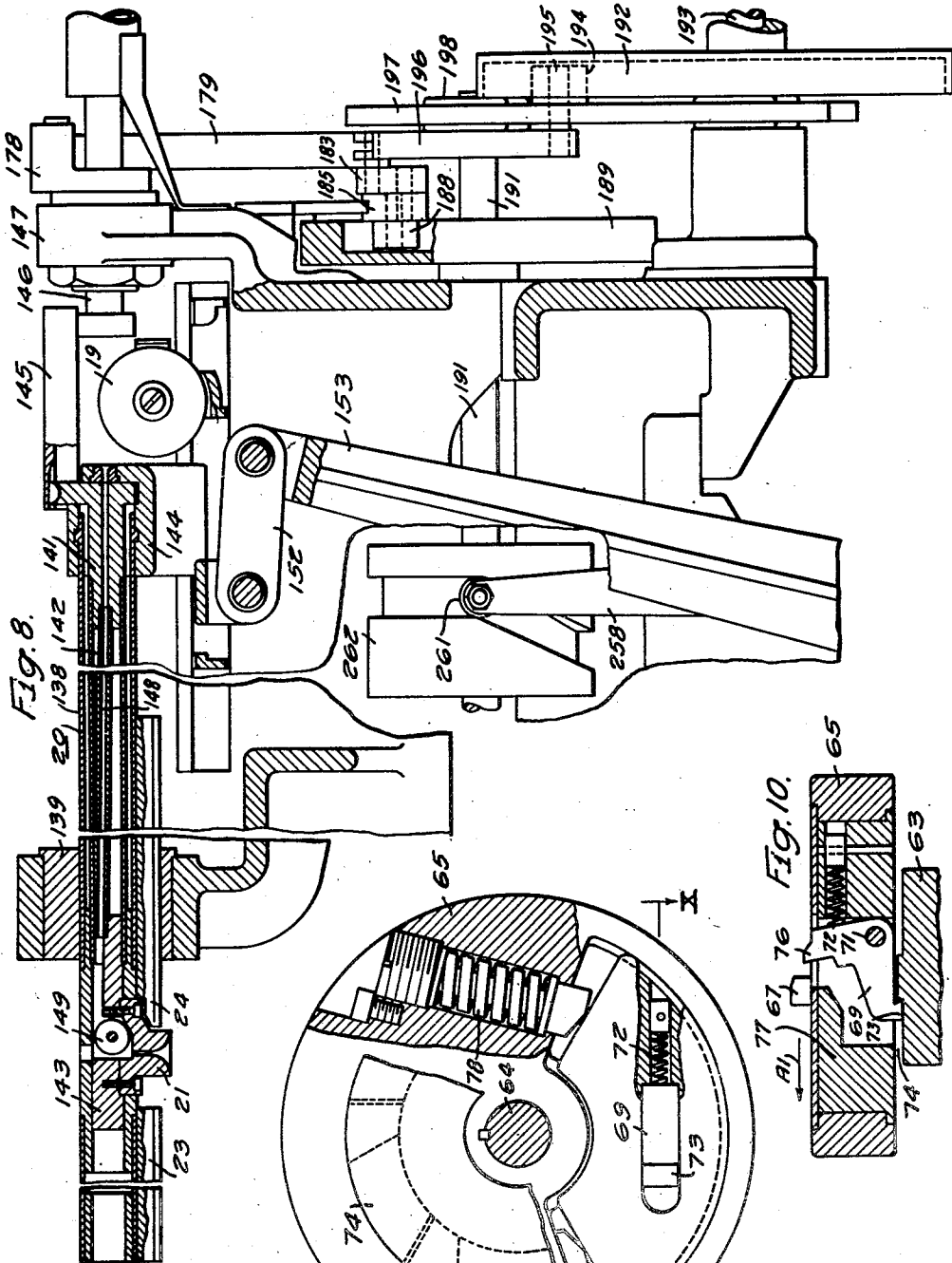
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D. E. CARPENTER  
COIL WINDING MACHINE

2,445,937

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27 Sheets-Sheet 6



WITNESSES:  
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FIG. 9

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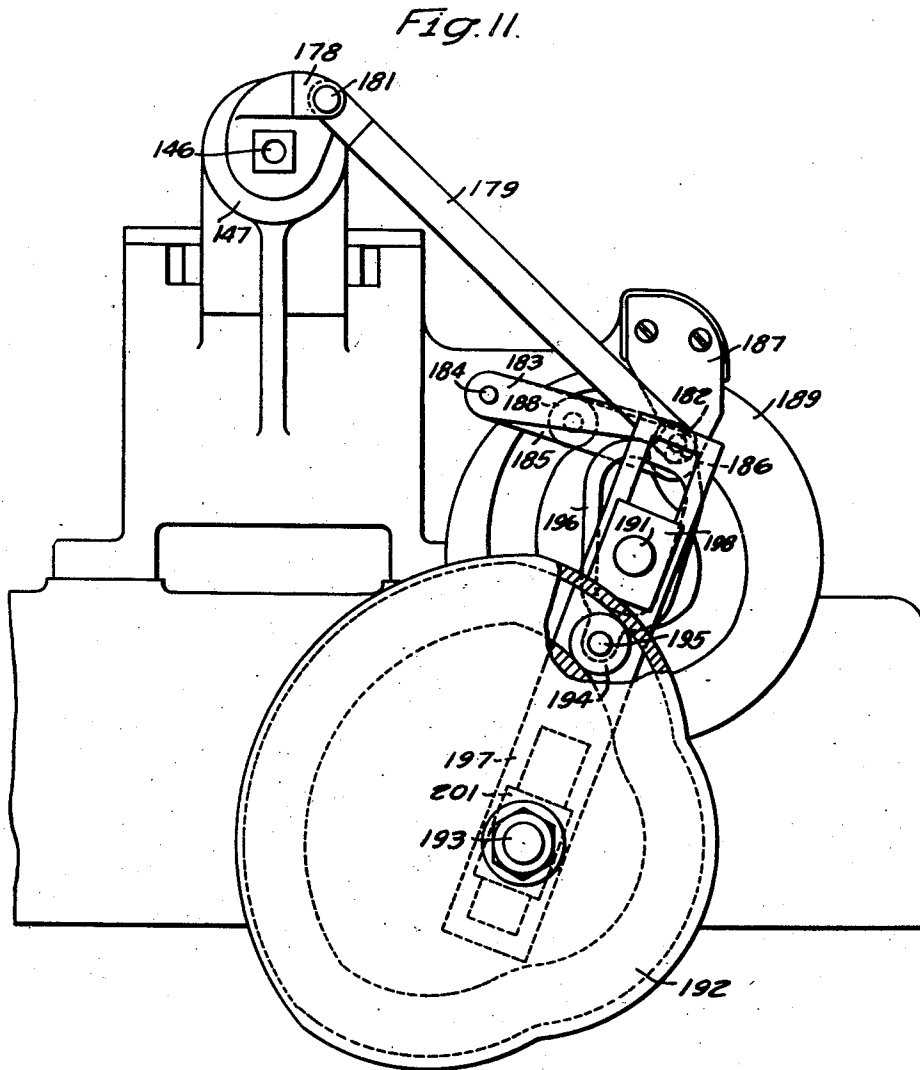
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COIL WINDING MACHINE

2,445,937

Filed May 9, 1945

27 Sheets-Sheet 7



WITNESSES:

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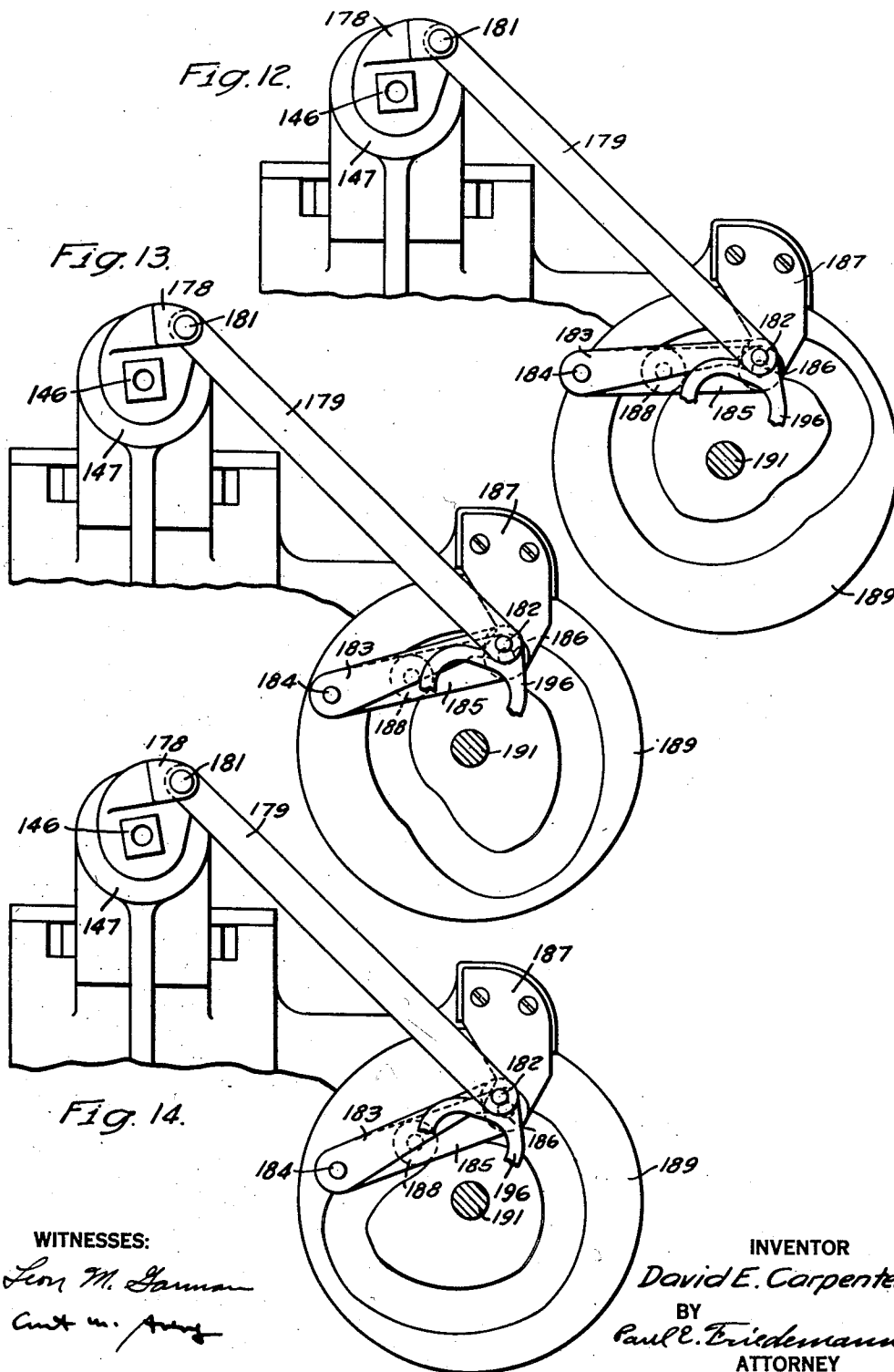
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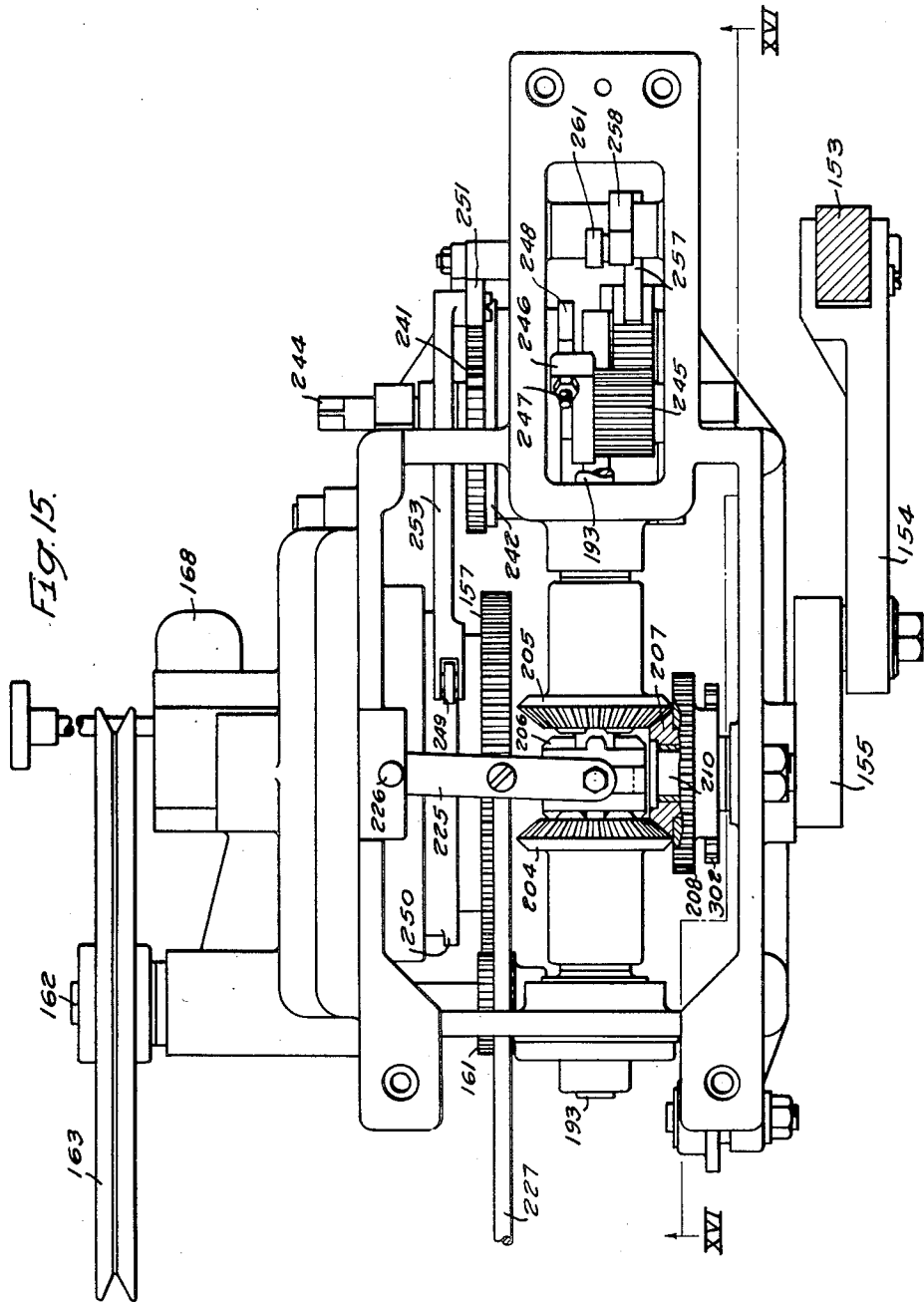
27 Sheets-Sheet 8



Filed May 9, 1945

## COIL WINDING MACHINE

27 Sheets-Sheet 9



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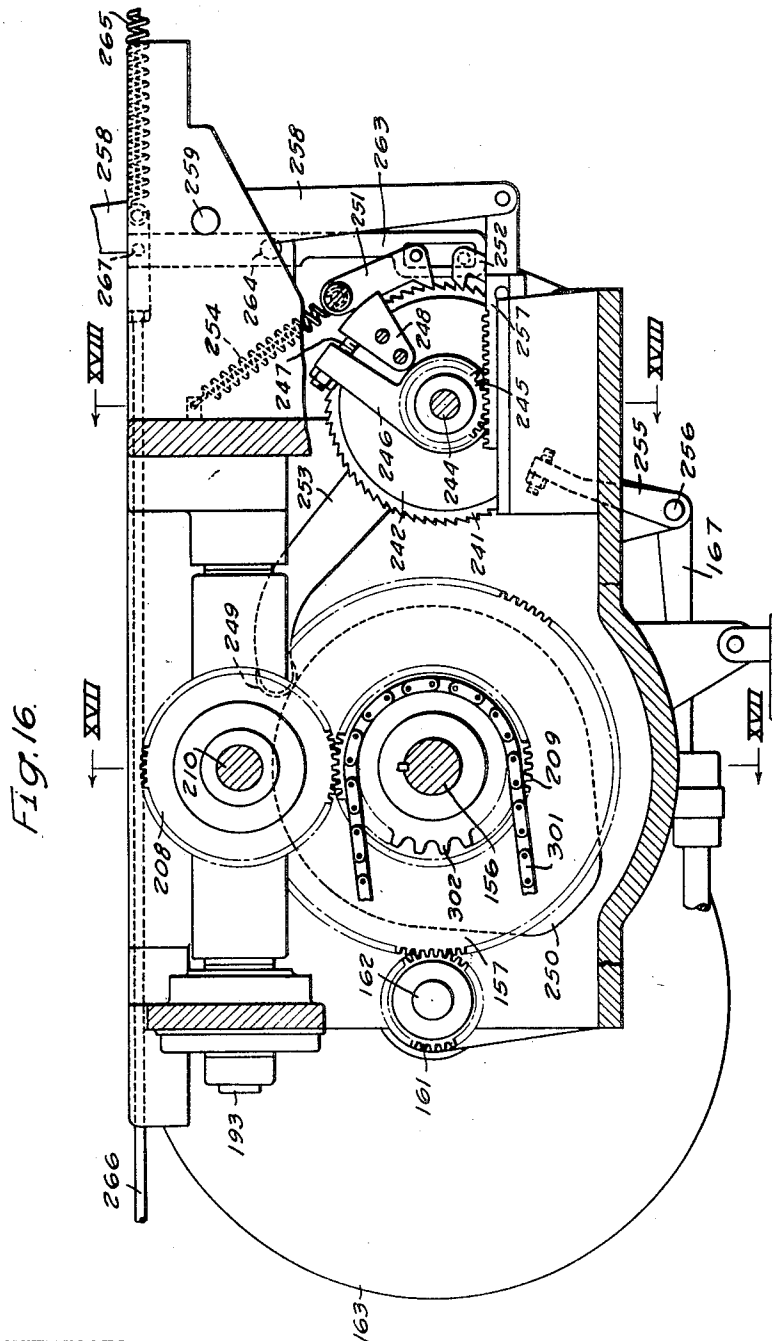
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**COIL WINDING MACHINE**

**2,445,937**

Filed May 9, 1945

27 Sheets-Sheet 10



**WITNESSES:**

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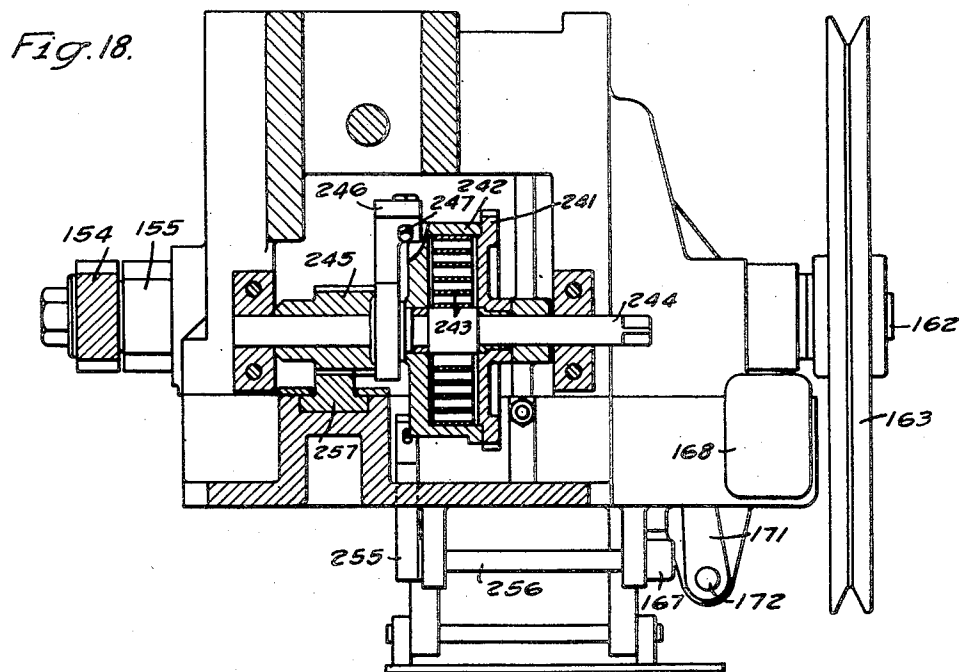
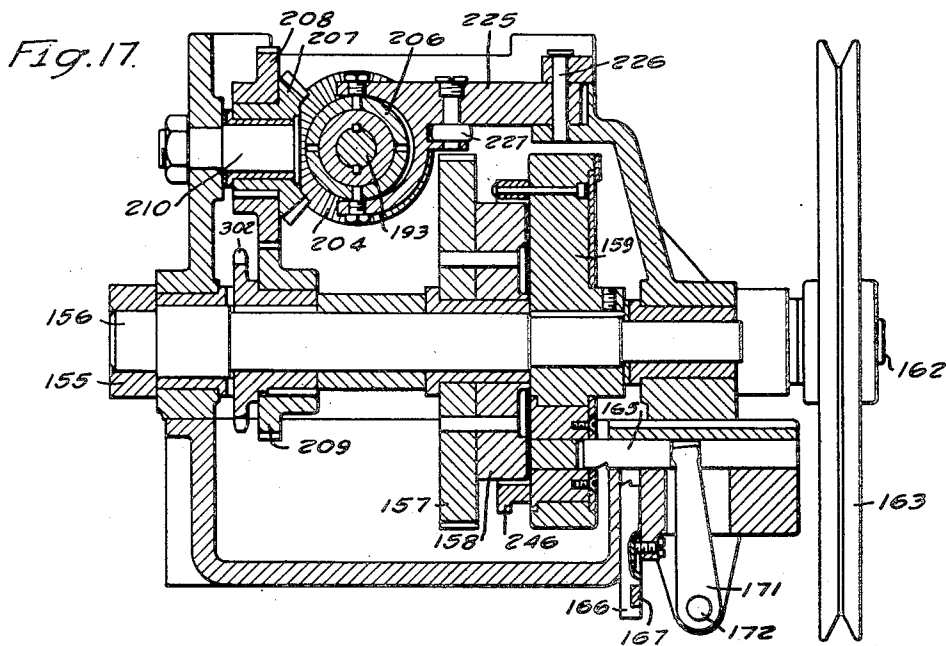
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COIL WINDING MACHINE

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Filed May 9, 1945

27 Sheets-Sheet 11



WITNESSES:

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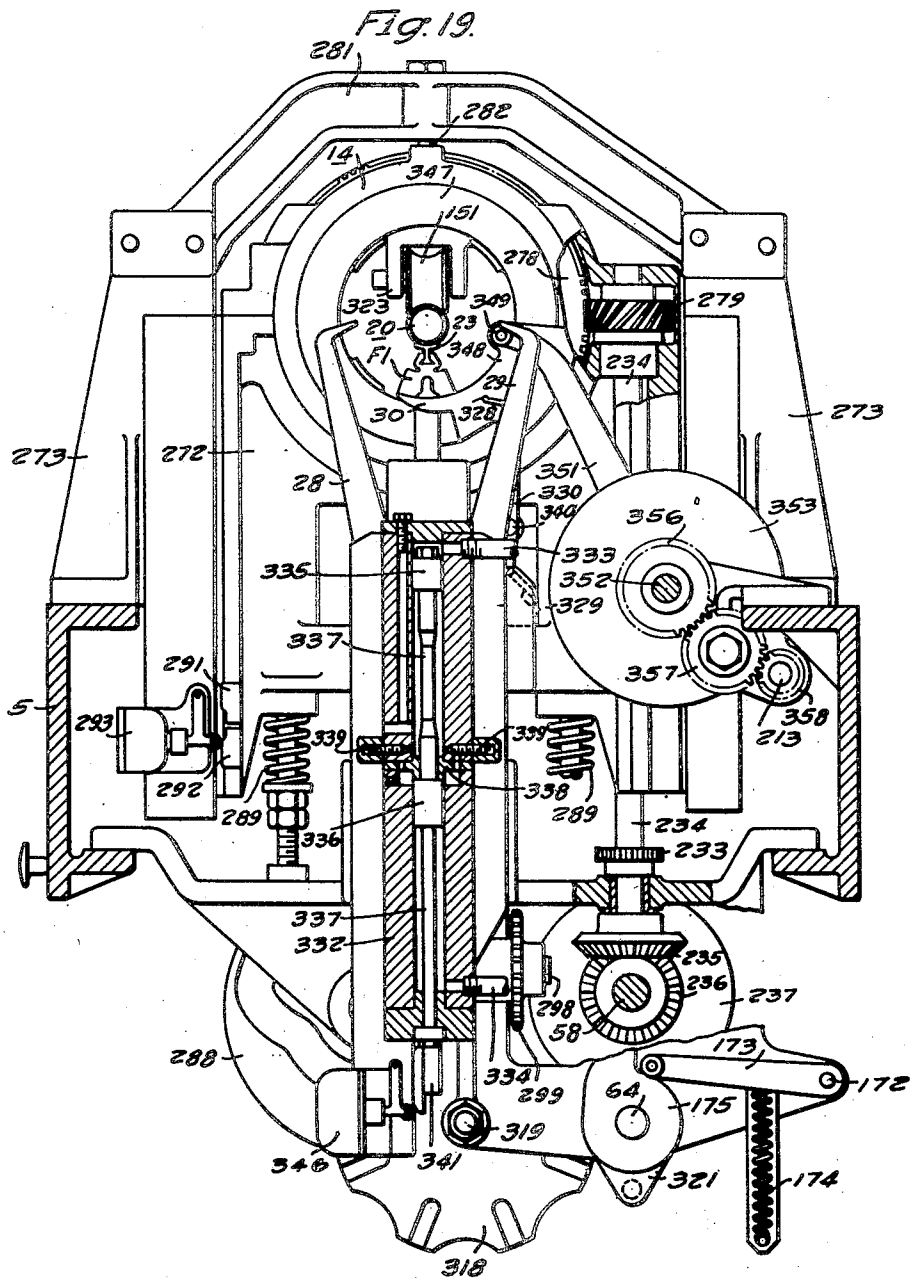
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COIL WINDING MACHINE

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27 Sheets-Sheet 12



WITNESSES:

*Leon M. Garman*  
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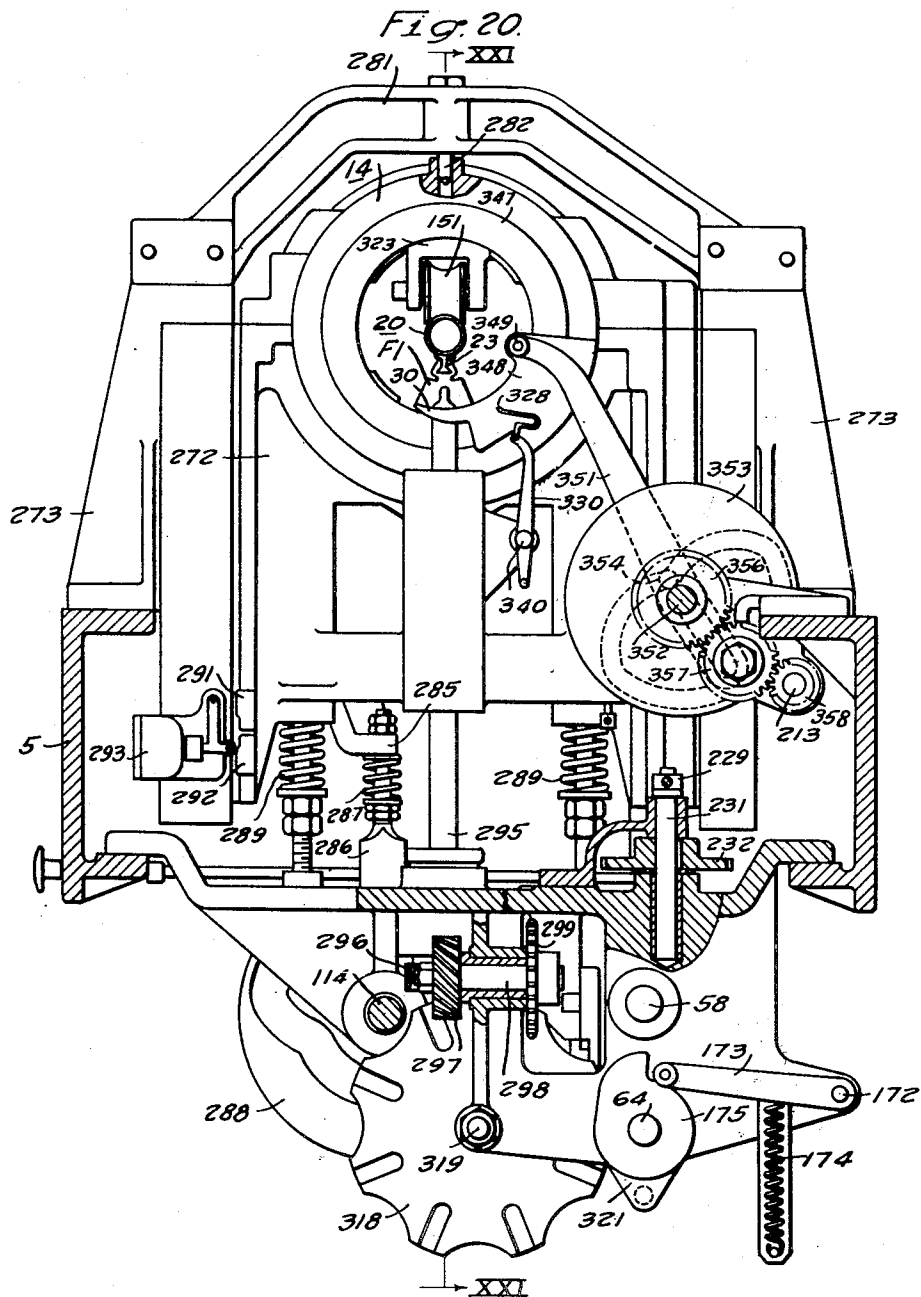
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COIL WINDING MACHINE

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Filed May 9, 1945

27 Sheets-Sheet 13



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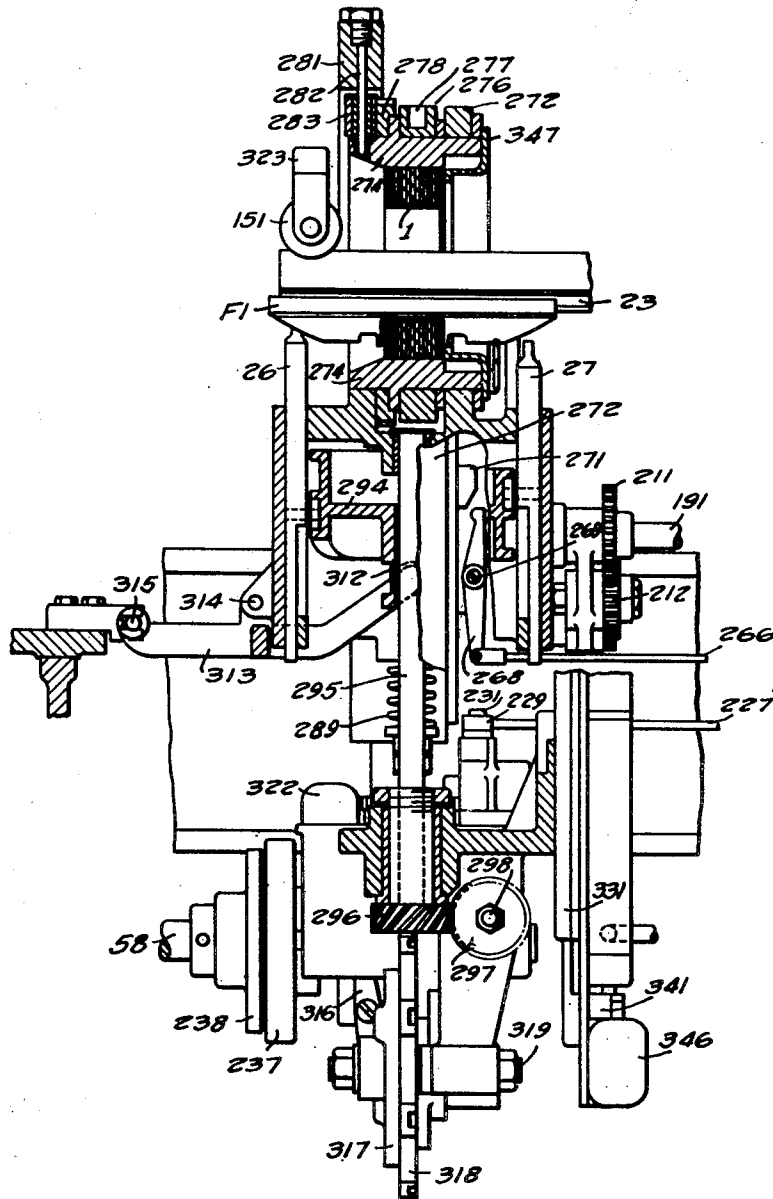
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2,445,937

Filed May 9, 1945

27 Sheets-Sheet 14

Fig. 21.



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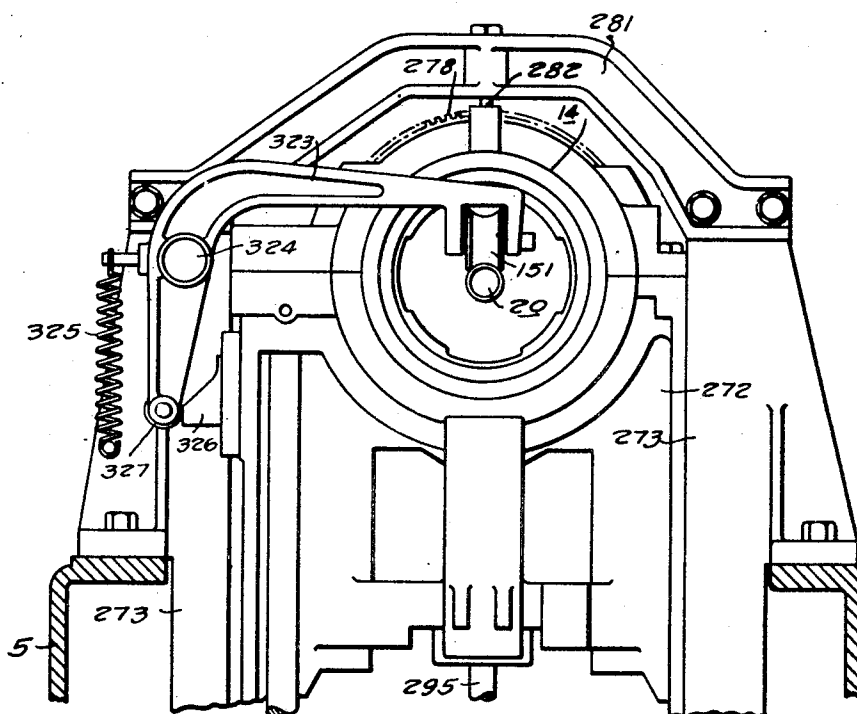
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COIL WINDING MACHINE

2,445,937

Filed May 9, 1945

27 Sheets-Sheet 15

Fig. 22.



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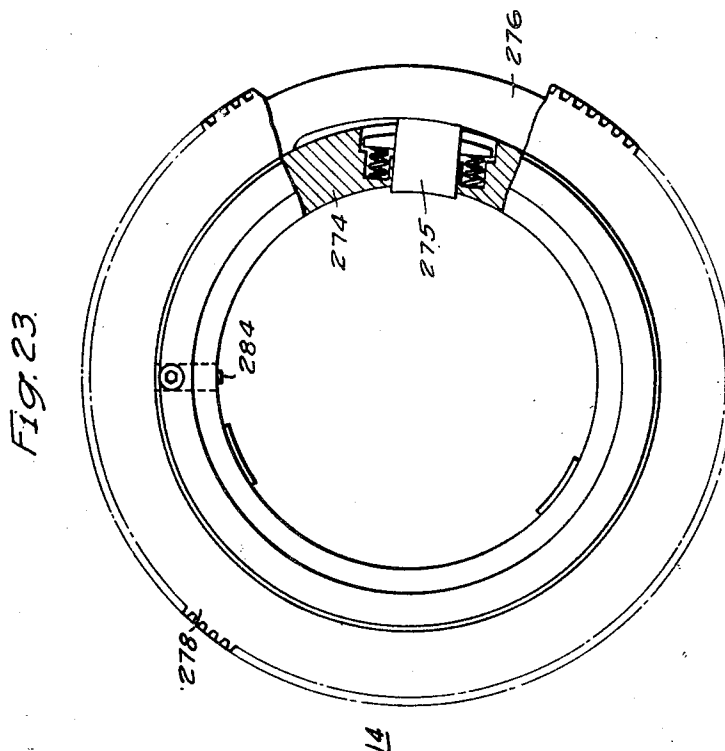
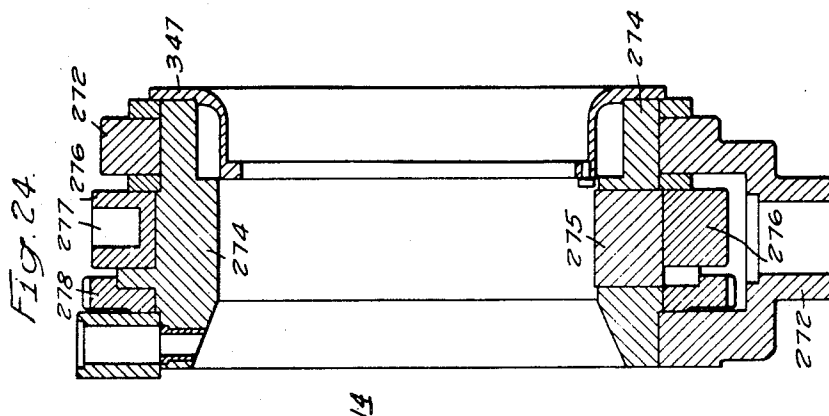
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D. E. CARPENTER  
COIL WINDING MACHINE

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27 Sheets-Sheet 16



WITNESSES:

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2,445,937

Filed May 9, 1945

27 Sheets-Sheet 17

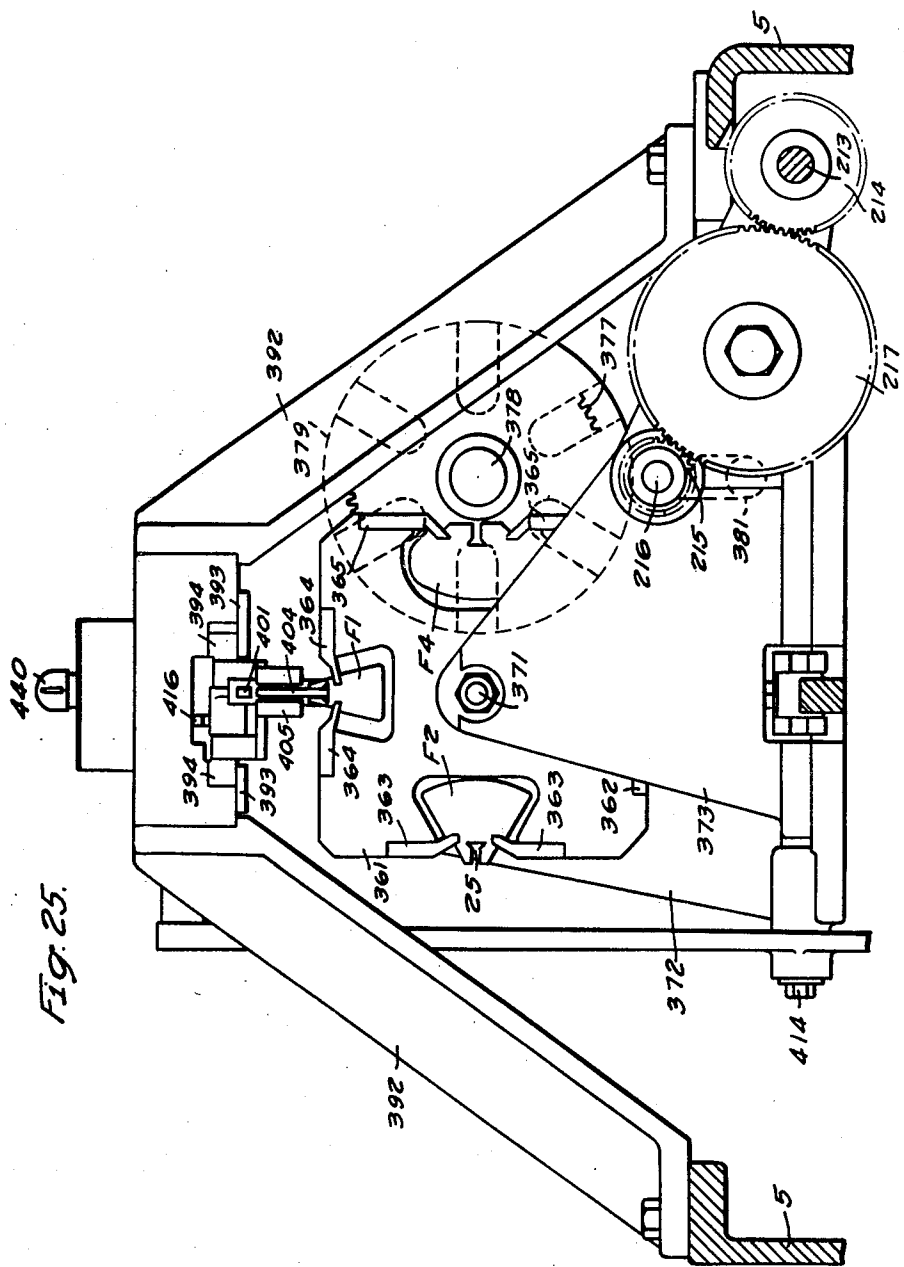


Fig. 25.

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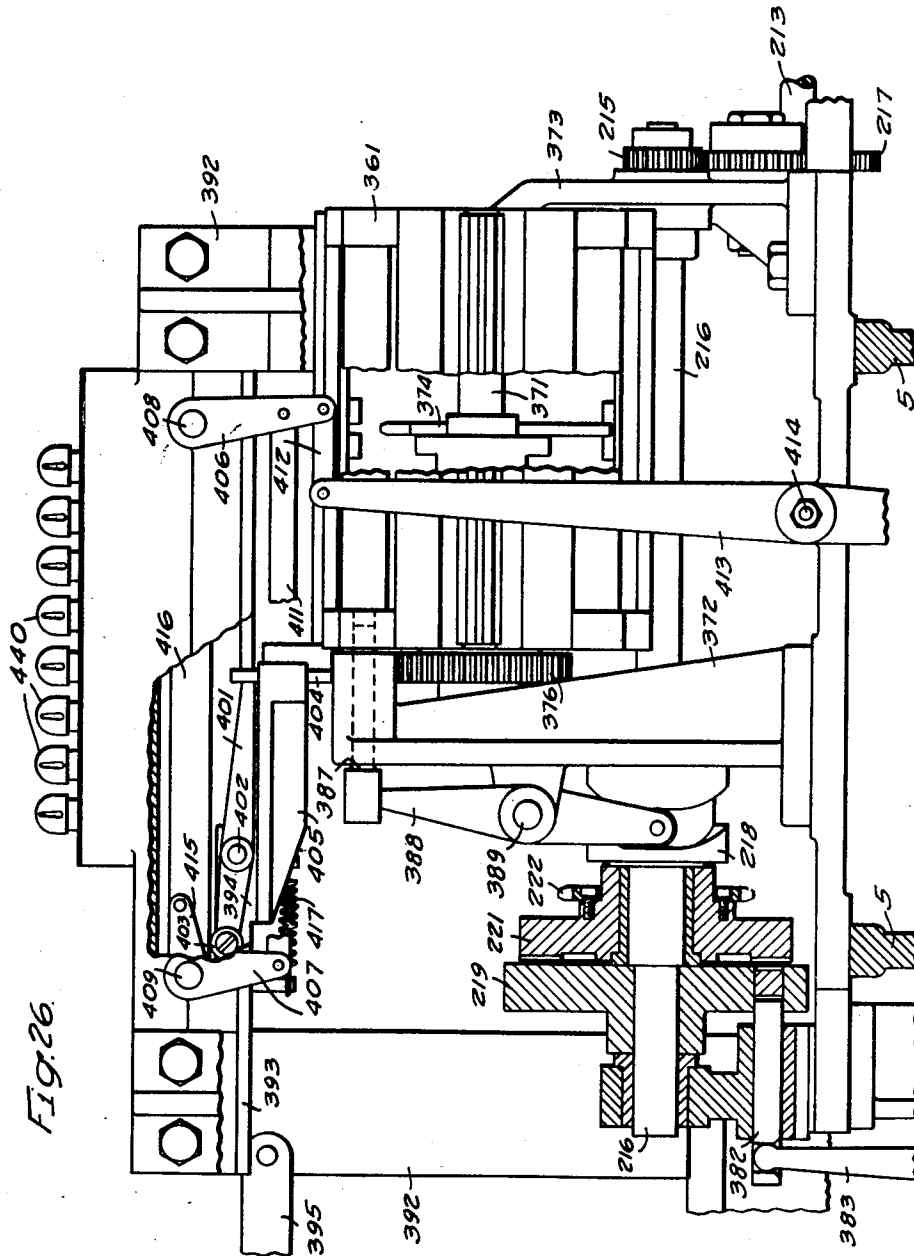
**July 27, 1948.**

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**COIL WINDING MACHINE**

**2,445,937**

Filed May 9, 1945

27 Sheets-Sheet 18



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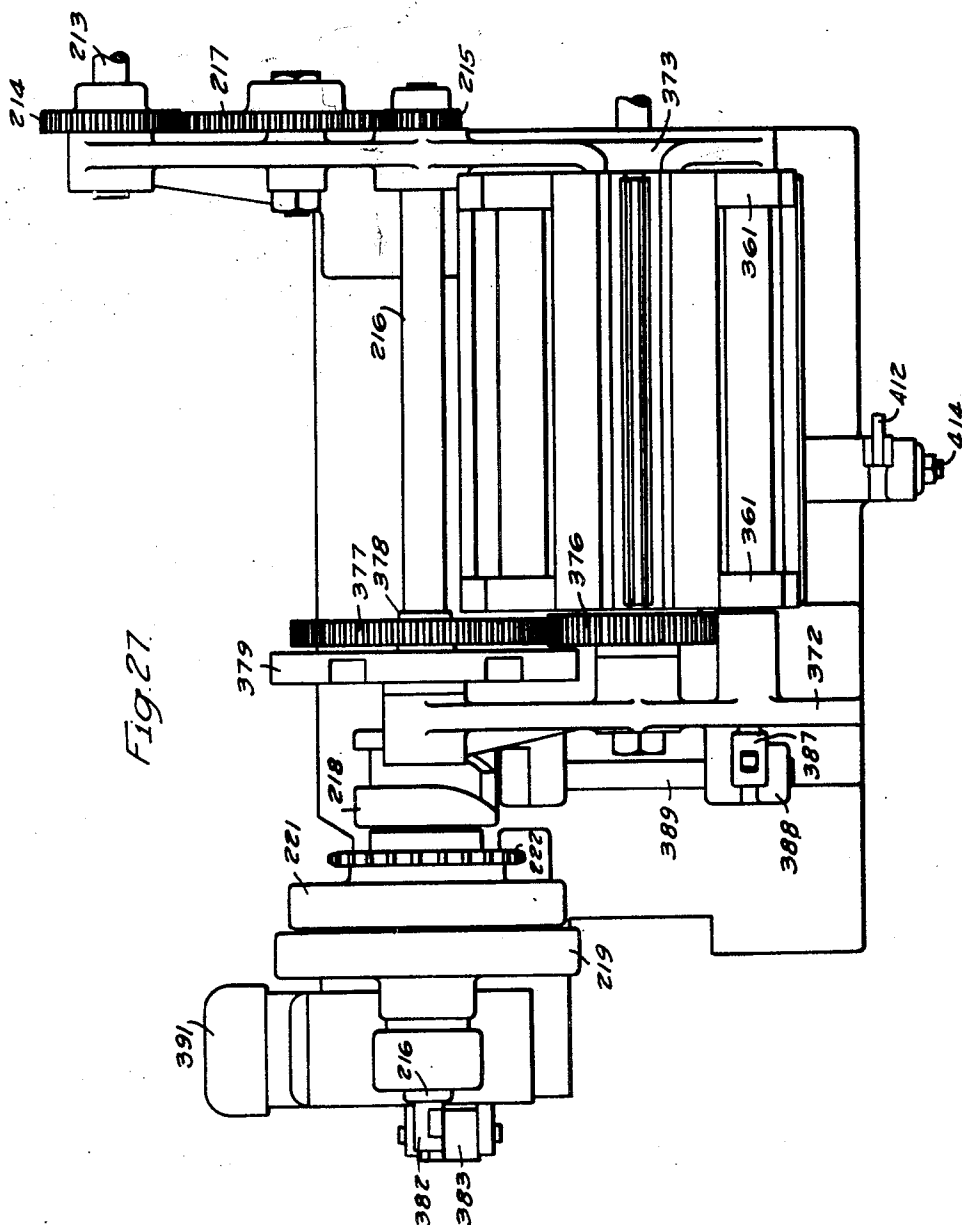
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COIL WINDING MACHINE

2,445,937

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27 Sheets-Sheet 19



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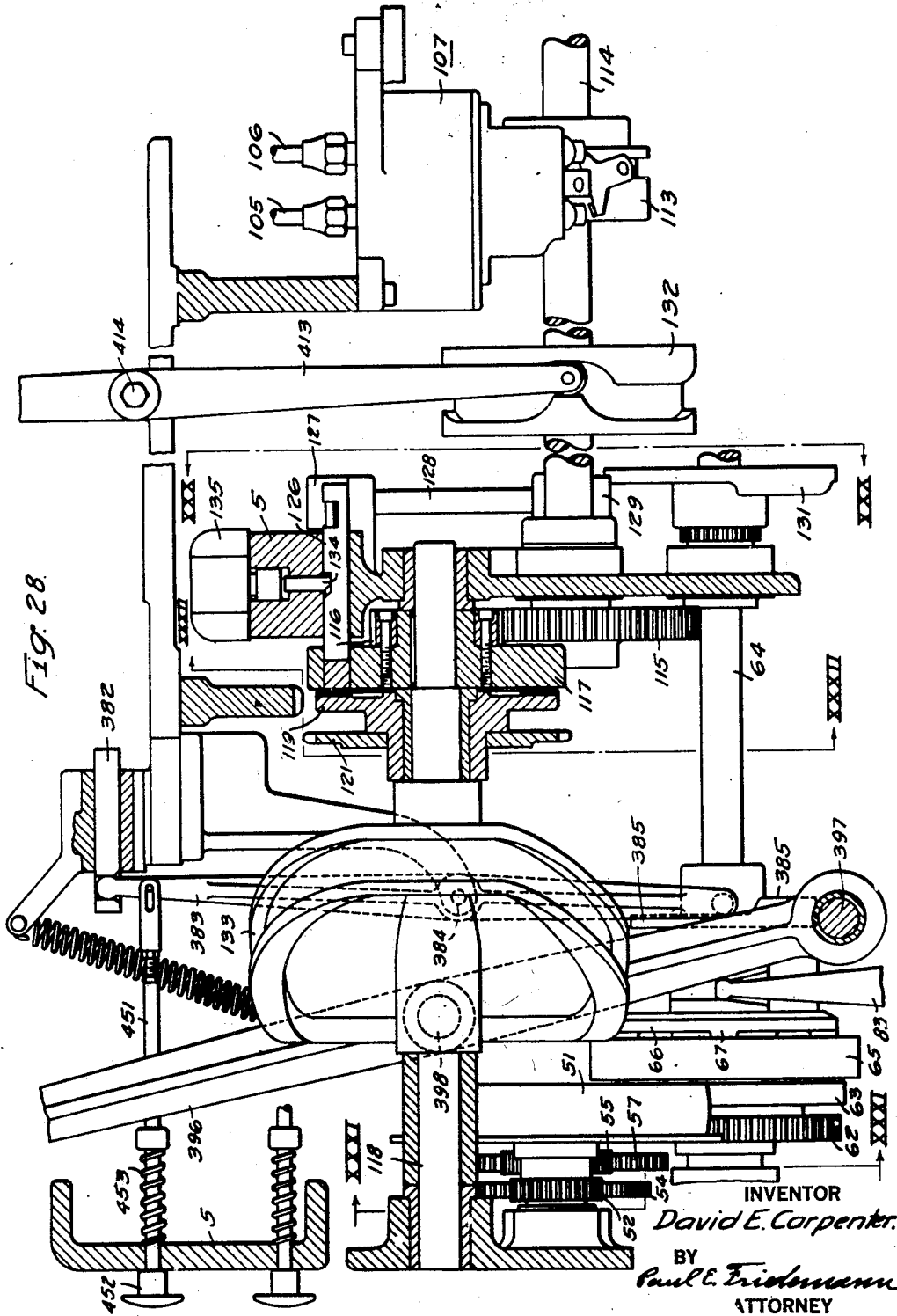
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2,445,937

COIL WINDING MACHINE

Filed May 9, 1945

27 Sheets-Sheet 20



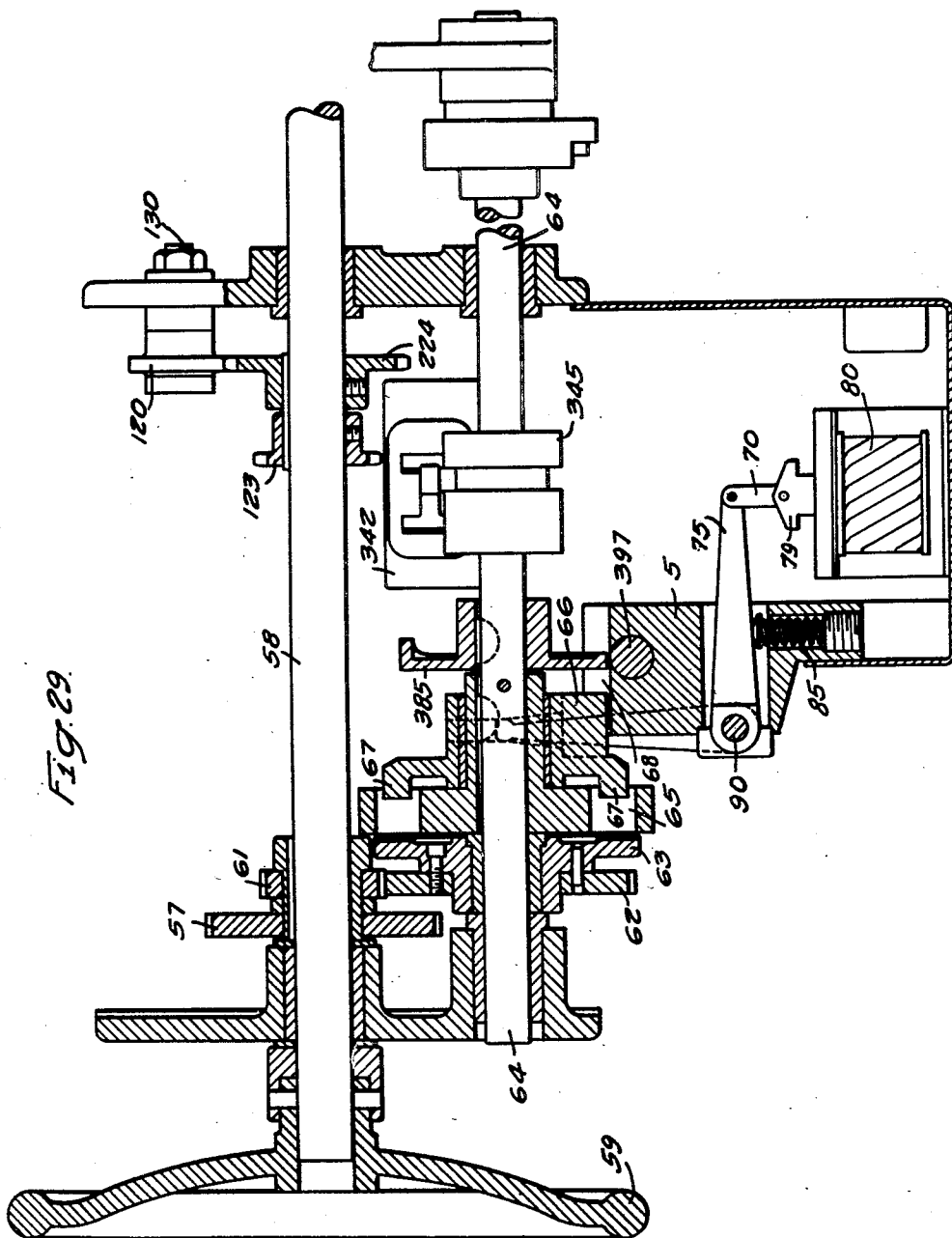
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COIL WINDING MACHINE

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Filed May 9, 1945

27 Sheets-Sheet 21



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2,445,937

Filed May 9, 1945

27 Sheets-Sheet 22

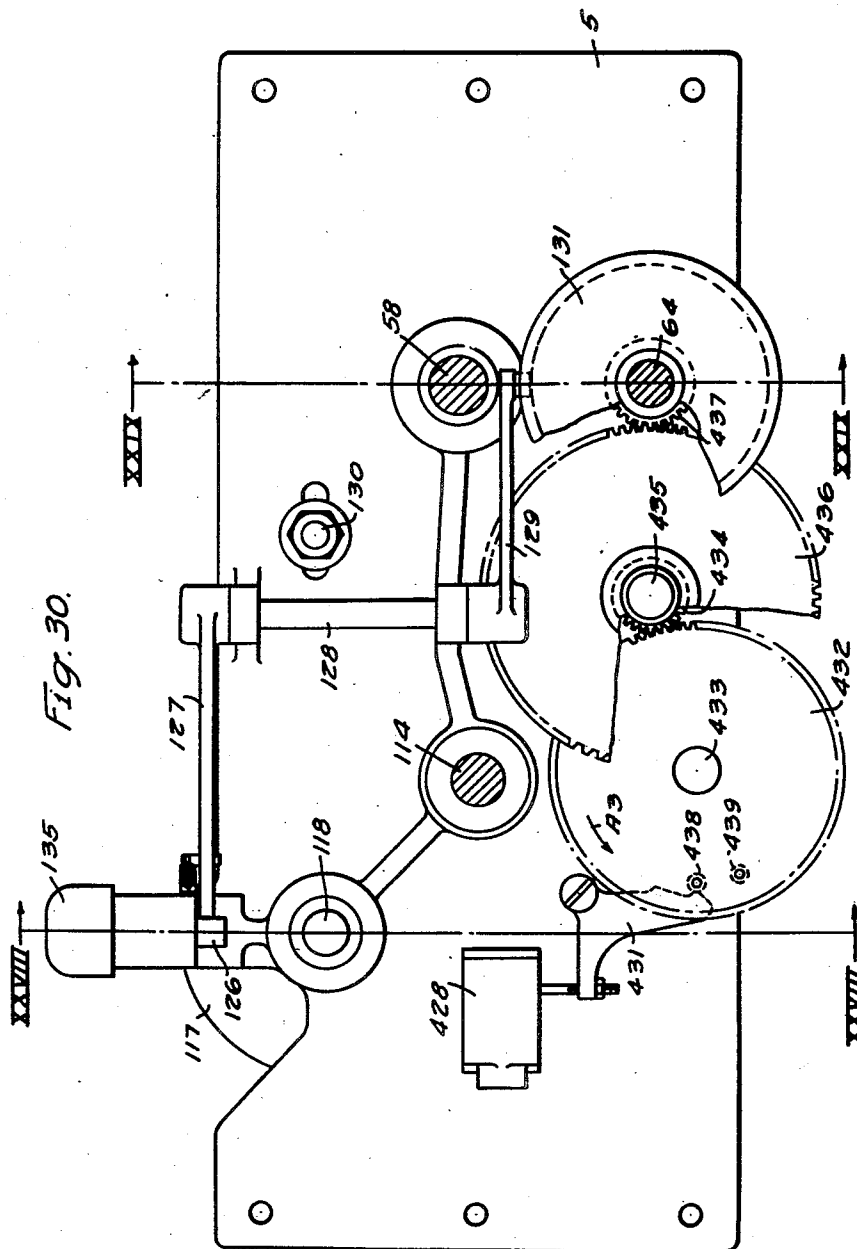


Fig. 30.

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COIL WINDING MACHINE

2,445,937

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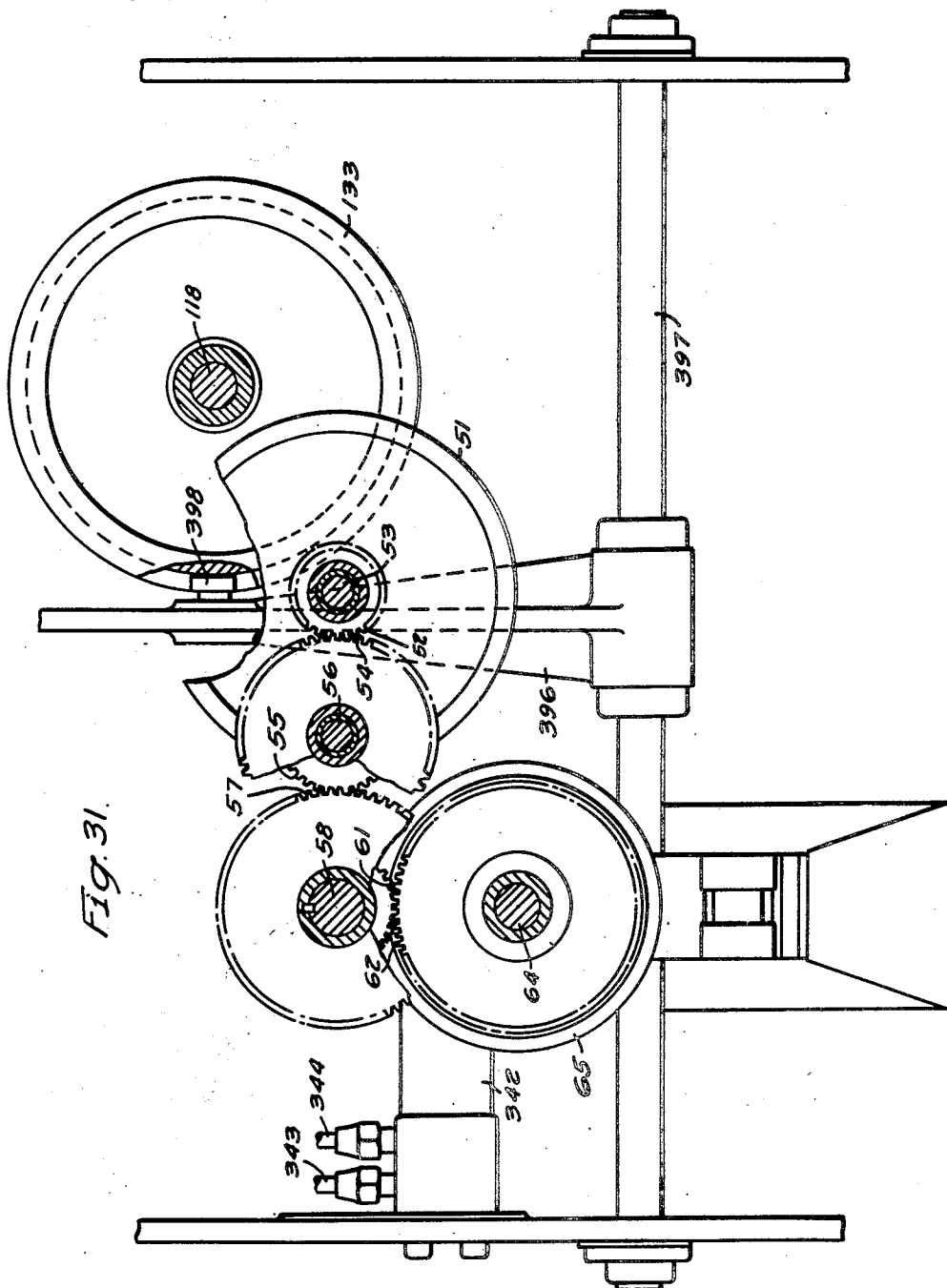


Fig. 31.

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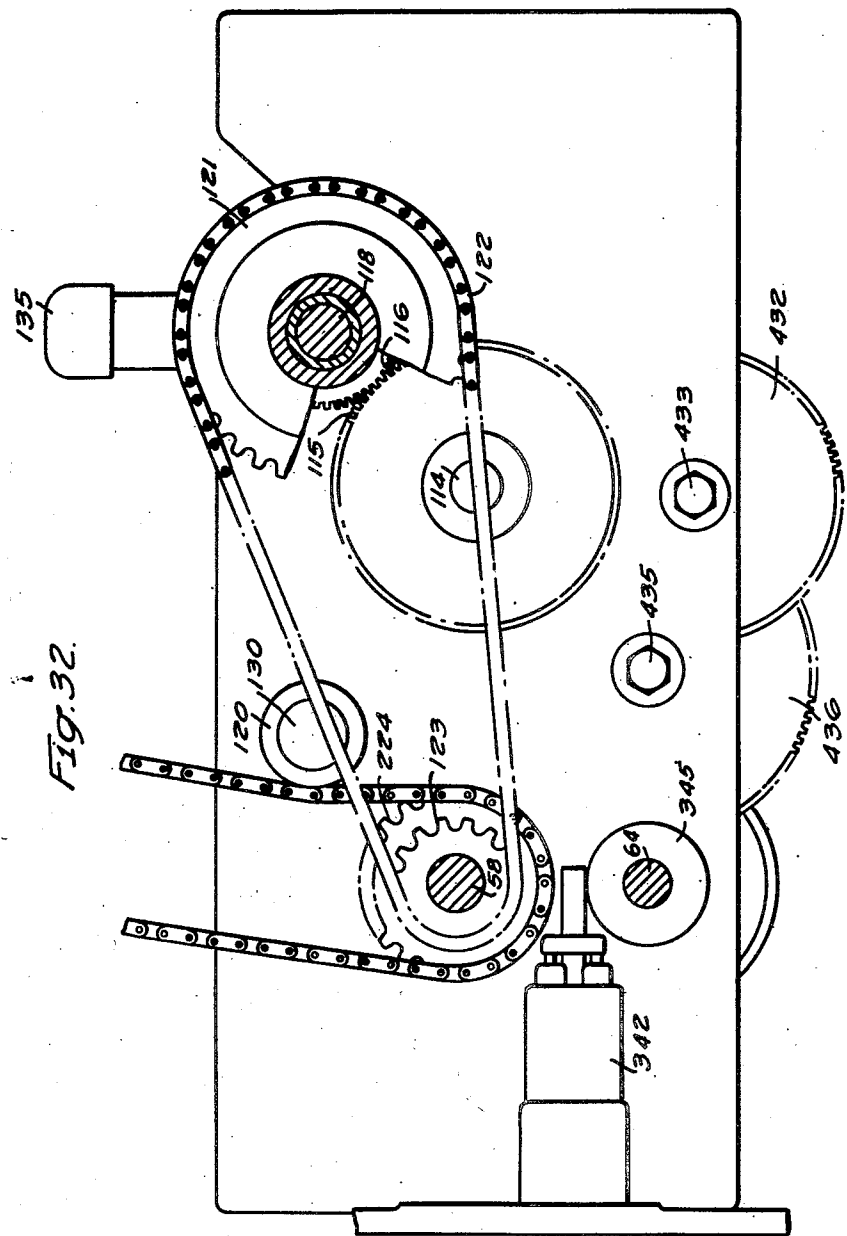
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COIL WINDING MACHINE

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27 Sheets-Sheet 24



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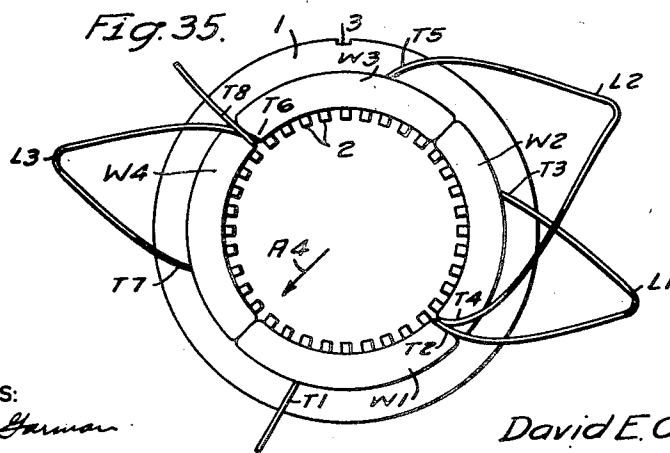
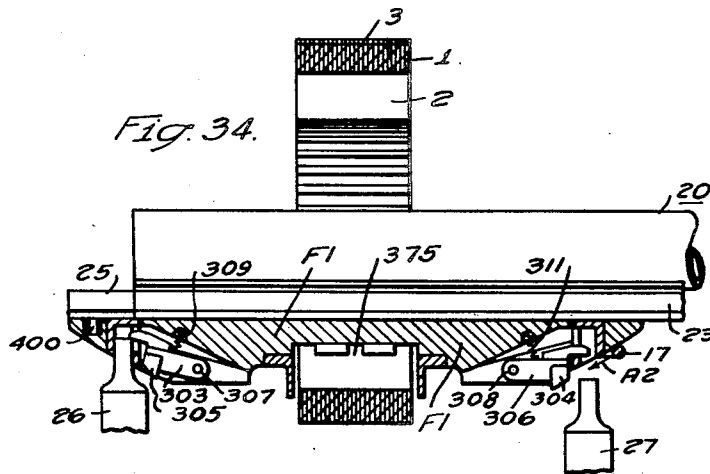
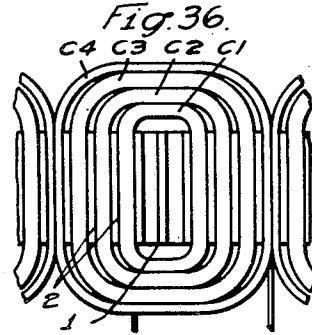
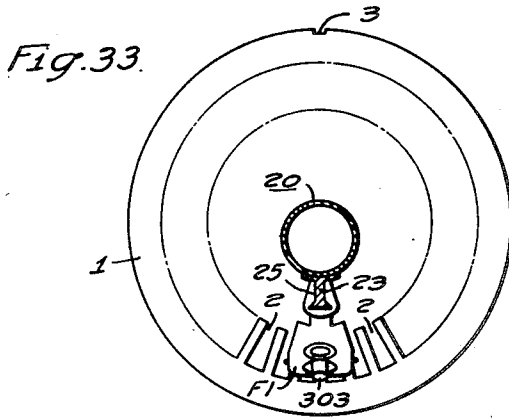
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27 Sheets-Sheet 25



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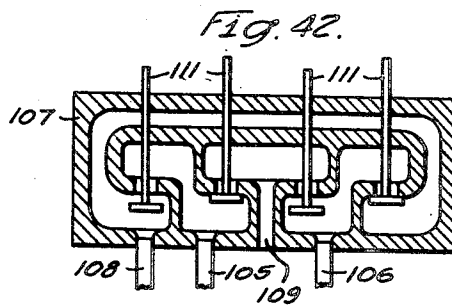
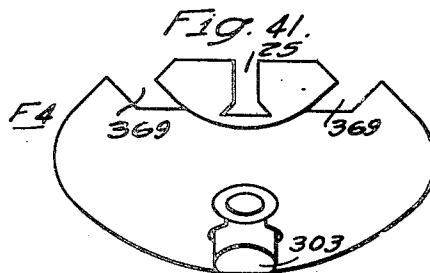
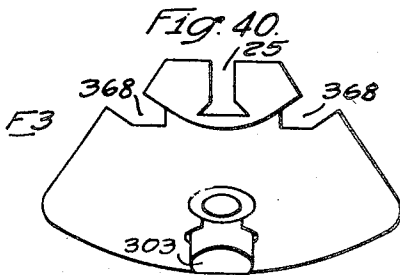
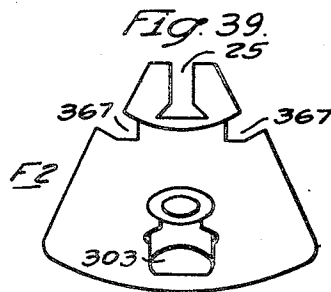
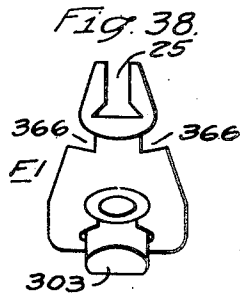
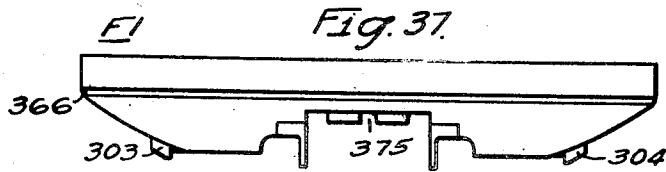
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27 Sheets-Sheet 26



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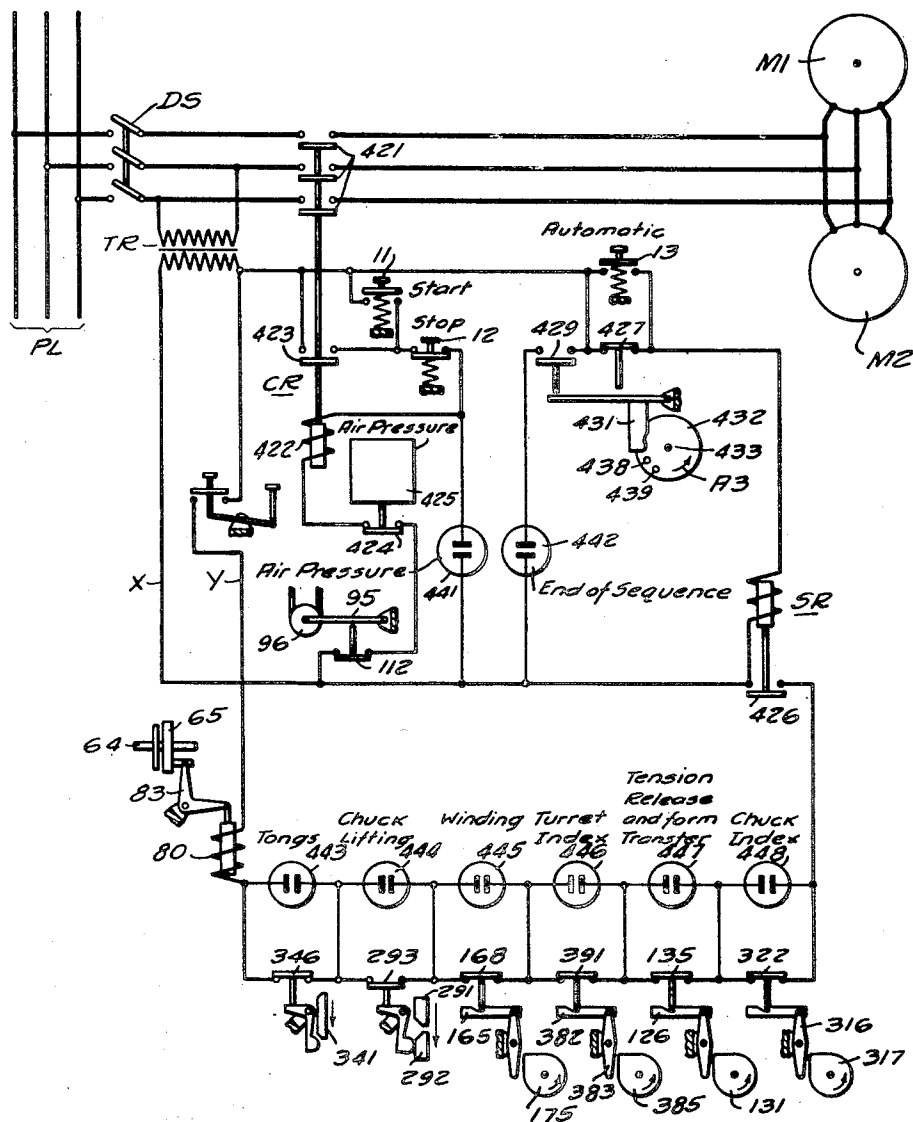
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COIL WINDING MACHINE

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27 Sheets-Sheet 27

Fig. 43.



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## UNITED STATES PATENT OFFICE

2,445,937

## COIL WINDING MACHINE

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to Westinghouse Electric Corporation, East  
Pittsburgh, Pa., a corporation of Pennsylvania

Application May 9, 1945, Serial No. 592,812

28 Claims. (Cl. 242—1)

1

My invention relates to machines for winding the coils of motors, generators and other electric apparatus.

It is an object of the invention to provide a machine capable of winding coils along the periphery of cylindric or annular bodies and in particular at the inner periphery of annular field or armature structures such as the field or energizing coils of stators.

Another object of the invention is to devise a coil winding machine which performs automatically and in the proper sequence the various operations required for forming electric machine windings that are composed of a plurality of coils, securing a desired number of turns for each of such coils, and placing each coil into the respective slots of a magnetizable structure.

It is also an object of my invention, in conjunction with the foregoing, to render the winding machine capable of producing a desired plurality of angularly displaced windings or coils and of performing automatically the indexing operation and reversal of winding direction required for providing an electric machine with a plurality of poles of alternately different polarity.

It is also an object of my invention to provide a machine of the type mentioned with devices for controlling and regulating the tension of the wire so that wire tension is kept at a desired value during the winding operation proper and is reduced whenever other steps are performed by the machine that are facilitated or improved by a release of tension.

A still further object of the invention is to devise a coil winding machine, which not only satisfies the aforesaid objects but is also distinguished by a performance of high accuracy and reliability, and which places so little stress on the wire and its insulation and on the coils produced that it permits the use of certain kinds of wire, for instance enamel-insulated wire, in cases where such wire is difficult or not economically applicable when using the winding methods and devices heretofore available.

These and other objects of the invention, as well as the means for achieving them in accordance with my invention, will be apparent from the following description of the embodiment exemplified by the drawings.

All figures of the drawings refer to the same machine for winding stators with the exception of Figs. 35 and 36, which are explanatory and show an example of a stator of the type to be wound on the machine.

Figure 1 is a front view of the complete ma-

2

chine as seen from the direction of the place occupied by the operator when servicing the machine; Fig. 2 is a longitudinal section through the machine, and Fig. 3 is a top view with some hoods removed in order to show the interior of the machine. For the purpose of clarity, a number of details have been omitted in Figs. 1 to 3, but these details are illustrated in full in the various figures mentioned hereinafter.

Fig. 4 is a front view of a wire supply stand which forms an accessory to the winding machine.

Figs. 5 and 6 represent the tension control device of the winding machine in sectional front and side views, respectively; and Fig. 7 is a section taken along the plane denoted in Fig. 6 by the line marked VII—VII.

Fig. 8 is a partly sectional longitudinal view of the shuttle bar section.

Fig. 9 illustrates the main clutch of the machine, and Fig. 10 is a cross section through the same clutch taken along the plane denoted in Fig. 9 by the line marked X—X.

Fig. 11 is a side elevation of the device for adjusting the angular throw of the shuttle bar; and Figs. 12, 13 and 14 represent the throw adjusting cam mechanism of the same device in three positions different from the one shown in Fig. 11.

Fig. 15 is a top view of the shuttle bar drive and turn counting mechanism; Fig. 16 shows the same drive and mechanism in a sectional view taken along the plane denoted in Fig. 15 by the line marked XVI—XVI; Fig. 17 is another cross section of the same drive and counting mechanism taken along the plane denoted by XVII—XVII in Fig. 16; and Fig. 18 represents still another section of the same drive and mechanism corresponding to the sectional plane denoted by XVIII—XVIII in Fig. 16.

Fig. 19 is a cross section through part of the winding machine extending mainly along the plane denoted in Fig. 2 by XIX—XIX and showing especially a tongs assembly of the machine;

Fig. 20 illustrates another transverse section through the winding machine and is partly similar to that of Fig. 19, the tongs assembly being removed in order to show details of the chuck section of the machine; Fig. 21 represents the same chuck assembly by a section taken in the plane denoted by XXI—XXI in Fig. 20; and Fig. 22 is a partial view of the same assembly from the rear of Fig. 20.

Figs. 23 and 24 represent the chuck proper by a lateral view and an axial cross section, respectively;

Fig. 25 is a side elevation of the form maga-

sine and transfer devices of the machine; Fig. 26 shows a part sectional front view, and Fig. 27 a rear view of the same device.

Fig. 28 is a longitudinal sectional view of the main driving and control section of the machine, corresponding to the left lower portion of the illustration in Fig. 2; Fig. 29 is another longitudinal sectional view of the main driving and control elements of the machine, the section being taken in a plane located behind the plane of section of Fig. 28.

Fig. 30 is a transversal sectional view taken along the plane denoted by XXX—XXX in Fig. 28. Fig. 31 is a transversal section along the plane denoted by XXXI—XXXI in Fig. 28; and Fig. 32 is a still further transversal cross section corresponding to the plane denoted in Fig. 28 by XXXII—XXXII.

Fig. 33 illustrates an axial view on a stator to be wound on the machine in correlation to the shuttle bar and one of the coil-shaping forms. Fig. 34 shows the same parts in a sectional front view; Fig. 35 is a schematic axial view of the finished stator, and Fig. 36 shows in developed form one of the four windings of the stator.

Fig. 37 is a front view of one of the coil-shaping forms while Figs. 38, 39, 40 and 41 represent side elevations of the four different forms appertaining to the machine.

Fig. 42 is an explanatory diagram representing a scheme of an air pressure control valve appertaining to the machine; and

Fig. 43 is a circuit diagram of the electric control and signalling system of the winding machine.

The construction and operation of the illustrated winding machine will be more readily understood if one first realizes what the machine is intended to do. Therefore, an example of a stator to be wound on the machine will first be described and a general outline of the required performance be given before turning to a detail description of the machine proper.

The design of a customary stator structure and its windings is apparent from Figs. 33 to 36. The stator core 1 consists of a pile of laminations which are fastened together to form an annular body with a series of slots, such as those denoted by 2, at its inner periphery. A slot 3 at the outer surface serves to identify and secure the proper position of the core when it is inserted into the winding machine or later placed into the housing of the motor or generator.

When completely wound, the stator here chosen as an example has four windings denoted in Fig. 35 by W1, W2, W3 and W4, respectively. Each of these windings is composed of four coils such as those shown in Fig. 36 at C1, C2, C3 and C4, respectively. Coil C1 has the smallest size and is placed into two inner slots. Coils C2, C3 and C4 have successively larger sizes and pass each through two slots of correspondingly wider spacing. The coils C4 of two adjacent windings extend through a common slot such as the one pointed at by the arrows A4 in Fig. 35. The number of turns of each coil is chosen in accordance with the requirements of each case. For instance, the numbers of turns may be 17—34—34—17 for the respective coils C1—C2—C3—C4 of each windings. The four coils of each winding are wound continuously in the same winding direction. Each coil as a whole has a winding direction opposite to that of the two adjacent coils in order to develop a magnet pole of north polarity when the adjacent windings induce south

poles or vice versa. Hence, when in Fig. 35 the terminal T1 of winding W1 represents the beginning of the winding and the winding turns extend clockwise to the end T2, the turns of winding W2 are wound counterclockwise between T3 and T4, while those of winding W3 extend clockwise between T5 and T6 and those of winding W4 counterclockwise between T7 and the terminal T8. The loops L1, L2 and L3 between adjacent windings are not always required to be as long as shown in the schematic showing of Fig. 35; but it is often desired to provide such loops in order to permit tapping or splitting the winding circuit. Then, of course, the taps or loops in the finished stator are placed flat against the windings in a more orderly manner than it appears from the diagram.

The machine according to the invention and described hereinafter is designed to perform automatically the operations necessary to provide a magnetizable core with a complete set of windings. Referring to the above-mentioned example of a four-pole stator, the machine is capable of winding the four coils of each winding into the proper slots of the stator structure and with the exact number of turns, reversing the winding direction when passing from one to the next winding, and forming loops or taps between the windings if and where desired.

The general layout of the machine is best apparent from Figs. 1, 2 and 3. The composite frame structure of the machine, generally denoted by 5, is provided with removable covers and hoods such as those denoted by 6, 7 and 8 (Figs. 1, 2), respectively, which cover substantially all parts that need not be accessible to the operator during the normal operation of the machine. Two electric motors M1 (Figs. 1, 43) and M2 (Figs. 2, 43) provide driving power and are controlled by a control system (to be described in a later place with reference to Fig. 43) whose operator-actuable control manuals are located on a panel 9 (Fig. 1) at the operator's side or front of the machine. The panel has a main "on and off" switch 10 for placing the machine in operative condition, a "start" push button 11, a "stop" button 12, and an "automatic" button 13 for controlling machine. A chuck assembly, denoted as a whole by 14 (Figs. 1, 2, 3), has a freely accessible chuck (later described in conjunction with Figs. 23 and 24) into which the core to be wound is inserted so that its geometrical axis is in parallel to the horizontal axis of the machine as shown in Figs. 1, 2 and 3.

The wire to be wound into the slots of the stator structure is taken from a supply reel 15 (Figs. 1, 4) which is mounted on a supply stand 16. Thence the wire 17 enters into the winding machine proper and passes first through a tension control device, denoted as a whole by 18 (Figs. 1, 2), which maintains the wire tension at a desired value during the winding operation, releases the tension automatically during certain other phases of operation, and serves also to stop the machine upon occurrence of a wire break. The wire 17 passes further over a guide roller 19 (Fig. 2) through the interior of a shuttle bar 20 which it leaves through an eye 21 located near the chuck assembly 14 and the stator accommodated therein (Figs. 1, 2).

During the winding operation the shuttle bar reciprocates longitudinally so that the eye 21, shown in Figs. 1 and 2 at the right of the chuck assembly 14, moves through the opening of the annular core to the left-hand side thereof. Near

5

the end of the stroke, the eye 21 turns angularly about the axis of the shuttle bar 20. Thereafter, with eye 21 in the new angular position the bar performs its horizontal return stroke, until the eye 21 is again at the right of the chuck assembly and stator. Then the eye turns angularly back to the original position. In this manner, the eye 21 completes one winding turn during each full cycle of shuttle bar motion. Hence, when the end of wire 17 is held fixed, one turn of wire is placed onto the stator by each such cycle of motion.

In order to insure that during this winding operation the wire slides into the proper slots of the stator core and to impart to each coil the desired shape and compactness, a guiding device or form is placed into the stator so that it rests upon the radial stator teeth within the area bordered by the slots into which the wire turns are to be placed. Since, as mentioned, the coils have four different widths, four such forms are needed for winding a stator of the type above chosen as an example. These forms are denoted by F1, F2, F3 and F4 in Figs. 37 to 41. When the first coil C1 of each winding is being wound, form F1 is placed on the stator in the position apparent from Figs. 1, 2, 21 and 34 and secures a proper guidance of the wire issuing from eye 21 and sliding into the stator slots for coil C1 (see Fig. 36). The number of turns wound by the shuttle mechanism is counted by a counting device which stops the shuttle bar when the correct number of turns for coil C1 are completed. Before the winding operation for coil C2 is started, form F1 is withdrawn from the stator and replaced by the next larger form F2 (Fig. 39). Similarly, after completion of coil C2, form F2 has to be replaced by form F3 (Fig. 40). After completion of coil C3, form F3 is replaced by form F4 (Fig. 41), and thereafter, upon indexing of the chuck and stator the cycle of insertion and withdrawal of forms is repeated again beginning with form F1 for placing the next winding on the stator.

These form exchange operations are performed by form magazine and transfer devices which, referring to Figs. 1 and 2, are located in the left-hand portion of the machine underneath and below the hood 7. When not inserted into the stator, the forms are held in a revolvable cage-shaped turret of the magazine (Figs. 25, 26) which is automatically indexed so as to place the required form in alignment with the shuttle bar. At the proper time, the transfer device acts to slide the form out of the turret cage into the stator core or back from the stator into the cage.

In order to secure during the winding operation the proper positioning of the then active form relative to the shuttle bar 20, the bar extends toward the left (Figs. 1, 2, 8, 19, 20, 33, 34) beyond the eye 21 and carries two dovetail rails 23 and 24 slidably engageable with a matching longitudinal slot 25 (Figs. 33, 34, 38 to 41) of the forms. For securing the active form in proper position relative to the stator core in which it is seated, the chuck assembly is provided with tappets 26 and 27 (Figs. 1, 2, 21, 34) which are engageable with respective openings of the form and, during the winding operation, move up and down in such a phase relation to each other that at any time at least one of the tappets engage the corresponding openings. Before exchanging a form, both tappets must be disengaged therefrom and the form must be unseated from the stator. This is effected by a downward movement of the chuck assembly including the tappets. After the in-

6

sertion of the next form, the assembly moves up and this causes the stator core and the tappets to engage the next form.

During the intervals of form exchange and chuck motion, the wire portion between the then stationary eye 21 and the wound portion of the stator winding is prevented from uncontrolled movements by a pair of tongs 28, 29 (Figs. 3, 19) which pull the wire portion downwardly. The tongs and part of the appertaining control mechanism (Figs. 3, 19) are located close to the chuck assembly 14 between the assembly and the machine portion covered by hood 8 (Figs. 1, 2).

A device for operating an angularly movable finger 30 (Figs. 19, 20), serving to provide the above-mentioned loops or taps L1, L2, L3 (Fig. 35), is associated with the chuck assembly.

For the purpose of a more detailed description, it appears convenient to distinguish between the following machine sections although it will be understood that these sections, with the exception of the supply stand, are interlinked, interlocked and dependent on one another:

1. Supply stand
2. Main drive and control section
3. Tension control section
4. Shuttle bar section
5. Turn counting device
6. Chuck section
7. Tongs section
8. Tap-forming device
9. Form magazine section
10. Electric control system

These sections will now be described in the order mentioned, and thereafter a description of the machine performance as a whole will be given.

#### 1. Supply stand

The supply stand 16 shown in Figs. 1 and 4 is known as such and is represented as one of the many available types of unreeling devices. Its purpose is to permit withdrawal of wire from the reel 15 without imposing appreciable tension on the wire while preventing a free over-running of the reel. The reel 15 is revolvably placed on a shaft 33 and associated with a friction brake whose brake shoe 34 is carried by a lever 35 fulcrumed at 36. The upper end of lever 35 is engaged by a tension spring 37 whose other end is attached to a yoke 38 pivoted at 39 and linked by a rod 40 to a lever 41 which is fulcrumed at 42. Lever 41 carries a pulley 43 and is biased by a spring 44 which tends to move the pulley upwardly. The wire 17 extends from reel 15 over pulley 43 to a stationarily journaled pulley 45 when it passes into the tension control section 18 (Figs. 1 and 2) of the winding machine proper.

When the wire loop around pulley 43 is too slack or without a wire passing over the pulley, the pulley is in fully raised position and the rod 40 holds the yoke 38 in its lowermost position. Yoke 38 then pulls spring 37 and brake lever 35 toward the left and thus forces the brake shoe 34 to stop the reel. When the wire 17 is under some tension, the pulley 43 is moved downwardly and causes the rod 40 to lift the yoke 38 so that it turns clockwise about its pivot and releases the brake spring. Hence, the brake shoe is now released and permits the wire to be pulled off the reel 15. Any excessive slackening of the wire loop will cause the pulley 43 to be lifted and so that the braking effect is increased.

It should be understood that this supply or unwinding stand is merely an accessory to the wind-

ing machine, may be readily replaced by other devices of similar function, and is described for the sake of completeness rather than as an essential feature of the invention proper.

## 2. Main drive and control section

As mentioned previously, the wire withdrawn from the supply stand passes first through the tension control section and through the shuttle bar section of the machine before it is wound onto the stator core accommodated by the chuck assembly and equipped with one of several forms issued by the turret and form transfer section. However, before dealing with any of these machine sections in detail, it appears appropriate to first describe in detail some of the driving and control elements which form part of the means for actuating these sections in the proper sequence.

The two electric motors M1 (Figs. 1, 43) and M2 (Figs. 2, 43) provide the power for driving all machine sections with the exception of the tension control section and the tong mechanism which are actuated by air pressure and require a connection to an available pressure line or pump. Motor M2 provides the driving effort for the reciprocatory motion of the shuttle bar, and for operating the turn counting device and the locking tappets of the chuck assembly. Motor M1 drives all other sections, except the two pneumatically actuated devices, and is also the main source of motion for the various adjustments that control the operation and operating sequence of most machine sections including the pneumatic devices.

Both motors run continuously at substantially constant speed as long as the main switch is closed and the machine in operative condition.

Motor M1 (Fig. 1) is belted to a pulley 51 (Figs. 28, 31). A gear 52, keyed to the shaft 53 of pulley 51, meshes with a gear 54 which is joined with a gear 55 on a common shaft 56. Gear 55 engages a gear 57 (Figs. 31, 29) on a shaft 58. This shaft, hereinafter called the "main drive shaft" of the machine, extends outwardly of the machine and carries at its exterior end a hand wheel 59 (Figs. 1, 2, 3, 29) which permits turning the shaft for inching and adjusting the machine manually. As long as motor M1 is running, the main shaft 58 is kept in continuous revolution by the above-described gear train between the pulley 51 and the main drive shaft.

Joined with gear 57 of the main drive shaft 58 is a pinion 61 (Figs. 29, 31) which is in continuous driving engagement with a gear 62 that is attached to a driving clutch member 63 floating on a shaft 64 which hereinafter is referred to as the "main control shaft." Adjacent to the clutch member 63 and keyed to the main control shaft 64 is a driven clutch member 65 (Figs. 29, 2) which has an axially displaceable clutch control member 66 (Fig. 29) with four noses 67 of equal angular spacing. These noses, in the position of control member 66 shown in Fig. 29 engage four corresponding openings of the driven clutch member 65. This engagement prevents the driven member 65 from rotating relative to control member 66 and since the latter engages a slot 68 of a part of the stationary frame structure 5, the members 65 and 66 and hence the main control shaft 64 do not revolve and are locked in a given position relative to the machine frame. At the same time, i. e. in the illustrated position of clutch control member 66 (Fig. 29), the

driven clutch member 65 is disengaged from the continuously rotating clutch member 63.

When clutch control member 66 is displaced to the right (Fig. 29), its noses 67 move out of the openings of the driven clutch member 65 until the latter is unlocked and free to be driven by the continuously rotating member 63. The axial displacement of control member 66 has also the effect of clutching the members 65 and 63 together immediately after clutch member 65 has been unlocked so that then the driven clutch member 65 and the main control shaft 64 are driven until the clutch is again disengaged and the driven clutch member stopped and locked. As will be understood from the following, each such temporary motion of the main control shaft 64 covers one-quarter of one revolution.

The clutch control and locking operation of the just-mentioned clutch, hereafter called the "main clutch," will be more fully understood from the showing in Figs. 9 and 10. As shown, the driven clutch member 65 has an angular lever 69 or "chicken" pivoted at 71 and biased by a spring 72. This spring tends to move the clutching end 73 of the "chicken" into engagement with one of a number of slots 74 of the driving clutch member 63 and is free to do so when the noses 67 of the clutch control member 66 are moved away from the driven member 65.

When the main clutch is in driving condition, as represented in Fig. 10, both clutch members rotate in the direction of the arrow A1. Assuming that now the control member is moved toward the driven clutch member 65, one of the noses 67 of the control member 66 may have the instantaneous position shown in Fig. 10. Shortly thereafter, the nose 67 will hit against the control end 76 of the "chicken" 69 and turn the "chicken" clockwise about pivot 71 against spring 72. As a result, the clutching end 73 of the "chicken" is withdrawn from the slot 74 of the driving clutch member 63. Immediately thereafter, the nose 67 enters into the opening of the driven clutch member 65 and arrests it in a fixed position relative to the machine frame structure.

If desired, the clutch may be provided with shock absorbing means, and such a modification is also illustrated in Figs. 9 and 10. The "chicken" 69 is carried by a body 77 which is angularly displaceable in the body of clutch member 65 and biased by two oppositely acting shock absorber springs of which one is denoted by 78 in Fig. 9.

The clutch control member 66 (Fig. 29) is actuated under control by an electromagnet or solenoid 80 whose armature or core 79 is connected to member 66 by a link 70 and an angular lever 75 fulcrumed at 90 (Figs. 29, 1) and biased by a spring 85 (Fig. 29). Whenever the machine operation reaches a stage where a change in adjustment of the main control shaft 64 is necessary, the solenoid 80 receives an electric impulse which causes it to move the clutch control member 66 (Fig. 29) toward the right. As will be explained, the electric impulse ceases before the driven clutch member has completed one-quarter revolution. Hence, the control end 76 of the "chicken" 69 (Fig. 10) will hit against the next nose 67 of the control member 66 (Fig. 10, 29). Since four such noses are equally spaced around the control member, the driven clutch member 65 and the control shaft perform exactly one-quarter revolution for each electric control impulse effective in the solenoid 80 and thereafter are stopped until the next control impulse is issued to the solenoid.

As mentioned, the main drive shaft and the main control shaft 58 are functionally interlinked with the various working sections of the machine. It will, therefore, greatly facilitate understanding the following detail description of the working sections if it is kept in mind that the main drive shaft 58 revolves continuously during the entire period in which the machine is an operative condition even when all working devices are at rest, while the main control shaft 64 revolves in steps of one-quarter revolution each initiated by a temporary energization of the solenoid.

### 3. Tension control section

Reverting to the wire 17 as it is withdrawn from the supply stand (Figs. 1, 2) and enters into the winding machine proper, it will be seen that the wire passes first over a sheave 81 and surrounds it in several turns (Figs. 5, 6, 7). A resiliently supported guide 82 (Fig. 6) holds the wire turns within a single layer in order to secure the desired constancy of tension control. Integral with sheave 81 is a brake drum 83 which cooperates with a manually adjusted fixed-drag brake and an automatic brake. The brake shoes 84 and 85 of the fixed-drag brake (Figs. 5, 6, 7) are adjusted in accordance with the minimum tension to be maintained when the automatic brake is fully released. The brake shoe 87 of the automatic brake is mounted on a holder 88 which is pivoted at 89 and carries an adjustable arm 91. A roller 92 journaled on arm 91 engages a cam 93 on shaft 94 (Figs. 7, 6). Shaft 94 has an arm 95 provided with a pulley 96. Arm 95 and cam 93 are both firmly secured to the shaft 94 so that when arm 95 (Figs. 5, 7) is lifted, the cam 93 permits the roller 92 and holder 91 to move clockwise about the pivot 89, thereby releasing the automatic brake.

The wire 17 passes from sheave 81 over the pulley 96 (Fig. 2) before it enters the shuttle bar. Therefore, the wire tension tends to lift pulley 96 and arm 95 and to release the automatic brake. However, the position of the arm 95 is also dependent upon the position of a piston 98 which is movable within an air pressure cylinder 99 and provided with a rack 101 in meshing engagement with a spur gear 102 on shaft 94 (Figs. 5, 6). The cylinder 99 has two ducts 103 and 104 in communication with the respective cylinder chambers on both sides of the piston, and these ducts are connected by pipes (not shown) with the respective ducts 105 and 106 of a control valve 107 (Figs. 2, 28). According to the schematic showing of Fig. 42, the valve 107 has a pressure supply duct 108 for connection to a pressure line or pump, and an exhaust duct 109 which opens into the ambient air. Depending upon the position of the valve stem 111, the pressure duct 108 is connected to one of ducts 105 and 106 while the exhaust duct 109 is simultaneously in communication with the other duct. Reverting to Figs. 5 and 6, it will be understood that when the valve is so controlled as to impose air pressure on duct 103 of cylinder 99, the other cylinder side is connected with the exhaust duct of the valve so that the piston 98 is forced to move toward the right (Fig. 5), thereby turning the gear 102 and shaft 94 clockwise. Hence the pulley arm 95 is then lifted and the cam 93 (Fig. 7) caused to release the automatic brake. In this manner, the application of air pressure to duct 103 (Fig. 5) releases the wire tension. When the control valve is adjusted to supply air pressure to duct 104 (Fig. 5), the piston 98 moves toward

the left with the tendency to lower the pulley arm 95. Due to the lifting tendency of the wire pull, however, the arm 95 will not drop to the lowermost position shown in Fig. 5 but will oscillate about an approximately half-way lifted position in which the cam 93 (Fig. 7) is effective to regulate the wire tension. Only in case of a wire break will arm 95 drop completely. It then actuates a push button switch 112 (Figs. 5, 43) which stops the machine.

The connection of valve 107 to the air line or pump is preferably provided with a pressure reducing or regulating valve (not shown) in order to adjust the air pressure and thereby the wire tension to a desired value. In order to control the valve 107 (Figs. 2, 28) so that it causes a regulation of wire tension during the winding operations and releases the tension during certain other operations, the control of the valve is interlinked with the operation of a number of other machine sections. A cam 113 on a shaft 114 (Figs. 28, 2) serves to adjust the valve to one or the other position depending upon the angular position of the cam. Cam shaft 114 carries a spur gear 115 which engages a driving pinion 116. Pinion 116 is firmly joined with a clutch member 117 keyed to a shaft 118. This shaft carries a floating clutch member 119 joined with a sprocket 121 (Figs. 28, 32) that is driven by a chain 122 from a sprocket 123 (Figs. 32, 29) keyed to the main drive shaft 58. The chain 122 is engaged by an idler 120 on a stub shaft 130. It will be remembered that, during the periods of operation, the main drive shaft revolves continuously. Hence, sprocket 121 and clutch member 119 (Fig. 28) are in continuous rotation, but this rotation is not transmitted to gears 116, 115, shaft 114 and valve-control cam 113 as long as clutch members 117 and 119 are disengaged.

In the position shown in Fig. 28, clutch member 119 is locked to the stationary frame structure 5 by means of a slider 126. When this slider is withdrawn toward the right from clutch member 117, it not only releases this member for rotation but also permits a spring biased part or "chicken" movably mounted in member 117 to enter into engagement with one of a number of slots of the driving clutch member 119, thus coupling the two members 117 and 119 together. The "chicken" is designed and operative in a manner similar to the "chicken" of the main clutch shown in Figs. 9 and 10 and described in the foregoing. The only essential difference between the main clutch of Figs. 9 and 10 and the one here dealt with lies in the fact that only one slider 126 is provided to cooperate with the clutch member 117 instead of the four noses 67 of the main clutch previously described. Consequently, the clutch member 117 for controlling the adjustment of valve 107 has only one fixed position and upon each release revolves one full turn before it is again stopped and arrested by the slider 126. During each such interval of rotation, the cam shaft 114 performs one-half of one revolution.

The clutch controlling slider 126 is linked to an arm 127 (Figs. 28, 30) which is mounted on a shaft 128. Another arm 129 fastened to the same shaft cooperates with a cam 131 of the main control shaft 64 (Figs. 30, 28, 2), which it will be remembered, revolves one-quarter revolution after each individual energization of the solenoid. The valve 107 (Fig. 28) of the tension regulating section is thus controlled in dependence upon the position of the main control shaft and, therefore,

also in dependence upon the occurrence of given sequential signals transmitted to the solenoid of the main drive and control section. It will further be noticed, for instance from Fig. 28, that the cam shaft 114 for controlling the valve 107 carries another cam 132, and that the shaft 118 of coupling members 117 and 119 carries a cam 133. Cams 132 and 133 control the form transfer device. It thus will be understood, though more fully apparent hereinafter, that the tension control section of the machine is linked together with the various other machine sections in order to secure the proper sequence of operation. As to this operating sequence, it may suffice for the present to state that during the coil winding operations proper, the valve 107 is adjusted to the position necessary to obtain automatic tension regulation, while the valve adjustment is changed to release the wire tension during the lowering and indexing periods of the chuck and the periods of form transfer.

Whenever and as long as the slider 126 (Fig. 28) is withdrawn from the clutch member 117 to effect a change in the adjustment of valve 107, a tappet 134 is engaged by a slanted surface portion of the slider and thus pushed upwardly to actuate an electric switch 135 (Figs. 28, 30, 43). This is one of the switches for controlling the energization of the main clutch solenoid. The circuit connections and function of switch 135 will be further explained when describing the control and signal system of the machine.

#### 4. Shuttle bar section

After leaving the roller 96 (Fig. 2) of the tension control section, the wire runs upwardly, then over the guide roller 19 and through the shuttle bar structure 20 which it leaves through the eye 21 as described previously. The shuttle bar 20 has an outer tubular structure 138 which carries the above-mentioned longitudinal dovetail rails 23 and 24 at its working end (Fig. 8) at both sides, respectively, of the eye 21. This composite structure is slidable in a bearing 139 but not revolvable relative thereto. Enclosed by the non-revolvable outer structure 138 is a revolvable inner structure composed of the parts 141, 142 and 143 of which the latter carries the eye 21. The tubular outer structure 138 is firmly secured to a slider 144 which serves to impart longitudinal reciprocal motion thereto. The revolvable inner structure is connected by a member 145 to a shaft 146 which is slidable and revolvable in a bearing 147 and serves to impart an angular motion to the eye 21 simultaneously with the reciprocations of the outer portion of the shuttle bar structure. Hence, when the structure is in operation, the eye performs the above-mentioned winding motion while the dovetail rails do not change their angular position.

An inner tubing 148 of copper and a guide roller 149 ensure a proper guidance of the wire through the interior of the structure (Fig. 8). The working end of the shuttle bar is engageable by a roller 151 (Figs. 1, 2, 22) which acts as a bearing during the winding operations but is lifted from the shuttle bar during form transfer periods.

The guide roller 19 (Figs. 2, 8) is pivotally mounted on the slider 144. This slider is guided for parallel motion along the stationary frame structure of the machine and connected by a link 152 to a drive lever 153 (Figs. 2, 8) which, when operated, imparts the reciprocatory horizontal component of winding motion to the shuttle bar.

Lever 153, in turn, is driven by a link 154 and crank 155 from a shaft 156 (Figs. 2, 15, 17, 18). Shaft 156 carries a floating spur gear 157 joined with a coupling member 158 and has also a keyed coupling member 159 (Figs. 17, 15, 16). Gear 157 meshes with a driving pinion 161 on a shaft 162 (Figs. 15, 16) which carries a sheave 163 (Figs. 15, 16, 2) driven by a belt 164 from motor M2 (Fig. 2). Since motor M2 is constantly running when the machine is in operative condition, shaft 162 and gear 157 with coupling member 158 (Fig. 17) are revolving continuously.

As shown in Fig. 17, the clutch member 159 is locked by a slider 165 so that the shuttle bar is at rest in the position illustrated in Figs. 1, 2 and 8. When slider 165 is shifted to the right (Fig. 17), clutch member 159 becomes unlocked and is coupled with the driving clutch member 158 in a similar manner and by similar means as described above with reference to clutch members 117 and 119. Then, the shuttle bar is reciprocated to perform its winding operation as long as the slider 165 remains withdrawn. A latch 166 controlled by an arm 167 (Figs. 17, 16) serves to secure the slider 165 in its withdrawn position.

Slider 165, when moved into the just-mentioned withdrawn position, actuates also an electric switch 168 (Figs. 18, 15, 43) which forms another element for controlling the solenoid of the main drive and control section in the electric control system still to be described.

Slider 165 is actuated by an arm 171 on a shaft 172 (Figs. 17, 18, 2) which extends toward the chuck assembly of the machine. Near the chuck assembly the shaft 172 carries an arm 173 (Figs. 19, 20) which is biased downwardly by an extension spring 174 and has a roller resting against a cam 175 keyed to the main control shaft 64. Once for each complete revolution of shaft 64, released by the solenoid, the arm 173 is lifted temporarily against the force of spring 174 (Figs. 19, 20) so that shaft 172 revolves sufficiently for releasing the clutch member 159 (Fig. 17) and coupling it with the driving clutch member 158 for actuating the shuttle bar. As mentioned, the slider 165, when withdrawn by the just-mentioned action of shaft 172, is locked by latch 166. Consequently, the shuttle bar continues running until the latch 166 is moved back into the illustrated position. An arm 167 (Figs. 17, 16) for controlling the latch 166 is spring biased toward latching engagement with slider 165 and is controlled by the turn counting device described below so as to stop the shuttle motion only after the desired number of turns has been wound.

The angular component or "throw" of the winding motion is imparted to the shaft portion 146 of the shuttle bar structure by a mechanism located at the right hand side of the machine. Shaft 146 carries a short crank member 178 (Figs. 2, 8, 11) which is revolvable but not axially displaceable in bearing 147 while the shaft portion 146 is axially displaceable but not revolvable relative to the crank member 178. Hence, an angular motion imparted to the member 178 can be transmitted to the shuttle bar structure without interfering with the longitudinal reciprocation of the structure.

A connecting rod 179 is pivoted at 181 to the crank member and at point 182 to a guiding arm 183. Arm 183 is linked at 184 to an adjusting arm 185 whose other end is pivotally attached at point 186 to a supporting plate 187 firmly secured to the frame structure of the machine.

13

Arm 185 carries a roller 188 which engages the cam groove of a throw-adjusting cam 189 mounted on shaft 191. A drive cam 192 on shaft 193 cooperates with another roller 194 which is journaled to a pin 195 attached to a driving link 196. The upper end of link 196 is pivoted about the pivot pin at 182. Roller pin 195 passes through an opening in an elongated guide 197 (Figs. 11, 8). A block 198 revolvable about shaft 191 engages the longitudinal edges of an upper opening in guide 197. The edges of a lower opening of the same guide are slidably engaged by a block 201 revolvably seated on shaft 193 (Fig. 11). By these means, the roller 194, when cam 192 is rotating, is constrained to move up and down along a straight line between shaft 191 and 193. During such motion, the driving link 196 moves also up and down, but its upper pivot point 182 is capable of departing laterally from the just-mentioned straight line, the path of motion of point 182 being determined by the adjustment of cam 189 in the manner explained presently.

The angular position of cam 189 remains fixed during any individual period of winding operation and changes only when the forms are exchanged. The position of cam 189 illustrated in Fig. 11, for instance, corresponds to a winding operation with form F1 for winding the smallest coil C1 of the stator winding. With cam 189 at rest, the position of roller 188 remains fixed so that the adjusting arm 185 and the pivot pin at 184 are also fixed during the interval under observation. The driving cam 192 rotates continuously during the period of shuttle reciprocation. Hence, the pivot pin at 182, driven by link 196, is forced to perform a constrained up and down motion along an arc whose center is at 184. This arcuate motion at point 182 causes the crank member 178 to oscillate angularly thereby imparting to the shuttle bar structure the angular throw of eye 21 needed for winding the coil C1.

When coil C1 is finished and the machine adjusted to wind the next large coil C2 a correspondingly larger angular throw of the eye 21 is required. To this end, and by means still to be described, the cam 189 is turned one quarter of a revolution in the clockwise direction. The new position then reached is shown in Fig. 12. In this position, arm 185 and pivot 184 are turned downwardly as compared with the position of the same parts in Fig. 11. Hence, the distance between the stationary axis of the shuttle bar and the temporarily fixed pivot point 184 is larger, and the angle between arm 183 and link 179 is also larger than before. As a result, when now the drive cam 192 (see Fig. 11, not shown in Figs. 12 to 14) starts rotating, the angular throw imparted to crank member 178 in eye 21 is correspondingly increased to make it conform with the larger width of coil C2.

After the completion of coil C2, the throw-adjusting cam 189 is turned another quarter revolution to the position of Fig. 13 where the pivot point 184 is displaced a further extent away from the shuttle bar, thus increasing the angle of throw in accordance with the width of coil C3 now to be wound.

The fourth and last position of cam 189 and pivot 184 is shown in Fig. 14. This adjustment corresponds to the maximum throw required for winding the largest coil C4.

It remains to be explained how the driving cam 192 is operated and how the quarter step

14

revolution is imparted to the throw adjusting cam 189.

Shaft 193 of driving cam 192 (Figs. 11, 8, 15, 16, 17) carries two floating bevel gears 204 and 205, and a reversing clutch 206 which is keyed to cam shaft 193 and permits coupling one or the other bevel gear to the shaft (Figs. 15, 16, 17). Bevel gears 204 and 205 mesh continuously with a driving bevel gear 207 that is joined with a spur gear 208 on shaft 210 (Figs. 15, 16, 17). Spur gear 208 is driven by a spur gear 209 of shaft 156 (Figs. 16, 17). Since shaft 156, as explained previously, drives also the crank 155 (Figs. 17, 15, 2) for imparting the horizontal component of reciprocating motion to the shuttle bar, the drive cam 192 (Figs. 11, 8) operates simultaneously with the shuttle reciprocation when and as long as the slider 165 of clutch members 159, 158 (Fig. 17) is withdrawn. The curve of the cam 192 (Fig. 11) is so shaped as to throw the shuttle eye angularly back and forth near the end of the horizontal stroke. In this manner the resultant motion of the eye is caused to follow the desired path.

Shaft 191 of the throw adjusting cam 189 (Figs. 11, 8, 2, 3) is driven through gears 211 and 212 (Figs. 2, 3) from shaft 213 (Figs. 2, 3, 19, 20). A gear 214 of shaft 213, in turn, is driven by a gear 215 on a shaft 216 (Figs. 2, 3, 25, 26) through an idler gear 217 (Figs. 3, 25, 26, 27). Shaft 216, which carries also a cam 218 (Fig. 26) appertaining to the turret indexing mechanism, has a keyed clutch member 219 and a floating clutch member 221, the latter being joined with a sprocket 222 (Figs. 26, 27, 2, 3) driven by a chain from a sprocket 224 (Figs. 29, 32) of the main drive shaft 58. When the clutch members 219 and 221 are coupled for indexing the turret cage, as will be more fully described in a later place, shaft 191 of the throw adjusting cam 189 (Fig. 11) is also driven and then adjusts the throw of the shuttle bar assembly in accordance with the new form then placed in readiness by the indexing motion of the turret.

As set forth previously, the sense of the winding motion must be reversed after the completion of each winding in order to make the next winding a pole of opposite polarity. To this end, the angular throw of the shuttle bar is reversible by means of the above-mentioned reversing clutch 206 (Fig. 15). Clutch 206 is controlled by a lever 225 which is pivoted at 226 and linked to a rod 227 (Figs. 15, 17). Rod 227 extends toward the chuck assembly (Fig. 21) where it is linked to an arm 229 on a vertical shaft 231 (Figs. 21, 20). Keyed to shaft 231 is a spur gear 232 (Fig. 20) meshing with a gear 233 on a shaft 234 (Fig. 19) which serves to index the chuck, as described below, and is driven through bevel gears 235 and 236 from main drive shaft 58 (Fig. 21) under control by two clutch members 237 and 238 whose operation will be explained later when describing the chuck assembly. It will thus be seen that the mechanisms for reversing the angular throw of the shuttle bar are tied up with those for indexing the chuck. Since such indexing occurs only after the completion of a complete four-coil winding and before starting the first coil of the next winding, it will now be understood how the machine takes care of a proper reversal in winding sense.

#### 5. Turn counting device

The turn counting device serves to control the winding operations for each individual coil to be

15

wound so as to give each coil an allotted predetermined number of wire turns.

A ratchet gear 241 (Figs. 15, 16, 17, 18) joined or integral with the housing 242 of a return spring 243 (Fig. 18) floats on a shaft 244 which carries, keyed thereto, a pinion 245 and a stop member 246 with an adjustable stop screw 247 (Figs. 15, 16, 18). A stop 248 is fastened to the spring housing 242. The spring tends to turn the housing and ratchet gear counterclockwise (Fig. 16) so that the stop 248 rests against the stop screw 247 when the ratchet gear is released in the position of rest shown in Fig. 16.

A pawl 251 and a detent 252 are normally biased by springs into engagement with ratchet 241. Pawl 251 is pivoted to a cantilever 253. This lever is fulcrumed about the ratchet shaft 244 and rests with a roller 249 against a cam 250 (Figs. 16, 15) under bias by a spring 254 (Fig. 16). Cam 250 is mounted on the shaft 156 which drives the crank 155 (Figs. 17, 18, 15, 2) for actuating the shuttle bar. Hence, pawl 251 is caused to advance the ratchet 241 clockwise (Fig. 16) a given angle for each turn wound by the shuttle bar. The stationarily pivoted detent 252 then holds the ratchet in the position reached so that the ratchet motion produced by the oscillations of pawl 251 is cumulative.

When the counted and integrated number of turns reaches a given number, stop 248 (Fig. 16) abuts against the arm 255 on the shaft 256 of arm 167 and moves the arm 167 counterclockwise (Figs. 16, 18). Arm 167, as described above, engages the latch 166 (Fig. 17) and pulls it out of engagement with the slider 165. The slider, under its spring bias then snaps back into the position shown in Fig. 17, thereby disengaging the clutch member 159 from the driving member 160 and arresting it relative to the machine frame. As a result, the shuttle motion is stopped when the desired number of turns is counted by the ratchet mechanism.

The number of turns wound during the operating period of the shuttle bar depends on the angular position of stop 246 (Fig. 16), i. e. on the extent of angular ratchet travel determined by that position. It is, therefore, necessary to adjust the position of stop member 246 in accordance with the number of turns to be wound for each particular coil.

To this end, pinion 245 is engaged by a rack 257 which is slidably mounted and linked to a lever 258 fulcrumed at 259 (Figs. 16, 18). A roller 261 journaled at the upper end of lever 258 engages the groove of a cam 262 (Figs. 8, 2, 3) on shaft 181. This shaft, as described, serves also to adjust the throw-adjusting cam 189 (Fig. 11) of the shuttle assembly. Consequently, whenever the machine adjusts itself for winding another coil, the cam 262 is also turned in order to set the turn counting mechanism to the number of turns to be given to the coil.

The curvature of the cam groove on cam 262 is shaped in accordance with the different number of turns of the respective different coils, and the cam is exchangeable for others designed for different desired coil or number combinations. To facilitate such an exchange, shaft 181 and cam 262 are readily accessible from the rear of the machine (Fig. 3) after removal of the hood 8 (Fig. 2).

After the counting mechanism has stopped the shuttle drive upon completion of the desired number of turns of a coil, it is necessary to reset the ratchet gear 241 before the next counting opera-

16

tion is started from the then desired zero position. The resetting is done by a yoke 263, fulcrumed at 264, which is biased by a spring 265 so that normally it does not interfere with the above-described operation of ratchet pawl 251 and detent 252 (Fig. 16). A releasing rod 266 is linked at 267 to the yoke 263. When rod 266 is pulled toward the left in opposition to spring 265, the yoke turns counterclockwise about fulcrum 264 and lifts pawl 251 and detent 252 from the ratchet 241. The return spring, thus released, is then effective to move the ratchet and spring housing back until the stop 248 abuts against the stop screw 247 of stop arm 246.

The ratchet release rod 266 (Figs. 16, 2, 21) extends toward the chuck assembly and is linked to a lever 268 (Fig. 21) which is stationarily fulcrumed at 269. The upper end of lever 268 lies in the path of a cam block 271 attached to the vertically displaceable supporting structure 272 of the chuck assembly. As will be pointed out more in detail, the structure 272 moves down after the completion of each coil and before the exchange of the form. Such downward motion causes the cam block 271 to engage the lever 268 and turn it clockwise a sufficient extent to shift the release rod 266, thereby releasing and resetting the turn counting mechanism.

#### 6. Chuck section

The chuck for accommodating the stator to be wound is mounted in the above-mentioned composite supporting structure 272 (Figs. 24, 19, 20, 21, 22, 2) which is slidably guided in standards 273 (Figs. 19, 20, 22, 3) which form part of the stationary frame structure of the machine. The annular chuck body 274 (Figs. 23, 24, 21) is revolvably secured in the vertically movable structure 272 and has three jaws 275 normally biased by springs to move outwardly. The outer surfaces of the jaws extend at an angle to the periphery and engage a correspondingly slanted wedge surface of a ring 276 so that when the latter is revolved by the operator, by means of a rod inserted into bore 277 (Fig. 24), the jaws 275 are forced inwardly in order to clamp the stator 1 inserted into the chuck (Fig. 21). The chuck body 274 has firmly attached thereto an annular spur gear 278 which engages a worm gear 279 (Fig. 19). The gearing is of the locking type so that the chuck body is normally prevented from revolving. A cross bar 281 connecting the standards 273 (Figs. 19, 20, 21, 22) carries a locking pin 282 which engages a sleeve 283 of the chuck body 274 (Fig. 21) when the chuck assembly is in raised position. Hence, the chuck body is stationary most of the time and is then safely locked in the proper position. When inserting the stator core into the chuck, the stator slot 3 (Figs. 33, 35) is brought in registry with a pin 284 (Fig. 23) so that a proper positioning of the core is secured.

During the winding operations, one of the forms, for instance form F1 as illustrated in Fig. 21, is seated on the stator core while being engaged by one of the dovetail rails 23 or 24 of the shuttle bar 20. In order to unseat the form from the stator preparatory to a form exchange and also for disengaging the chuck body from the locking pin 282 (Figs. 20, 21) preparatory to the chuck indexing, the chuck assembly must be lowered.

The lifting mechanism for lowering and raising the chuck assembly at the proper time is designed as follows. An arm 285 (Figs. 20, 2) is firmly attached to the slidable supporting struc-

ture 272 and carries a vertical driving rod 286 which is slidable relative to arm 285 but normally held in a fixed position relative thereto by means of a shock absorbing compression spring 287. The lower end of member 286 carries a roller (not shown) which engages the cam groove of a cam 288 (Figs. 20, 2). The weight of the slidable chuck assembly is approximately counterbalanced by supporting springs 289 (Figs. 20, 19, 21). Hence little effort is required to lift and lower the assembly.

The chuck lifting cam 288 is keyed to the shaft 114 (Figs. 20, 2) which, as described above, actuates also the control cam 113 of the tension control section as well as a cam 132 (Figs. 2, 28) of the form transfer device and is driven through gears 115, 116, clutch members 117, 119, and sprocket gear 121 (Fig. 28) from the main driving shaft 58 under control by the clutch slider 126. Consequently, the up and down motion of the chuck assembly is correlated to tension control and form transfer.

Two cam blocks 291 and 292 (Figs. 19, 20) are secured to the chuck supporting structure 272 and control an electric switch 293 (Figs. 19, 20, 43) so that the switch is closed when the chuck assembly is raised and lowered and open during the raising and lowering motion. Switch 293 serves as an interlock in the electric control system to be described in a later place.

It has been mentioned that two tappets 26 and 27 engage the form alternately during overlapping intervals of time in order to secure the form in proper position during the winding performance. These tappets are vertically slidable in the supporting structure 272 (Figs. 21, 2) and have each a roller in engagement with respective cam grooves of a double cam 294. Cam 294 is feathered on a vertical shaft 295 (Figs. 21, 2, 20) which is journaled in the structure 272 and carries at its lower end a helical gear 296 (Fig. 21) in engagement with a mating gear 297. The shaft 298 of gear 297 has a sprocket 299 (Figs. 20, 19, 2) driven by a chain 301 from a sprocket 302 (Figs. 2, 15, 16, 17) keyed to the shaft 156 that operates the crank arm 155 of the shuttle drive under control by the coupling members 158 and 159 and the appertaining control slider 165 (Fig. 17). Hence, the driving power for tappets 26 and 27 is derived from the shuttle drive, i. e. ultimately from motor M2 (Fig. 2), and the up and down motion of the tappets is effective in synchronism with the winding operation of the shuttle bar.

The function of the tappets 26 and 27 will be more fully understood from a reference to Fig. 34. As there shown, each form has two buttons 303 and 304 integral with two respective arms 305 and 306 which are pivoted at 307 and 308 and biased by a spring 309 and 311, respectively, so that the buttons 303 and 304 normally project from the form as shown in Fig. 37. The tappets 26 and 27, when entering into locking engagement with the form, entrain the end of the pertaining button arm and thus force the button into the body of the form (see tappet 26 in Fig. 34).

Fig. 34 represents a phase of operation in which the form F1 is locked in position by the tappet 26 while tappet 27 is disengaged. In this stage, the wire 17 issuing from the eye of the shuttle bar is being wound onto the form so that its end is about to slide downwardly along the form at the side of tappet 27 and in the direction of the arrow A2. A moment later, the wire 17 will hit

against the button 304 near tappet 27. As a result, the wire is temporarily prevented from sliding further along the form while the tension on the wire and the travel of the eye pays out wire which travels downward along the side of the guiding form (with no longitudinal movement of the wire) and passes progressively into the slot as though it were rotating about the button 304 downward in a counterclockwise direction. When the eye of the shuttle bar has progressed far enough, the wire has taken a position inside the slot for the full length of the core, but just inside, when the tappet 27 moves up and engages the form and lifts the button 304 to release the hold on the wire. The tension then snaps the wire the balance of the movement into the slot and draws up the slack to form a tight fit of the part of a turn to the previous turns. Now the tappet 26 is withdrawn from the form. Hence, when now the wire 17 reaches the left-hand side of the form, the left button 303 is in projected position and stops the sliding motion of the wire temporarily in the same manner as did previously the right-hand button, until the returning tappet 26 again releases the wire for further motion. This operation is repeated during the period of the winding operation due to the action of the cam mechanism described in the foregoing.

The tappet control cam 294, though not revoluble relative to the appertaining cam shaft 295, is movable along this shaft. A neck portion 312 (Fig. 21) of cam 294 is engaged by an arm 313 which is pivoted at 314 to the vertically displaceable supporting structure 272 of the chuck assembly and fulcrumed about a stationary pin 315. The arm 313 secures the cam 294 in its proper position when the chuck assembly is in the lifted position shown in Fig. 21. During the downward motion of the chuck assembly, the arm 313, turning about pin 315, moves the tappet cam 294 downwardly along shaft 295 so that the cam performs a larger lowering motion than the chuck. Since the tappets 26 and 27, by their respective cam rollers, are linked to the cam 294, they also move downward to a larger extent than the chuck. As a result, both tappets are pulled away from the form in order not to interfere with the subsequent form transfer.

When all four coils of a winding have been wound, and after the chuck assembly is lowered and the last operative form withdrawn into the turret cage, the chuck must be indexed one quarter revolution before the first form for the next winding is inserted and the chuck assembly again lifted into winding position. The indexing motion is imparted to the chuck body through the above-mentioned gears 278 and 279 through the vertical shaft 234 (Fig. 19). As mentioned, shaft 234 carries at its lower end a bevel gear 235 which meshes with a bevel gear 236 on the main drive shaft 58. Bevel gear 236 is firmly joined with the clutch member 237 (Figs. 19, 21) that floats on the main drive shaft and cooperates with the driving clutch member 238 keyed to the shaft. It will be remembered that these clutch members serve also to control the oscillating cam 192 (Fig. 12) of the shuttle bar section, but it remains to be explained how these clutch members are controlled.

The construction of clutch members 237 and 238 (Fig. 21) is substantially similar to that of the clutches previously referred to. That is, the driven clutch member 237 is normally stopped in a fixed position by a slider (similar to slider 165 in Fig. 17) which, when withdrawn, causes a

"chicken" of clutch member 237 to engage a slot of the driving member 238 in a manner similar to the coupling operation of the "chicken" 69 in Figs. 9 and 10. The control slider (not shown) of clutch member 237 (Figs. 21, 19) is actuated by a lever 316 whose lower end rests against a control cam 317 (Figs. 21, 2) which is coaxially joined with a Geneva gear 318 on a shaft 319 (Figs. 21, 2, 19, 20). The driver 321 of Geneva gear 318 is keyed to the main control shaft 64 together with the cam 175 which, as described above, controls arm 173 of shaft 172 (Figs. 19, 20) for actuating the slider 165 of the shuttle bar control clutch member 159 (Fig. 17). Hence the intermittent quarter revolution of the main control shaft 64, under control by the solenoid 86 (Fig. 29) takes care of indexing the chuck, by means of the Geneva mechanism, one quarter revolution after the completion of the four coils of each stator winding.

Associated with the slider for controlling the clutch members 237 and 238 is an electric switch 322 (Figs. 21, 43) which is actuated by the clutch slider in much the same way as the above-mentioned switches 135 and 168 by the appertaining respective sliders 126 and 165. Switch 322 is opened when and as long as the clutch members 237 and 238 are coupled with each other, i. e., during each indexing operation of the chuck assembly, and cooperating with the other switches in controlling the solenoid of the main control clutch. This will be explained below when referring to the electric control and signal system of the machine.

The roller 151 (Figs. 1, 2, 3, 19, 20, 21, 22), serving as a slide bearing for the shuttle bar 20 during the winding performance proper, has its supporting arm 323 pivoted at 324 to one of the stationary standards 273 of the chuck assembly (Fig. 22). Arm 323 is biased by a spring 325 which tends to lift the roller off the shuttle bar 20. When the chuck assembly is in the raised position, as is the case during winding operations, a cam block 326 (Fig. 22) mounted on the vertically movable chuck support 272 engages a roller 327 journaled to arm 323 and thus holds the bearing roller 151 onto the shuttle bar 20 in opposition to the spring 325. Consequently, when the chuck assembly moves downward preparatory to an exchange of forms, the roller 151 is moved out of the way of the form transferring machine parts.

Referring to Fig. 20, it will be noted that the slide structure 272 of the chuck assembly carries a lever 330 pivoted at 340 which carries a hook 328 and has a pin at the lower lever end in engagement with a stationary cam slot 329. Whenever the chuck assembly moves downward, the slot 329 guides the lever 330 in such a manner that the hook 328 swings toward the vertical center axis and thus prevents the wire from slipping out of the stator slot. This lever and hook mechanism represents merely an accessory for securing greater safety of operation, but since the wire is usually prevented from uncontrolled movements by the tong assembly described hereinafter, the hook is effective only in exceptional cases and not necessarily required for certain types of cores and wires to be fabricated.

#### 7. Tongs section

During those periods of operation in which the chuck is lowered from its normal working position, the wire portion between the shuttle eye and the stator would be apt to become dislocated or entangled unless it were then held in a safe posi-

tion. The tongs section serves to perform this holding function. Its working parts are located between the chuck assembly and the shuttle bar drive and mounted on a stationary support which forms part of the composite machine frame structure 5 and is shown in Figs. 2, 3, and 21 at 331 close to the chuck assembly.

A cylinder 332, secured to support 331 (Figs. 19, 21) has two pipe connections 333 and 334 at its upper and lower ends respectively, for the supply and exhaust of pressure air. A piston structure having two piston members 335 and 336 connected by a rod 337 is slidable within the cylinder 332 (Fig. 21). Rod 337 passes through a partition 338 which is perforated by ducts through which the upper and lower cylinder chambers communicate with each other. The effective cross section of these ducts is adjustable by means of two screws 339. When the piston structure is in the illustrated lifted position, the cylinder chamber above partition 338 is filled with oil. When air pressure is applied to duct 333, while duct 334 is free for exhaust, the air pressure, acting on piston member 335 forces the piston structure downwardly and causes the oil to flow through the ducts of the partition 338 into the lower cylinder chamber between partition 338 and piston member 336. Conversely, when thereafter the duct 334 is placed under air pressure with duct 333 free for exhaust, the piston structure is moved up under return displacement of the oil.

The tongs 28 and 29 (Figs. 19, 3) are connected to an attachment 341 at the lower end of piston rod 337 (Figs. 19, 21) so that when the piston structure moves downward from the position shown in Fig. 19, the tongs are also lowered. The tongs are so guided that their prongs close and overlap each other in the initial interval of the downward motion. Thus the wire portion between shuttle eye and stator slot is caught pulled down and thus safely held relative to the stator core while the form is being exchanged or the stator indexed. Shortly before the prongs close and touch the wire, the tension control section acts to release the wire tension. Due to the above-described pneumatic-hydraulic action of the tong mechanism, the pulling operation occurs swiftly and yet under smooth acceleration and deceleration. After completion of a chuck indexing operation or form exchange and after the chuck assembly has been lifted into working position, the tongs are again raised and opened. Immediately thereafter the tension control section places the wire under tension and the wire snaps back into taut condition before the shuttle bar begins its next winding operation. The smoothness and elasticity of the forces thus imposed on the wire by the pneumatic tong mechanism and pneumatic tension control devices secures a high operating speed with a minimum of stress that might otherwise injure the wire. As a matter of fact, the above-described application of pneumatically controlled apparatus in those machine sections that affect the tensioning and tautening conditions of the wire is an essential factor for the success achieved with the illustrated machine and permits the fabrication of wire, such as enamel insulated wire, that used to be difficult or virtually impractical to use in electric machine windings of the type here involved.

The means for controlling the application of pressure to the air connections 333 and 334 (Fig. 19) of the tong mechanism comprise a valve 342 (Figs. 31, 32, 29) which is a duplicate of the above-described valve 107 (Fig. 28) of the tension

control section. That is, the tongs control valve 342 is designed in accordance with the schematic diagram of Fig. 42 and has a duct for connection to a pressure air line or pump and an exhaust duct which are alternately connected to two pressure ducts marked 343 and 344 in Fig. 31. Ducts 343 and 344 are connected by pipes (not shown) with respective ducts 333 and 334 (Fig. 19). A cam 345 (Figs. 29, 32) serves to place the valve in one or the other position, thereby connecting either the duct 343 to the air line and the duct 344 to the exhaust opening or the duct 344 to the air line and the duct 343 to the exhaust opening. Cam 345 is keyed to the main control shaft 64 which, as described, originates also the control of the tension control valve and the control of the form turret and form transfer section. This tie-up secures the above-mentioned sequence and timing of the tong operation.

The end attachment 341 of the piston structure for operating the tongs is provided with a cam which co-operates with a switch 346 (Figs. 19, 21, 43) so that the switch is closed in the upper and lower end positions of the tongs but open in the intermediate positions, i.e., when the tong mechanism is in motion. The switch 346 forms part of the electric control and signal system to be described hereinafter.

#### 8. Tap-forming device

It has been mentioned, with reference to Fig. 35, that certain types of stators require the provision of connections or taps between windings, such as represented by the taps or loops L1, L2 and L3. The device for forming such taps is associated with the chuck assembly. The chuck body 214 (Fig. 24) carries a ring 347 which is revolvable relative to the chuck and provided with a finger plate 348 with the above-mentioned peripherally projecting finger 30 (Figs. 20, 19). A pivot pin 349 is linked to an arm 351. The lower end of arm 351 is loop-shaped and slidably seated on a shaft 352. A cam 353 is keyed to shaft 352 and engaged by a roller or follower pin 354 of arm 351. When cam 353 is in the illustrated position, pin 354 and arm 351 are in the lowermost position. When cam 353 is turned one-half revolution, the arm 351 is lifted so that pivot 349 and plate 348 are turned counterclockwise together with ring 347. As a result, the finger 30 is turned toward the right and upwardly out of the path of the wire.

Shaft 352 of cam 353 carries a gear 356 in meshing engagement with an idler gear 357 (Figs. 19, 20). A pinion 358 for driving the idler gear is mounted on the above-mentioned shaft 213. Spur gear 214 (Figs. 25, 27) is in driving connection, through an idler 217, with gear 215 on shaft 216 (Figs. 25, 27, 2) whose operation is controlled by the clutch members 219 and 221 as described above when referring to the shuttle bar section. It should be remembered that the shafts 216 and 213 are also geared to the shaft 191 (Figs. 2, 8) that adjusts the number of turns to be wound for each coil. Hence these various devices are controlled in proper relation to one another and also in harmony with the indexing devices of the turret section. Consequently, by providing proper gear ratios, the finger plate of the tapping device will move into the path of the wire at the time when the machine is intended to make a tap between stator windings.

Most of the time the finger 30 (Figs. 20, 19) is held in raised position and thus out of the way of the wire. When the fourth coil of a stator wind-

ing is completed and a tap is to be provided between that coil and the first coil of the next winding to be wound, the tapping device comes into action in the following manner.

Immediately upon completion of the last coil, the shuttle bar stops, the wire tension is released, the tongs pull the wire downward, all as explained in the foregoing. Then the form previously seated in the stator is withdrawn into the turret by the form transfer device still to be described. Thereafter the form turret is indexed in order to place the first form for the next winding into proper position for being transferred to the stator which, in the meantime, has also been indexed. The indexing motion of the turret is controlled by devices which, as mentioned, also adjust the turn counting mechanism, the throw control means of the shuttle bar, and of the tapping device. Hence, concurrently with the indexing motion of the turret, the finger 30 is lowered into the position shown in Figs. 19 and 20. During this phase of operation, the wire is still held down by the tongs so that the wire portion between shuttle eye and stator slot passes underneath the finger 30. Subsequently, the new form is seated in the stator, the chuck assembly is lifted, and the tongs are raised and opened. Now the parts shown in Fig. 19 have all the illustrated positions. When now the wire tension is restored by the tension control section so that the wire snaps upward, the finger 30 is still above the wire and the wire lies taut against the underside of the finger as shown at 17 in Fig. 19. Then the shuttle starts winding the next coil. While performing the winding motion about the form, the winding path of the shuttle eye lies above the finger 30. Hence, a loop of wire is formed between the last turn of the preceding coil and the first turn of the coil now in fabrication, and this loop corresponds to one of the loops L1, L2 and L3 of Fig. 35.

While the new coil is being wound, the finger 30 does not interfere with the winding operation and hence may stay in place until after the coil is finished. Then, during the next indexing motion of the turret, i. e., before the second coil of the same winding is started, the finger is moved back into the inoperative position. Only after the completion of all coils of the winding, in other words after each complete revolution of the turret, is the finger moved back to the tap producing position.

It will be understood that a tap may be provided between any adjacent windings, coils or turns by a corresponding selection of the gear ratios and cam shape of the tapping device if a number or arrangement of taps different from the example of Fig. 35 is desired.

#### 9. Form magazine section

The cage structure 361 of the turret (Figs. 2, 25, 26, 27) has four pairs of rails denoted by 362, 363, 364 and 365, respectively, (Fig. 25) engageable with corresponding pairs of grooves 366, 367, 368, 369 of forms F1, F2, F3, F4, respectively, (Figs. 38 to 41). The shaft 371 of the cage structure 361 (Figs. 2, 25) is nonrevolvable and firmly secured to standards 372, 373 (Figs. 26, 25). The standards are rigidly mounted on the stationary machine frame structure 5 so as to form component parts thereof. The stationary turret shaft 371 carries a latching plate 374 (Figs. 2, 26) engageable with a groove 375 (Fig. 37) in the saddle portion of each form. The latching plate 374 is so shaped that it enters only into the latch groove of three of the forms thus securing these

forms in proper position during the indexing revolution of the turret, while no latching engagement is established with the one form that at any time is located in the top portion of the turret. Thus, the top form is free to be slid into and out of the turret cage.

Firmly attached to the cage structure is a spur gear 376 (Figs. 26, 27) mating with a gear 377 (Figs. 27, 25) on the shaft 378 of a Geneva gear 379. The Geneva driver 381 (Fig. 25) is keyed to the above-mentioned shaft 216 (Figs. 25, 26, 27) for actuating, through parts 215, 217, 214, 213 (Fig. 25), the tapping device and adjusting the turn counting mechanism and the throw control device of the shuttle bar. It has also been mentioned, when describing the throw adjusting means of the shuttle bar section, that shaft 216 is driven by sprocket 222 from the main drive shaft 58 under control by clutch members 219 and 221. These clutch members are controlled by a clutch slider 382 in a manner similar to the clutches described previously. Slider 382 is actuated by a lever 383 (Figs. 26, 27, 28) which is pivoted at 384 (Fig. 28) to the machine frame structure and engages a cam 385 (Figs. 28, 29) of the main control shaft 64. Hence, the solenoid 80 of the main drive and control section provides also the control impulse for causing an indexing motion of the turret cage.

The Geneva drive 379, 381 (Fig. 25) is of the non-locking type, and a separately operating device is provided to latch the turret directly with the machine frame structure. The latching device has a bolt 387 (Figs. 26, 27) slidable in standard 372 and engageable with one of four latch openings in the cage structure 361. Bolt 387 is linked to a lever structure 388, fulcrumed by a shaft 389 and engaging the control cam 218 on the above-mentioned index control shaft 216. Due to the lost motion between driver and gear of Geneva drives, the Geneva gear 379 (Fig. 25) is turned only after the shaft 216 has passed through an initial interval of revolution. During this interval, the cam 218 (Figs. 26, 27) withdraws the bolt 387, thus unlatching the cage 361 until after it has been indexed one quarter revolution by the action of the Geneva drive.

An electric switch 391 (Figs. 27, 43) is actuated by the slider 382 (Figs. 27, 26) so as to be open when the clutch members 219 and 221 are coupled to perform the turret indexing, throw-adjusting and turn-counter adjusting operations. This switch is another control element of the electric control system of the machine to be referred to below.

The mechanism for transporting the forms between turret and chuck is arranged on a bridge structure 392 (Figs. 25, 26, 2) which forms part of the stationary frame structure of the machine and has two guide rails 393 (Figs. 25, 26) extending above the turret cage in the longitudinal direction thereof. A slide 394 is guided on rails 393 and linked to a pusher rod 395 (Figs. 26, 2, 3) which connects it to a lever 396 (Figs. 2, 28, 31) fulcrumed by a shaft 397. A roller 398 (Figs. 28, 31) journaled on lever 396 is in engagement with the cam 133 on shaft 118 (Figs. 28, 31, 2, 3) which, as described before, is geared to the shaft 114 (Fig. 28) of the tension control cam 113 and driven by sprocket 121 from the main drive shaft 64 when the slider 126 is withdrawn from clutch member 117. Shaft 118 with cam 133 turns a full revolution at a time with the effect of shifting the lever 396 and the form transfer slider 394 (Figs. 25, 26)

toward the chuck assembly and back to the illustrated position.

A lever 401 is pivoted at 402 to slider 394 and carries at one end a roller 403 while its other end engages a pin 404 which is vertically slidable in a part 405 of slider 394. The lower end of pin 404 is engageable with a bore 400 (Fig. 34) of each form. Two arms 406 and 407 having pivot shafts 408 and 409, respectively (Fig. 26), are linked together by a bar 411 for parallel motion. Arm 406 is further connected by a link 412 with the upper end of a lever 413 (Figs. 26, 28, 2), pivoted at 414 (Figs. 26, 28), whose lower end (Fig. 28) has a roller in engagement with the cam 132 on the cam shaft 114 of the tension control valve 107. Shaft 114, as explained, turns one half revolution for each individual full-turn operation of clutch member 117 and shaft 118 (Fig. 28). During each such half revolution of shaft 114, arm 413 is caused to move back and forth, thereby shifting the arms 406 and 407 (Fig. 26) counterclockwise and back. The two pivot shafts 408 and 409 of arms 406 and 407, respectively, each carry a member, such as the one denoted in Fig. 26 by 415, which extends at an angle to the appertaining arm 407 or 406 and is pivotally linked to a bar 416. When the two arms 406 and 407 turn clockwise, as just mentioned, the bar 416 is lowered by the two members; and when the arms 406 and 407 return counterclockwise into the illustrated position, the bar 416 is again lifted.

The roller 403 of lever 401 is so arranged relative to the bar 416 that it rolls along the bar when the slide 394 travels back and forth along the rails 393. A biasing spring 417 disposed on the slider 394 tends to turn the lever 401 clockwise. Hence, the roller 403 is always held in rolling engagement with the bar 416. As long as the bar 416 is lowered, as shown in Fig. 26, it forces the roller downward and thus holds the pin 404 (Figs. 26, 25) lifted out of engagement with the form. When bar 416 is lifted, roller 403 will follow and permits the spring 417 to pull the pin 404 down so that it will now engage the matching bore 400 (in Fig. 34) when sliding along the form.

The two cam drives of the form transfer mechanism are so correlated that the above described horizontal travel of the slide 394 and vertical motion of the form engaging pin 404 occur in the following sequence.

At the start of a winding sequence, all four forms are located in the turret cage with form F1 in the top position and ready to be transferred to the stator. Slide 394 is now moved from the position shown in Fig. 26 toward the chuck, and bar 416 is lifted. Hence, while the slide 394 with lever 401 and pin 404 starts travelling, the pin is lowered. It catches into the bore of form F1 and takes the form along, thus sliding it out of the cage and onto the dovetail rail 23 (Fig. 34) of the shuttle bar 20. Then the bar 416 is lowered and lifts the pin 404 off the form. Thereafter, the slide 394 moves back into the initial position while the form F1 remains in the stator core to be properly seated therein by the subsequent lifting motion of the chuck assembly.

Cam 132 has an extra offset in its track which operates just before the slide 394 reaches its initial position and after pin 404 is lifted and disengaged from the form. The offset operates to move the slide 394 a further extent so as to clear the turret cage in order not to interfere with the subsequent indexing motion of the turret. The cam track has also the effect of halting the slide 394 temporarily when it moves from its out-

ermost position toward the chuck so that during the stopping interval the pin 404 is lowered to engage the form before the slide continues its motion to carry the form into the core.

When, at a later time, form F1 is ready to be exchanged, the form transfer device repeats its operation but this time moves the slide 394 idle toward the stator with pin 404 lifted. At the beginning of the return stroke, pin 404 is lowered, catches into the bore of form F1 and thus entrains the form back into the turret cage. After the subsequent indexing of the cage, the transfer device performs a full stroke in the first described manner so that now form F2 is slid onto the dove-tail rail 23 of the shuttle bar 20 before the transfer device returns idle to the starting position. The same double-stroke operation is repeated for the exchange of forms F2—F3, F3—F4, F4—F1 and so forth until the stator is completely wound. Then the last form F4 is withdrawn into the cage and the machine is stopped with all forms back in the turret and form F1 ready for winding another stator.

#### 10. Electric control system

The electric control and signal system of the machine is shown diagrammatically in Fig. 43 in which all of the above-mentioned electric devices are represented schematically, the various switches being shown in association with schematic illustration of appertaining mechanical control parts in order to facilitate locating these devices and parts in the other drawings.

The two drive motors M1 and M2 are connected to a power line PL through a disconnect switch DS under control by the main contacts 421 of a contactor CR whose operating coil 422 actuates also an interlock contact 423. A transformer TR provides excitation for the main leads X and Y of the control circuits under control by the main switch 10. The coil circuit for contactor CR contains the normally open start button 11, the normally closed stop button 12 and the normally open "automatic" button 13 shown in Fig. 1. Buttons 11 and 12 are series-connected with contactor coil 422 between mains X and Y. This series connection includes also the switch 112 (see Fig. 5) of the tension control section which is opened only in the event of a wire break. The same series circuit extends also through the contact 424 of a pressure-responsive device 425. This device is connected in the pressure conduit leading from the air pressure line or pump to the two control valves 107 and 342 (see Figs. 28, 29, 42) of the tension control section and tong assembly respectively. Contact 424 is closed only when the air pressure is switched on and serves to permit operating the machine only after the proper pressure has been applied and as long as such pressure is being maintained.

After the closure of switches DS and 10, motors M1 and M2 can be started by depressing the start button 11. With switches 112 and 424 closed, the circuit of coil 422 is now completed so that contactor CR picks up and energizes both motors. The interlock contact 423 of contactor CR closes a self-holding circuit so that the motors remain energized when thereafter the start button is released. The motors, therefore, continue running until the operator depresses the stop button 12 and thus interrupts the self-holding circuit, or until contact 424 opens due to failure in air pressure, or until switch 112 opens due to a wire break. The occurrence of any such failure will immediately stop and deenergize the motors

M1 and M2 but not the control circuit. It will be understood that electric overload-responsive devices may also be provided in order to stop the machine automatically upon occurrence of overload or short circuit.

With motors M1 and M2 running, the machine is ready for operation but its working sections remain at rest as long as the solenoid 80 controlling the main clutch (see Fig. 29) receives no starting impulse. The first starting impulse is applied by depressing the "automatic" button 13 (see Fig. 1). This button controls the coil circuit of a relay SR whose contact 426 is series-connected with the solenoid 80 between mains X and Y. The solenoid circuit extends also in series through all previously mentioned switches 322, 135, 391, 168, 293, 346, but these switches are closed before the beginning of a winding sequence so that the closure of contact 426 in relay SR completes the solenoid circuit and hence causes the machine to start operating. Relay SR remains normally closed so that its contact 426 does not, as a rule, participate in the subsequent electric control actions during the further operating sequence of the machine. However, the first operation performed by the machine is to turn the main control shaft into an angular quarter position, during which motion the form transfer clutch is engaged by withdrawing and then releasing the appertaining slider 126. The tension release valve opened by the previous operation of this same clutch is reversed to apply tension to the wire while the form transfer is returning to its normal position and the chuck unit is completing its upward movement. Switch 135 is opened and interrupts the solenoid circuit by the movement of slider 126 and halts the main control shaft when it has advanced or turned this quarter movement. Also interlock switches 293 and 346 in the solenoid circuit are opened by the ensuing lifting of the chuck and the motions of the tongs so as to insure that these parts arrive at their proper positions before the solenoid can operate to cause the next successive operation of the shuttle bar. When the chuck unit and the tongs have completed their motions and are in their correct positions, switches 135, 293 and 346 are closed permitting a current impulse to operate the solenoid. As a result, the control shaft 64 turns another quarter revolution and causes the shuttle bar to start operating. The clutch slider 165 appertaining to the shuttle bar drive then opens the switch 168 and thereby deenergizes the solenoid. In this manner each group of operations initiated by the control shaft 64 immediately deenergizes the solenoid 80 and provides for another energization only after this group of operations is completed until the performance has passed through the whole sequence of operations required for a complete winding job or for any predetermined portion thereof.

At the end of the sequence, a contact 427 in the coil circuit of relay SR is opened so that relay SR drops off and prevents the further energization of the solenoid until, after the removal of the finished stator and the insertion of another stator core into the chuck, the "automatic" button 13 is again depressed by the operator.

The "end of sequence" contact 427 forms part of an electric double switch 428 (Fig. 30) which has also a signal contact 429 (Fig. 43). Both contacts 427 and 428 are actuated by a lever-and-cam member 431 (Figs. 43, 30) in cooperation with a dowel disk 432 which rotates during the operation of the machine in the direction of

the arrow A3 and completes a single full revolution during the whole operating sequence of the machine. Disk 432 is joined with a spur gear on a shaft 433 (Figs. 43, 30, 32) and driven by a pinion 434 which idles on a shaft 435 and is joined with a spur gear 436. Gear 436, in turn, is driven, by a pinion 437 of the main control shaft 64 (Figs. 30, 32). The gear train between main control shaft 64 and dowel disk 432 has a total reduction ratio of 1 to 36 so that 144 individual quarter revolutions of the main control shaft are required to turn the disk 432 one full revolution.

A dowel or dog pin 438 is inserted in disk 432 so that it engages the cam surface of member 431 shortly before the end of a complete operating sequence. The pin 438 will then displace the cam member 431 sufficiently to close contact 428 (Fig. 43) leaving at first the contact 427 unaffected. Thereafter, the last quarter turn of the sequence will cause the pin 438 to shift the cam member 431 a further extent so that contact 427 is opened and the machine stopped.

Consequently, when a new sequence is started by depressing the "automatic" button 13, the contact 427 is at first open. However, the initial energization of relay SR due to the closure of button 13 causes the main control shaft to perform its first quarter turn. As a result, contact 427 is closed and maintains the coil circuit of relay SR completed when thereafter the "automatic" button 13 is released.

If it is desired to make the machine stop automatically at any intermediate point of its sequence, it is merely necessary to provide the disk 432 in the proper places with one or more additional dowel pins. An example of a case where a stoppage in an intermediate phase may be desired will be elucidated with reference to the stator shown in Fig. 35. As mentioned, the largest coils C4 of adjacent windings of this stator are wound through common stator slots. Hence the largest turns of winding W1 border directly the largest turns of winding W4 in the slot pointed at by the arrow A4. While, in general, the potential difference between adjacent turns of the windings is very small, the just-mentioned design has the result that in the slot at arrow A4 a relatively high potential difference occurs between the turns of winding W1 and the adjacent turns of winding W4. In order to avoid electrical overstress of the wire insulation at this point, it may be necessary or advantageous to insert a strip of insulation between windings W1 and W4 at the place denoted by the arrow. This requires stopping the machine temporarily as soon as coil C3 of winding W4 is completed and to restart the machine after the operator has inserted the strip.

To this end, the disk 432 (Figs. 43, 30) is provided with a second dowel pin 439 which is so located that it will first close the signal contact 429 and then stop the machine by opening the contact 427 (Fig. 43) after the completion of coil C3 in winding W4.

The control system is further equipped with a number of signal lamps denoted as a group by 440 in Figs. 1, 2, 3, 25 and 26. These lamps serve to indicate to the operator or supervisor the instantaneous stage of operation of the machine. In the circuit diagram of Fig. 43, the individual lamps are shown at 441, 442, 443, 444, 445, 446, 447 and 448 as consisting of glow discharge lamps.

Lamp 441 lies across coil 422 of contactor CR

and is lit when contact 423 of contactor CR is closed, i. e., as long as the machine is in operative condition. Deenergization of coil 422 due to failure of air pressure or wire break will cause lamp 441 to extinguish, thus indicating to the operator one of the just-mentioned causes of failure.

Lamp 442 is controlled by the above-mentioned signal contact 429 and hence becomes lit shortly before the end of a working sequence or before any other selected intermediate stoppage. By watching the lamp 442, the operator who may service one or more other machines during the working periods of the machine, can readily determine from a distance whether his presence is required or will soon be required for exchanging the stator core or, for instance, for inserting the above-mentioned insulating strip.

Lamps 443 to 448 are connected across the switches 346, 293, 168, 391, 135 and 322, respectively, and hence light up only when the appertaining switch is opened. These lamps are lighted repeatedly during the operating sequence. If for any reason, the machine should stop prematurely, the lamp of the switch then open will stay lit and thus indicate to the operator or attendant the particular machine section or clutch where the machine trouble is apt to originate. The supervision and readjustment of the machine is thus greatly facilitated.

Aside from the above-described automatic performance and stoppage, the control system also permits the operator to stop the machine at any time and any phase of its operating sequence by depressing the stop button 12. After starting the machine and depressing the "automatic" button 13, the machine can be inched at will by actuating the stop and start buttons 12 and 11 alternately in any desired intervals of time. Inching operations can also be performed by turning the hand wheel 59 of the main drive shaft 58 (Figs. 1, 2, 29).

Provision is further made to operate any of the clutches and hence any of switches 168, 391, 135 and 322 (Fig. 43) of the machine by manual actuation in order to cycle or re-cycle the machine by skipping certain phases of the sequence. To this end, the various clutches described in the foregoing are equipped with manual controls which are preferably led to the outside of the machine to be readily accessible to the adjuster. An example of such a manual control device is shown in Fig. 28 as representative, in principle, of all the others. As shown, a rod 451 is linked to the control lever 383 of the slider 382 appertaining to the turret indexing and locking clutch member 219 (Fig. 26). Rod 451 is provided with a knob 452 exteriorly of the machine frame structure 5 and can be pulled in opposition to a biasing spring 453, thereby coupling the clutch and indexing the turret cage.

#### 11. Performance

Referring to the example of a four-pole stator as shown in Figs. 35 and 36, a complete operating sequence of the above-described machine proceeds as follows.

With the machine at standstill and inoperative, all four forms are in the turret cage, and the chuck assembly and tongs are lowered. Assuming the wire to be threaded through the shuttle bar and the air pressure effective, the closure of switches DS, 10 and the subsequent actuation of the start button 11 will place the machine in operative condition with both electric motors

running. After inserting a stator core into the chuck and fastening the wire end thereto, the "automatic" button is depressed. This starts the sequence of steps mentioned below.

1. Form F1 is transferred from turret cage to chuck and engages the dove-tail rail of the shuttle bar (28).

2. The chuck assembly moves up so that the form is seated in the stator core and one of the vertical tappets (26, 27) engages the form, while the bearing roller (151) moves into the shuttle bar.

3. The tongs move up and open.

4. Tension is put on the wire so that it tautens.

5. The shuttle bar starts operating with an angular throw corresponding to the width of form F1. During the winding operation, the two vertical tappets operate alternately to secure the form in proper place and to release the two movable form buttons in order to properly shape and position the individual winding turns. During this performance, the winding turns are counted by the ratchet mechanism.

6. When the correct number of turns are wound, the ratchet mechanism causes the shuttle bar to stop.

7. The tension adjusting device releases the wire tension.

8. The wire is pulled down by the tongs.

9. The chuck moves down. The vertical tappets are disengaged from the form. The bearing roller is lifted from the shuttle bar.

10. The form F1 is withdrawn into the turret cage.

11. The turret cage is indexed to place another form F2 in proper position. The throw control cam is adjusted for the new form F2. The counting ratchet mechanism is adjusted for the new number of turns to be wound.

12. The new form F2 is transferred to chuck.

13. The chuck assembly moves up, the tappet engages the form. The bearing roller is lowered onto the shuttle bar. The tongs open. Tension is put on the wire.

14. The shuttle bar continues operating, with the angular throw and for the number of turns now adjusted until the correct number of turns are wound.

15. Steps 6 through 14 are repeated twice for forms F3 and F4 to form coils C3 and C4 of winding W1.

16. After completion of coil C4 of winding W1, the tension is released, the tongs close and pull the wire downward.

17. The tap-forming device moves the loop-forming finger (30) into operative position.

18. The chuck moves down, disengages the tappets from form F4 and lifts the bearing roller.

19. Form F4 is withdrawn into the turret cage. The turret cage is indexed to place form F1 in position.

20. The chuck with stator core is indexed for winding W2. The winding direction of the shuttle bar is reversed.

21. Form F1 is transferred to the chuck.

22. The series of steps 2 through 20 is repeated twice for windings W2 and W3, respectively.

23. Thereafter, the series of steps 2 through 14 is repeated three times for forms F1, F2 and F3, respectively, until completion of coil C3 of winding W4. Then, steps 6 through 10 are repeated for withdrawal of form F3 and indexing of form F4.

24. Now, all working devices of the machine stop to permit the insertion of an insulating strip

between C4 of winding W1 and coil C4 of winding W4 now left to be wound.

25. After insertion of the insulating strip, the operator pushes the "automatic" button 13. Form F4 is transferred to the chuck. The tongs open. The wire is put under tension. The shuttle bar starts winding the last coil. After completion of the coil, the shuttle bar stops, the chuck assembly is lowered, form F4 is withdrawn into the turret cage, the turret is indexed, the chuck is indexed, and the machine stops to permit removing the finished stator.

With motors M1 and M2 running at a speed of 1200 R. P. M. and 1800 R. P. M. respectively, the complete sequence including all manipulation mentioned and concerning a four-pole stator with four-coil windings as exemplified, can be performed in less than 5 minutes. This is a small fraction of the time needed when winding the stator by the known methods. Besides, the machine ensures that all coils have the exact number of turns, are wound with a uniform tension of desired value, and are uniform and satisfactory as regards shape and compactness. As mentioned, the machine also secures a smooth handling of the wire without local overstress on its conductor or insulation. Thus, the invention not only reduces the time needed but leads also to a virtually complete elimination of rejects and to greatly improved products.

It has been mentioned that the machine can readily be adapted for winding coils of differently selected numbers of turns merely by providing turn counter cams (262) of corresponding cam configuration. It will further be obvious that a set of different exchangeable chuck bodies or different sets of coil shaping forms may be applied in order to make the same machine capable of winding stators of different size or coil of different size or shape, and it will also be understood that the principles exemplified for a four-pole stator, are likewise applicable for machines capable of winding magnetic cores of a different pole number or with a different number of individual coils in each winding. It will further be understood by those skilled in the art that a similar machine can be made to wind lap windings by causing it to index the chuck more often and by a properly chosen angle to obtain the required overlapping of the windings. In such cases, a single coil shaping form may be sufficient so that the turret cage may be kept stationary or, in a special machine, be dispensed with. Other changes concerning the construction of gears, transmission, clutches and the like details will also offer themselves to those skilled in the art if desired, and the electric devices and circuits permit also of various modifications within the principles and essential features of the invention. For instance, more than two electric motors may be applied to drive the various machine sections, or on the other hand, a single source of driving power may be used instead of two motors shown in the drawings. In view of these and other possibilities of modification, all within the scope and gist of the invention, this specification is presented for the purpose of disclosure, explanation and exemplification, while the scope and essential features of the invention are set forth and defined by the claims annexed hereto.

I claim as my invention:

1. A machine for winding coils into the slots of electric machine cores, comprising rotatable chuck means for accommodating a core, a reciprocatory structure having an eye at its working

end for the passage therethrough of the wire to be wound, drive means for reciprocating and angularly oscillating said eye so that said eye and the wire issuing therefrom perform a winding motion substantially about a slotted portion of the core, coil-shaping form means disposed to engage the core so as to guide the wire from said eye into the proper slots of the core, means for rotating said chuck means a given indexing angle, control means for alternately operating said drive means and said chuck rotating means, and tension control means engageable by the wire for maintaining the wire at a desired tension during said winding motion.

2. A machine for winding coils into the slots of electromagnetic cores, comprising revolvable means for accommodating a core, a reciprocatory structure having an eye at its working end for the passage therethrough of the wire to be wound, drive means for reciprocating and angularly oscillating said eye so that said eye and the wire issuing therefrom perform a winding motion substantially about a slotted portion of the core, coil-shaping form means disposed to engage the core so as to guide the wire from said eye into the proper slots of the core, means for indexing the core a given angle of revolution, control means for causing said indexing means to operate in intervals between periods of said winding motion, tension regulating means engageable by the wire for maintaining the wire approximately at a constant tension during said periods, and means for controlling said tension regulating means to reduce the wire tension during said indexing intervals.

3. A machine for winding coils into the slots of electromagnetic cores, comprising a vertically displaceable chuck assembly for accommodating a core, a horizontally reciprocable shuttle structure having an angularly movable eye for the passage therethrough of a wire to be wound, means for driving said shuttle structure so as to impart reciprocation and angular movement to said eye in order to have said eye and the wire issuing therefrom perform a winding motion substantially about a slotted portion of the core, coil-shaping form means engageable with said core so as to guide the wire from said eye into the proper slots of the core during said winding motion, means for lifting and lowering said chuck assembly between winding operations of said shuttle structure in order to thereby engage and disengage respectively said form means relative to the core, means for indexing the core in said assembly when said assembly is lowered in order to thereby displace the core angularly relative to said eye and said form means, tension regulating means engageable by the wire for maintaining the wire at a desired tension during the winding operations of said shuttle structure, and means for controlling said tension regulating means to reduce said tension during periods when said assembly is out of its raised position.

4. A machine for winding coils into the slots of electromagnetic cores, comprising a vertically displaceable chuck assembly for accommodating a core, a horizontally reciprocable shuttle structure having an angularly movable eye for the passage therethrough of a wire to be wound, means for driving said shuttle structure so as to impart reciprocation and angular movement to said eye in order to have said eye and the wire issuing therefrom perform a winding motion substantially about a slotted portion of the core, coil-shaping form means engageable with said core so

as to guide the wire from said eye into the proper slots of the core during said winding motion, means for lifting and lowering said chuck assembly between periods of winding operation of said shuttle structure in order to thereby engage and disengage respectively, said form means relative to the core, a tongs mechanism disposed for pulling the wire portion between the core and said eye downward, control means for said mechanism to operate it in periods beginning before the lowering of said chuck assembly and ending after return of said chuck assembly of its raised position, means for indexing the core in said assembly when said assembly is lowered in order to thereby displace the core angularly relative to said shuttle structure and said form means, tension control means engageable by the wire, and means for controlling said tension control means so as to maintain the wire substantially at constant tension during said periods of winding operation while reducing the tension during the periods of operation of said tongs mechanism.

5. A machine for winding wire coils into a slotted core, comprising means for accommodating the core, a shuttle structure having an eye for issuing the wire to be wound and means for moving the eye so as to perform a winding motion, a plurality of differently shaped forms for guiding the wire into the slots of the core as it issues from said eye in order to produce coils of respectively different widths, magazine means for accommodating said forms, and means for selectively placing one of said forms onto said core between winding periods of said shuttle structure.

6. A machine for winding wire coils into a slotted core, comprising means for accommodating the core, a shuttle structure having an eye for issuing the wire to be wound and means for moving the eye so as to perform a winding motion, turn counting means for stopping said structure after completion of a number of consecutive winding motions, a plurality of differently shaped forms for guiding the wire into the slots of the core as it issues from said eye in order to produce coils of respectively different width, magazine means for accommodating said forms, form transfer means for selectively placing one of said forms onto said core between winding periods of said shuttle structure, and tension regulating means engageable by the wire for maintaining the wire substantially at a constant tension, during the winding operations of said shuttle structure, and means for controlling said tension regulating means to reduce the wire tension during the form transfer intervals.

7. A machine for winding coils into slots of magnetizable cores, comprising a vertically displaceable chuck assembly for accommodating a core, a horizontally reciprocable shuttle structure having an angularly movable eye for the passage therethrough of a wire to be wound, means for driving said shuttle structure so as to impart reciprocation and angular movement to said eye in order to have said eye and the wire issuing therefrom perform a winding motion substantially about a slotted portion of the core, a plurality of coil-shaping forms of graduated width each being seatable on the core for guiding the wire into the core slots as the wire issues from said eye during said winding motion in order to produce coils of, respectively, different width, magazine means for accommodating said forms, form transfer means for selectively placing one of said forms onto said core between winding periods of said shuttle structure, means for lowering and

lifting said chuck assembly in order to thereby unseat and seat, respectively, one of said forms relative to the core, tension control means engageable by the wire, and means for controlling said tension control means so as to maintain the wire substantially at constant tension during said periods of winding operation while reducing the tension during the periods in which said chuck assembly is moved out of its lifted position, and means for holding the wire down in proper relation to the core during the periods of reduced tension.

8. A machine for winding multiple-coil windings onto slotted cores, comprising a vertically displaceable chuck assembly for accommodating a core, a horizontally reciprocable shuttle structure having an angularly movable eye for the passage therethrough of a wire to be wound, means for driving said shuttle structure so as to impart reciprocation and angular movement to said eye in order to have said eye and the wire issuing therefrom perform a winding motion substantially about a slotted portion of the core, a plurality of forms of graduated width each being seatable on the core when said chuck assembly is lifted for guiding the wire into the core slots as the wire issues from said eye during said winding motion in order to produce coils of respectively different width, a turret for accommodating said forms, means for indexing said turret to place said forms sequentially into position for being transferred to the core, form-transfer means for shifting said forms between said turret and the core when said chuck assembly is in lowered position, means for indexing the core in said chuck assembly after the completion of a multi-coil winding when said chuck assembly is lowered, an adjustable turn counting mechanism for controlling said drive means to operate said shuttle structure so as to perform a given number of winding motions at a time, control means for adjusting said counting mechanism in dependence upon the operation of said turret indexing means so as to adjust said number in accordance with the one form seated on the core at that time, and lifting means for said chuck assembly effective to lower said assembly after the completion of each individual number of winding motions and lifting said assembly before the beginning of the next number of winding motions.

9. A machine for winding multiple-coil windings onto slotted cores, comprising a vertically displaceable chuck assembly for accommodating a core, a horizontally reciprocable shuttle structure having an angularly movable eye for the passage therethrough of a wire to be wound, means for driving said shuttle structure so as to impart reciprocation and angular movement to said eye in order to have said eye and the wire issuing therefrom perform a winding motion substantially about a slotted portion of the core, a plurality of forms of graduated width each being seatable on the core when said chuck assembly is lifted for guiding the wire into the core slots as the wire issues from said eye during said winding motion in order to produce coils of respectively different widths, a turret for accommodating said forms, means for indexing said turret to place said forms sequentially into position for being transferred to the core, form-transfer means for shifting said forms between said turret and the core when said chuck assembly is in lowered position, means for indexing the core in said chuck assembly after the completion of a multi-coil winding when said chuck assembly is

lowered, an adjustable turn counting mechanism for controlling said drive means to operate said shuttle structure so as to perform a given number of winding motions at a time, control means for adjusting said counting mechanism in dependence upon the operation of said turret indexing means so as to adjust said number in accordance with the one form seated on the core at that time, lifting means for said chuck assembly operative to lower it temporarily after the completion of each said numbers of winding motion, holding means for temporarily engaging the wire between said eye and the core in order to hold the wire properly located during lowering periods of said chuck assembly, tension control means engageable by the wire, and means for controlling said tension control means so as to maintain the wire substantially at constant tension during said periods of winding operation while reducing the tension during the periods of operation of said holding means.

10. A machine for winding multiple-coil windings onto slotted cores, comprising a vertically displaceable chuck assembly for accommodating a core, a horizontally reciprocable shuttle structure having an angularly movable eye for the passage therethrough of a wire to be wound, means for driving said shuttle structure so as to impart reciprocation and angular movement to said eye in order to have said eye and the wire issuing therefrom perform a winding motion substantially about a slotted portion of the core, a plurality of different forms inside each being seatable on the core when said chuck assembly is lifted for guiding the wire into the core slots as the wire issues from said eye during said winding motion in order to produce coils of respectively different widths, a turret for accommodating said forms, means for indexing said turret to place said forms sequentially into position for being transferred to the core, form-transfer means for shifting said forms between said turret and the core when said chuck assembly is in lowered position, means for indexing the core in said chuck assembly after the completion of a multi-coil winding when said chuck assembly is lowered, an adjustable turn counting mechanism for controlling said drive means to operate said shuttle structure so as to perform a given number of winding motions at a time, control means for adjusting said counting mechanism in dependence upon the operation of said turret indexing means so as to adjust said number in accordance with the one form seated on the core at that time, throw adjusting means associated with said control means for changing the extent of angular motion of said eye in accordance with the width of said selected form, lifting means for said chuck assembly operative to lower it temporarily after the completion of each said numbers of said motion, tension control means engageable by the wire, and means for controlling said tension control means so as to maintain the wire substantially at constant tension during said periods of winding operation while reducing the tension during periods when said chuck assembly is moved from its lifted position.

11. A machine for winding slotted multi-pole cores for electric machines, comprising a revolvable chuck for accommodating the core, a shuttle structure having an eye in proximity to said chuck for issuing the wire to be wound, a drive having means for imparting a reciprocatory component motion of a given stroke to said eye and reversible means for imparting an angular com-

35

ponent motion to said eye whereby said eye is caused to perform a resultant winding motion of reversible direction, throw-adjusting means associated with said drive means for changing the extent of said angular component motion, a plurality of forms of different size engageable with the core for guiding the wire from said eye into the proper core slots during said winding motion, magazine means for accommodating said forms, form-transfer means associated with said magazine means for engaging said forms sequentially with the core, control means connected with said throw-adjusting means for changing said angular throw in accordance with the one form engaging the core at a time, means for indexing the chuck, and control means associated with said indexing means and said reversible means for causing them to index said chuck and reverse the direction of said winding motion after the completion of each sequence of form transfers.

12. A machine for winding slotted multi-pole cores, comprising a revolvable chuck for accommodating the core, a shuttle structure having an eye in proximity to said chuck for issuing the wire to be wound, a drive having means for imparting a reciprocatory component motion of a given stroke to said eye and reversible means for imparting an angular component motion to said eye whereby said eye is caused to perform a resultant winding motion of reversible direction, throw-adjusting means associated with said drive means for changing the extent of said angular component motion, a plurality of forms of different size engageable with the core for guiding the wire from said eye into the proper core slots during said winding motion, magazine means for accommodating said forms, form-transfer means associated with said magazine means for engaging said forms sequentially with the core, control means connected with said throw-adjusting means for changing said angular throw in accordance with the one form engaging the core at a time, means for indexing the chuck, control means associated with said winding means and said reversible means for causing them to index said chuck and reverse the direction of said winding motion after the completion of each sequence of form transfer, tension regulating means engageable by the wire, control means for causing said tension regulating means to maintain the wire substantially at a given tension during the periods of said winding motion and to reduce the tension during the indexing and form-transfer periods, and means temporarily engageable with the wire between said eye and the core for securing it in proper position during the periods of reduced wire tension.

13. A machine for winding wire coils along the inner periphery of a slotted annular core, comprising a chuck for accommodating the core, a shuttle structure having a bar extending and reciprocable in a parallel direction to the axis of said chuck and an eye member designed for issuing the wire to be wound and disposed on said bar near said chuck and angularly reciprocable about said direction, means for driving said bar and said eye member so that the latter performs a resultant winding motion, a coil-shaping form seatable across the inner peripheral surface of the core in said chuck for guiding the wire from said eye member into the proper slots of the core, said bar and said form forming together a rail and groove coupling so that said form when seated on the core is slidably engaged by said bar.

14. A machine for winding wire coils along the

36

inner periphery of a slotted annular core, comprising a chuck for accommodating the core, a shuttle structure having a bar extending and reciprocable in a parallel direction to the axis of said chuck and an eye member designed for issuing the wire to be wound and disposed on said bar near said chuck and angularly reciprocable about said direction, means for driving said bar and said eye member so that the latter performs a resultant winding motion, a coil-shaping form seatable across the inner peripheral surface of the core in said chuck for guiding the wire from said eye member into the proper slots of the core and projecting in said direction and on both sides over the core, means disposed for locking said form in properly seated position on the core during the winding operation of said shuttle structure and comprising two tappets at both said sides respectively, substantially at a right angle to said direction and being individually movable toward and away from said form and temporarily engageable with said form when moved toward said form, and control means for actuating said tappets alternately and in a given phase relation to the operation of said shuttle structure whereby during said winding motion the wire is permitted to pass alternately by said tappets.

15. A machine for winding wire coils on slotted cores, comprising a chuck assembly for accommodating the core, a shuttle structure issuing the wire to be wound, drive means for imparting winding motion to said structure, form means engageable with the core for guiding the wire into the proper slots of the core during said winding motion, said structure and said form means being slidably engageable with each other in order to hold said form means positioned in one coordinate direction of said winding motion, and two alternately operating locking means associated with said chuck assembly and engageable with said form means to prevent it from moving in the other coordinate direction of winding motion, and means for controlling said two locking means in synchronism with said drive means so that said locking means are alternately moved out of the path of the wire.

16. A machine for winding wire coils on magnetizable cores, comprising means for accommodating the core, a shuttle structure for issuing the wire, drive means for actuating said shuttle means to perform a winding motion, tension regulating means having a sheave peripherally engageable by the wire as it passes to said shuttle structure, a brake mechanism for frictionally impeding the revolution of said sheave, pneumatic cylinder and piston means for controlling said mechanism, and control means having a valve for controlling said cylinder and piston means so as to set said brake mechanism for maintaining the tension of the wire at a desired value during said winding motion and releasing the tension during periods between winding operations.

17. A machine for winding wire coils on magnetizable cores, comprising a vertically displaceable chuck assembly for accommodating the core, a substantially horizontally movable shuttle structure for issuing the wire, drive means for actuating said shuttle structure to perform a winding motion, form means engageable with the core when said assembly is in lifted position for guiding the wire from said shuttle structure into the proper slots of the core, means for lowering said chuck assembly preparatory to an exchange of said form means, wire holding means tempo-

rarily engageable with the wire between said shuttle bar and the core during the lowering intervals of said chuck assembly, tension regulating means having a sheave peripherally engageable by the wire as it passes into said shuttle structure, a brake mechanism for frictionally impeding the revolution of said sheave, pneumatic cylinder and piston means for controlling said mechanism, and control means having a valve for controlling said cylinder and piston means so as to set said brake mechanism for maintaining the tension of the wire at a desired value during said winding motion and releasing the tension during said lowering intervals of said chuck assembly.

18. A machine for winding wire coils on magnetizable cores, comprising a vertically displaceable chuck assembly for accommodating the core, a substantially horizontally movable shuttle structure for issuing the wire, drive means for actuating said shuttle structure to perform a winding motion, form means engageable with the core when said assembly is in lifted position for guiding the wire from said shuttle structure into the proper slots of the core, means for lowering said chuck assembly during periods between winding operations so as to disengage said form means from the core, indexing means associated with said assembly for revolving the core a given angle when said assembly is lowered, a tongs assembly for engaging the wire between said shuttle structure and the core and pulling the wire downwardly preparatory to the lowering of said chuck assembly and holding the wire pulled down during said periods, tension regulating means having a sheave peripherally engageable by the wire as it passes into said shuttle structure, a brake mechanism for frictionally impeding the revolution of said sheave, pneumatic cylinder and piston means for controlling said mechanism, and control means having a valve for controlling said cylinder and piston means so as to set said brake mechanism for maintaining the tension of the wire at a desired value during said winding motion and releasing the tension after the release of the wire by said tongs assembly and before the beginning of another winding operation of said shuttle structure.

19. A machine for winding wire coils on magnetizable cores, comprising a vertically displaceable chuck assembly for accommodating the core, a substantially horizontally movable shuttle structure for issuing the wire, drive means for actuating said shuttle structure to perform a winding motion, form means engageable with the core when said assembly is in lifted position for guiding the wire from said shuttle structure into the proper slots of the core, means for lowering said chuck assembly preparatory to an exchange of said form means, form transfer means for exchanging said form means, a wire holding mechanism having a pair of tongs for pulling the wire downwardly between the core and said shuttle structure and being provided with pneumatic cylinder and piston means for operating said tongs, control means having a valve for causing said pneumatic means to operate said pair of tongs so as to hold down the wire between winding operations of said shuttle structure for intervals of time beginning before the lowering of said chuck assembly and ending after its return to the lifted position, tension regulating means having a sheave peripherally engageable by the wire as it passes into said shut-

tle structure, a brake mechanism for frictionally impeding the revolution of said sheave, pneumatic cylinder and piston means for controlling said mechanism, and control means having a valve for controlling said cylinder and piston means so as to set said brake mechanism for maintaining the tension of the wire at a desired value during said winding motion and releasing the tension during said intervals of tongs operation.

20. A device for controlling the tension of a wire of a coil winding machine, comprising a sheave to be peripherally engaged by the wire, guiding means for holding the wire against said sheave, a friction brake for impeding the revolution of said sheave, a cam for controlling said brake, a pivotally mounted arm connected to said cam and carrying a roller to be engaged by the wire as it passes from said sheave, said arm being biased for pivotal motion in the direction required for tightening said brake while being moved in the opposite direction at increasing wire tension whereby said brake is caused to maintain an approximately constant wire tension, pneumatic cylinder and piston means associated with said cam for moving it to a position in which said brake is adjusted for released tension, and pneumatic control means having a valve connected with said cylinder and piston means for selectively setting the device for tension regulation and tension release.

21. A machine for winding wire coils on electric machine cores, comprising a vertically displaceable assembly having a revolvable chuck for accommodating the core, lifting means for intermittently lifting and lowering said assembly, indexing means for intermittently revolving said chuck progressively a given angle, a shuttle structure for issuing the wire to be wound, shuttle drive means disposed for actuating said structure to perform a winding motion and having throw-adjusting means for varying the angular throw of said motion and reversing means for reversing the winding direction of said motion, a turn counting mechanism for controlling said shuttle drive means so as to cause it to wind a given number of turns during the respective individual periods of winding operation, a plurality of forms of different size seatable on the core when said assembly is lifted and disengageable from the core when said assembly is lowered, magazine and form-transfer means for accommodating said forms and placing them selectively, one at a time, on the core in order to have the selected core guide the wire from said structure into the proper slots of the core during said winding operations of said shuttle structure, wire holding means for temporarily engaging the wire in order to hold it pulled down between the core and said shuttle structure in intervals of time intermediate the winding operation of said shuttle bar and while said assembly is removed from its lifted position, tension control means for regulating the tension of the wire during said winding operations and releasing the tension during said intermediate intervals, and means for actuating said lifting means, shuttle drive means, magazine and form-transfer means, wire holding means and tension control means in a predetermined sequence required for winding a set of multi-coil windings, said actuating means including power drive means and a plurality of independently operable clutches for connecting said power drive means to the means to be actuated at a time, a stepping mechanism for selecting the means to be operated

at progressive phases of said sequence and controlling said throw-adjusting means and said reversing means in given phases of said sequence, a main coupling disposed between said power drive means and said stepping mechanism, electromagnetic means for actuating said main coupling so as to advance said stepping mechanism one step for each energization of said electromagnetic means, an electric control circuit disposed for energizing said electromagnetic means and having a plurality of electric switches associated with said respective clutches so as to be actuated when said respective clutches are operated due to the stepwise adjustment of said stepping mechanism, whereby each adjustment of said stepping mechanism is initiated by one of said switches to set the machine for a subsequent phase of said sequence in dependence upon the termination of the preceding operating phase of said sequence.

22. A machine as set forth in claim 21, comprising a rotatable member geared to said stepping mechanism so as to perform at most one full revolution during each complete operating sequence of the machine, and electric contact means controlled by said member and connected with said control circuit for deenergizing said circuit at the end of said sequence in order to then stop the machine.

23. A machine as set forth in claim 21, comprising a disk geared to said stepping mechanism so as to revolve once during each complete operating sequence of the machine and being disposed for the reception of at least one dog pin at a point selected in accordance with a point of said sequence at which it is desired to stop the machine, and electric contact means actuatable by said dog pin and connected with said circuit for deenergizing it when said pin reaches the position in which said switch is actuated.

24. A machine as set forth in claim 21, comprising operator-actuatable contact means connected with said circuit to control the energization and deenergization thereof in order to permit starting, stopping and inching the machine.

25. A machine as set forth in claim 21, comprising operator-actuatable mechanical controls associated with said clutches to permit operating them independently of the operation of said control circuit in order to skip selected phases of said operating sequence for the purpose of adjusting the machine.

26. A machine as set forth in claim 21, comprising a group of signal lamps electrically associated with said switches so as to be lit in dependence upon the switches open and closed at a time, said lamps being located exteriorly of the machine to indicate the instantaneous condition of the machine.

27. A machine for winding wire coils onto cores, comprising a chuck for holding a core, a shuttle structure having an eye portion for issuing the wire to be wound and being capable of performing winding motion, tension control means for holding the wire taut as it issues from said eye during said winding motion, wire holding means engageable with the wire between said eye and said chuck for deflecting the wire from its taut position, a tap-forming device having a part disposed near said chuck and movable into a position where it lies between the deflected wire and the path of said winding motion, and means for controlling said wire holding means and said tap-forming device to first deflect the wire, then move said part into said position and then release the wire between winding operations of said shuttle structure in order to cause said part to retain a wire loop.

28. A machine for winding wire coils into radial slots across the inner surface of an annular core, comprising a chuck for accommodating the core, a shuttle structure reciprocable substantially in a direction in parallel to the axis of the accommodated core and having an eye disposed for issuing the wire to be wound, means for driving said shuttle structure so that said eye performs a winding motion, a coil-shaping form seatable on the inner peripheral surface of the core for guiding the wire into the proper slots of the core as it issues from said eye during said winding motion, said form having two stop buttons biased to normally project from said form into the path of the wire in order to temporarily retain the wire and being movable into said form against their bias, said buttons being located at both axial sides respectively of the core when the form is seated in the core, two tappet means for alternately moving said buttons temporarily into said form in order to release the retained wire, and means for controlling said tappet means to operate in synchronism with said shuttle structure.

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