C. R. UNDERHILL.

WINDING MACHINE.

APPLICATION FILED NOV. 15, 1913.

1,143,335.

Patented June 15, 1915.

3 SHEETS—SHEET 1.

Fig. 1

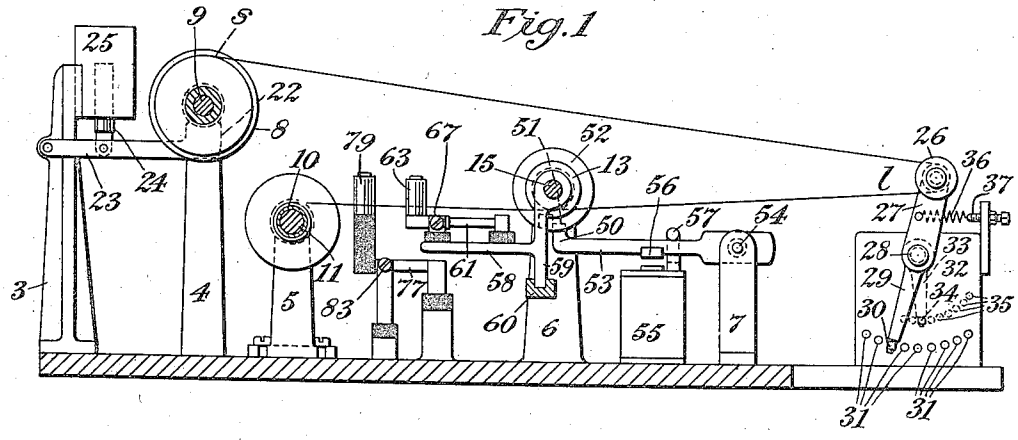
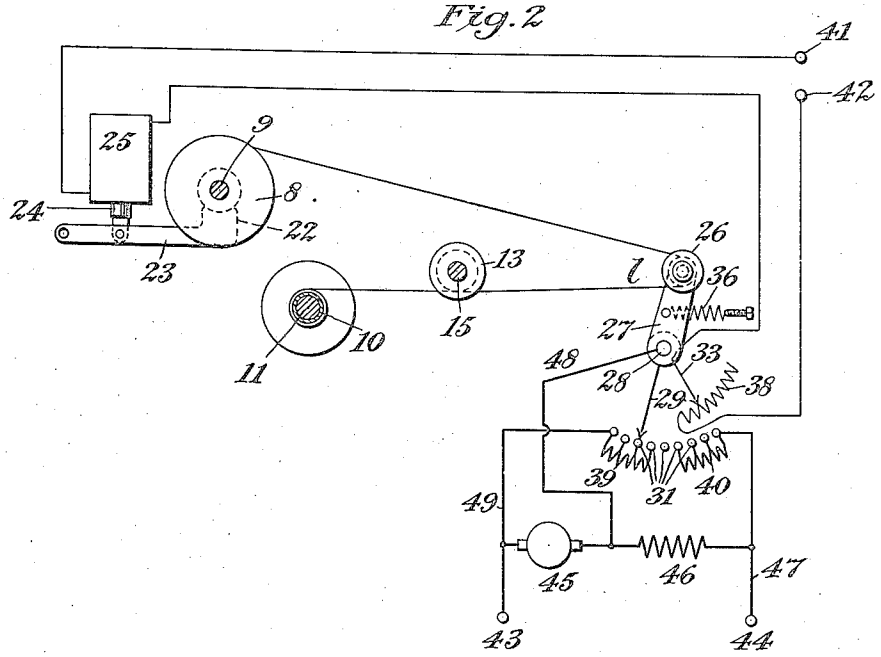


Fig. 2



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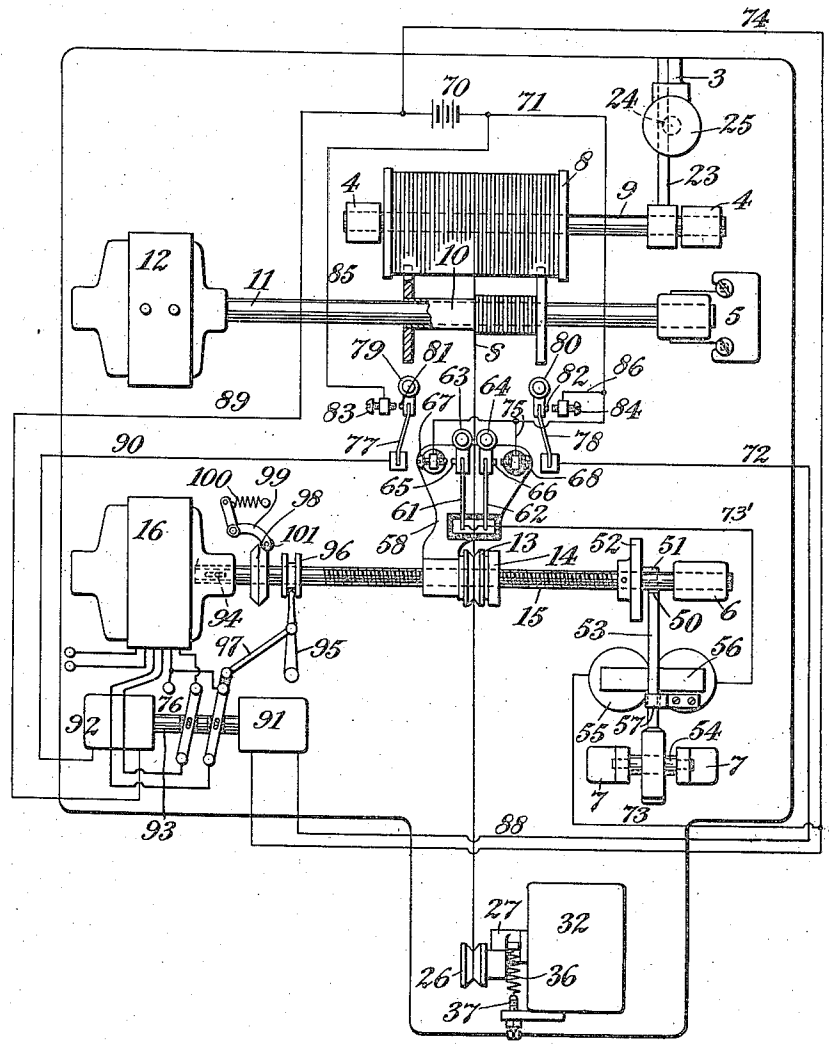
3 SHEETS—SHEET 2.

Fig. 3



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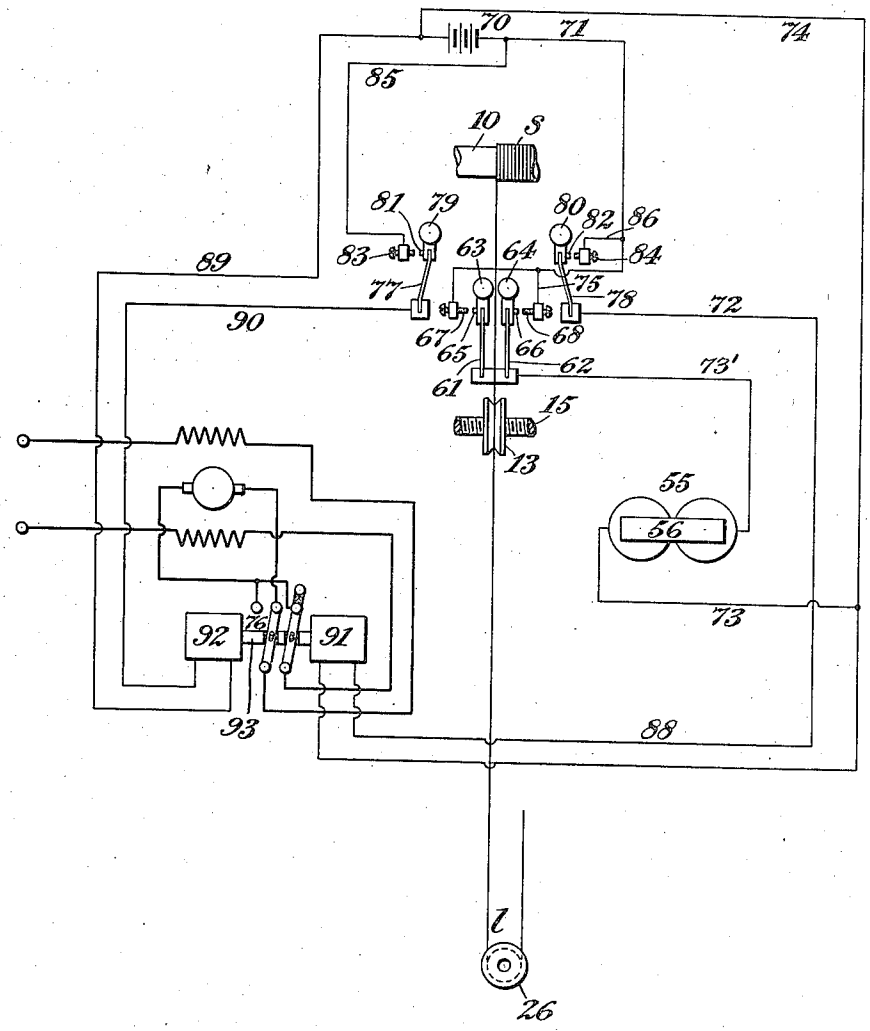
3 SHEETS—SHEET 3.

Fig. 4



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UNITED STATES PATENT OFFICE.

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WINDING-MACHINE.

1,143,335. Specification of Letters Patent. Patented June 15, 1915.

Application filed November 15, 1913. Serial No. 801,153.

To all whom it may concern:

Be it known that I, CHARLES R. UNDERHILL, a citizen of the United States, and a resident of New Haven, in the county of New Haven and State of Connecticut, have invented certain new and useful Improvements in Winding-Machines, of which the following is a specification.

This invention relates to a winding machine, and particularly to a machine for winding coils of wire traveling at high speed and under considerable tension, so that the coils formed will be in close contact with one another.

The principal object of the present invention is to provide a machine in which electromagnets made from insulated wire may be wound at high speed and a substantial constant tension maintained on the traveling strand while at the same time utilizing the strand itself to control both its own rate of travel and the manner in which the coils are wound in close contact with one another.

In winding magnets it is important to keep the tension on the wire throughout the winding operation as nearly constant as possible, and it is well known that it is exceedingly difficult to do this. In order to obtain the desired result I deem it important to provide for a mutual control between the speed of the winding mandrel and the speed of the spool or source of supply of wire to be wound upon that mandrel. To obtain such a mutual control lightness of parts is important, it being particularly important that the mandrel itself be light and that all inertia and momentum capable of effecting the rate of travel of the strand at the winding point may be as far as possible eliminated.

In winding insulated wires, in order to obtain the maximum number of coils in a given space, it is necessary to provide suitable means for laying the strand in such a manner that the coils will be in close contact with one another instead of spaced at predetermined distances apart. To do this I provide suitable means for giving the traveling strand a suitable lag so that each coil that has been wound may serve as a guide for the next succeeding coil, substantially as in the old hand-winding process. In winding insulated wires in this manner to form electromagnets it is particularly important to have a sensitive control of the position or lag of the strand during the winding of each turn, especially when winding at high speed.

The principal object of this invention is to provide an improved winding machine in which there is both a sensitive control of the tension on the traveling strand adapted to maintain such tension substantially constant, and in which there is also a very sensitive regulation by the action of the traveling strand itself of the winding of that strand in such a manner as to form a helix made up of coils in close contact with one another.

The particular embodiment of the present invention which is illustrated herein is a winding machine in which the transverse pull of the tensioned strand traveling at high speed is depended upon to govern the action of suitable controlling means operated by power outside the strand itself for positively changing the angle of lag of the strand automatically as required at various stages of the winding operation, the machine illustrated embodying both a suitable tension device of the type shown and described in my prior application, Serial No. 795,623, filed October 17, 1913, and a suitable feed mechanism of the general type disclosed in my prior application, Serial No. 796,181, filed October 20, 1913.

Other features of my present invention not hereinbefore referred to will be hereinafter described and claimed and are illustrated in the accompanying drawings, in which,

Figure 1 is a sectional side elevation of a simple type of winding machine embodying suitable means for automatically controlling the rate of travel of the strand being wound through the tension exerted on said strand, and also embodying means controlled by said tensioned strand for automatically laying the successive coils in close contact with one another in each direction of winding; Fig. 2 is a diagrammatic view and partial side elevation of those portions of said machine which cooperate for controlling the tension of the strand; Fig. 3 is a diagrammatic plan with parts broken away, of the machine shown in Fig. 1, and illustrates both the tensioning means and the means for controlling the laying of the coils in close succession, and

Fig. 4 is a diagrammatic view and partial plan illustrating more particularly the electrical controlling means governing the laying of the coils and the reversing of the direction of winding.

Similar characters designate like parts in all the figures of the drawings.

All of the various operating parts of the winding machine shown may be mounted upon a suitable base, such as 2, or upon suitable standards rising therefrom, the principal ones of which are shown at 3, 4, 5, 6 and 7. In this case the supports 4 and 5 constitute the means for mounting the spool or source of supply from which the strand comes and the winding mandrel on which said strand is to be wound.

The supply spool is indicated at 8 and is mounted on a short shaft or arbor, 9, on the supports 4, in such a manner as to turn freely unless its movement is positively retarded. The mandrel, which may be of the type shown at 10, is supported by the upright 5, in this case through a long winding arbor or shaft, 11, constituting part of the driving means for the mandrel, it being illustrated as the armature shaft of an electric motor, 12, employed for turning said mandrel.

The strand in passing from the spool 8 to the mandrel 10 travels, as usual, around a guide-sheave operative for laying the strand on the mandrel in coils in close succession. This guide-sheave may be of the type indicated at 13, it being shown as suitably mounted on a feed-nut, 14, for traveling movement back and forth along a feed-screw, 15, which may be rotated by any suitable driver, such as an electric motor, 16. This feed-screw here constitutes an extension of the armature shaft of the motor 16, and has its free end mounted in the upright 6 for support. It will be noticed that separate driving means are employed for turning the feed-screw and the arbor of the winding mandrel respectively in order that the work to be done in turning the winding mandrel may be reduced to the minimum.

In the case of the winding mandrel 10, while the rate of rotation should be substantially constant, yet in order to obtain a proper regulation of the winding action provision must be made for varying the speed of said mandrel and for obtaining a variation in the speed substantially instantaneously. For this reason the motor 12 should be one in which such a variation of speed may be readily obtained. That shown is a series motor having suitable means for controlling the action thereof and obtaining a close regulation of the speed of rotation of the armature shaft 11. I prefer to regulate the speed of this shaft by shunting more or less of the current normally passing through the field windings or armature windings, as the case may be. The manner in which this regulating action is preferably secured will be hereinafter described more in detail.

In addition to obtaining a close regulation of the rate of travel of the wire or other strand at the winding point of the mandrel, I also preferably employ means for obtaining a close regulation of the rate of travel of said strand at the point of supply. In the present case this regulation results from the employment of a brake having a graduated braking action, preferably under electrical control. I have illustrated in this construction a brake, 22, mounted on the end of a brake-lever, 23, pivoted on the support 3 and connected at a suitable point to the core, 24, of a solenoid, 25, connected in a suitable regulating circuit. The braking action of this device may be closely regulated by correspondingly regulating the pull of the solenoid.

The rate at which the strand travels is intended to be controlled by the tension thereon, this tension serving in the present case to control the rate of travel both at the point of supply and at the winding point. In order that the changes in the tension of the strand being wound may bring about a substantially instantaneous regulation of the speed of the motor 12 controlling the winding operation, or of the spool 8 controlling the paying out of the strand, or of both of these, the portion of the strand between the point of supply and the winding point is preferably carried around a suitable guide-point to form a loop and this guide-point is shiftable in a path of considerable length. The object of this is to obtain at the guide-point controlled by this loop a very sensitive action and to transmit the movement that takes place at this guide-point to another point controlling the rate of travel of the strand being wound. This guide-point in the present case is the axis of a guide-sheave, 26, mounted to turn in this instance on a rock-arm, 27, suitably pivoted at 28, and having in the construction shown a controller-arm or switch-arm, 29, carrying a contact, 30, adapted to travel over a series of contacts, 31, of a suitable rheostat, 32, for the purpose of obtaining a fine regulation of the flow of current in a controlling electric circuit, in this case the circuit of the series motor 12 governing the winding mandrel. A second controller-arm or switch-arm, 33, is also shown in fixed relation with the rock-arm 27 and carries a contact, 34, movable over a series of contacts, 35, of said rheostat in a manner similar to that illustrated in connection with the contacts 30 and 31. This second switch-arm and row of contacts here control the current through the solenoid 25.

The rock-arm 27 together with the switch-arms 29 and 33 and the guide-sheave 26

constitute a light rocking element freely movable about the axis 28 in one direction under the influence of the tension exerted by the shortening loop, *l*, of the strand, *s*, being wound, and also freely movable in the opposite direction under the influence of a suitable actuator, such as a light spring, 36, opposing the pull of said shortening loop. The tension of the spring 36 may be regulated, as shown in Fig. 1, by an adjusting-screw, 37. As the strand travels around the various rotary elements from the spool 8 to the winding mandrel and the rate of travel of the strand at the point of supply or at the winding point, or both, varies from time to time, the length of the loop *l* will correspondingly change and as it does the rock-arm 27 with its guide-sheave 26 will be swung in one direction or the other and the ratio of the movement of the mandrel and the supply-spool at every moment will be accurately indicated and measured by the position and movement of said rock-arm and the parts connected thereto. Said rock-arm will, of course, swing to the right in Fig. 1 as the tension on the strand between the point of supply and the winding point decreases, and will swing to the left as said tension increases, and becomes effective to overcome the power exerted by the spring 36. As said rock-arm swings in one direction or the other the controller-arms 29 and 33 will correspondingly swing over the contacts 31 and 35 of the two sets of resistances of the rheostat 32, and the current passing through the brake-controlling solenoid 25 and the series motor governing the rate of rotation of the mandrel will be correspondingly cut down or built up as the case may be.

The manner in which the automatic electrical controlling means just described operates to regulate the rate of travel of the strand both at the point of supply and the winding point will be clear by referring to the diagram in Fig. 2, in which the controller-arms 29 and 33 are indicated by arrows as coöperating with the rows of contacts 31 and 35 of two sets of resistance coils, one of which is indicated at 38 and serves to control the solenoid 25, while the other is divided into two sections, 39 and 40, controlling respectively the armature and field windings of the series motor 12.

41—42 and 43—44 designate terminals which, it will be understood, are connected with a suitable source or sources of electric energy, and it will be seen that when there is no resistance 38 in the circuit of the solenoid 25 and no resistance 39 or 40 in shunt with the circuit of the armature 45 or the field windings 46 of the motor 12 the full strength of the current employed to energize said solenoid will flow through the same and the full strength of the current used in the motor 12 will pass through both the armature windings and the field windings of said motor. The manner in which the controller-arm 33 moving in either direction from a central point cuts the sections of the resistance coil 38 into or out of circuit will be obvious. This solenoid circuit is shown in light lines in Fig. 2 to distinguish it from the circuit through the motor. When the controller-arm 29 is on the central contact of the series 31 the circuit of the motor 12 will be directly through the field windings and the armature windings thereof, as will be clear from said diagram. When, however, the controller-arm 29 swings either to the right or to the left on to the contacts controlling either the resistance 40 or the resistance 39 a shunt of greater or less resistance around either the field windings or the armature windings, as the case may be, will be established and a portion of the current traversing such windings will be correspondingly shunted, as will be clear from said diagram. When said controller-arm 29 reaches its extreme right-hand position the field windings 46 will be completely shunted and all the current will pass from terminal 44 through conductor 47, resistance 40, controller-arm 29 and conductor 48, to and through the armature windings without passing through the field windings; while when in its extreme left-hand position all of the current will pass from terminal 44 through conductor 47, through the windings 46, the conductor 48, controller-arm 29 and conductor 49, to the opposite terminal 43 without passing through the armature windings 45, and thus an absolute short circuit of the armature will be established, and the motor will be instantaneously stopped automatically when the controller-arm 29 reaches its extreme left-hand position.

As before stated, the strand in its passage from the supply spool 8 to the winding point of the mandrel 10 passes around the guide-sheave 13 carried by the feed-nut 14. The feed-nut 14 and the feed-screw 15 controlling its movements are here illustrated as a simple and well-known means for obtaining the desired traverse movements of the strand as it passes to the mandrel. Other means might of course be employed to accomplish the same result. In the present case these two parts 14 and 15 constitute the main elements of the positive operating means hereinbefore referred to for assuring the passage of the strand to the winding point of the mandrel with a lag corresponding substantially to the lag of the strand in hand-winding. Normally, however, said feed-nut and feed-screw have no movement, they being held under restraint by suitable means and released when the lag of the strand becomes too great. In this case an escapement mechanism having a shiftable

pawl, such as 50, normally in position for engaging the stop, 51, carried by the feed-screw 15, is employed for the purpose of releasing said feed-screw and permitting it to turn. The escapement members 50 and 51 coöperate in such a manner as to permit, in this case, only a single rotation of said feed-screw when released, the movable pawl 50 when withdrawn from the path of the stop 51 on the collar, 52, of the feed-screw being almost immediately returned into the path of said stop to engage it at the end of one rotation of said screw. Here the escapement pawl 50 is carried at the end of an armature-lever, 53, pivoted at 54 on the support 7 and normally held in the path of the stop 51 by any suitable means. It is preferably retracted out of the path of the stop 51 by the action of electrical controlling means including an electro-magnet, 55, the armature of which is shown at 56. A suitable back-stop, 57, limits the upward movement of the armature-lever 53. The magnet 55 is intended to be energized whenever the strand *s* lags too far behind the normal. It will be seen that as the winding arbor 11 turns and with it the mandrel 10 a series of coils will be wound on the mandrel which will cause the winding point of the strand to shift gradually from one end to the other of the mandrel. If the guide-sheave 13 is set at the beginning of the winding operation, as should be the case, in such a position that its guide-point has a slight lag with respect to the winding point at the mandrel and said guide-sheave remains stationary it will be obvious that the angle of lag of the strand and of said guide-point will increase progressively. The specific construction illustrated herein is one in which the controlling means operates intermittently to reduce this angle of lag by permitting an intermittent feed movement of the feed-screw 15 and the guide-sheave 13 carried thereby, this intermittent feed movement serving to permit the guide-point intermittently to follow up the movement of the strand at the winding point.

To bring about the release of the escapement mechanism just described, I have shown electrical controlling means embodying a light circuit-controlling arm in the path of the moving strand and in position to coact therewith and be shifted thereby when the angle of lag of the strand is excessive, the position of the strand at such time of course being largely determined by the tension exerted thereon. Preferably two of these circuit-controlling arms are employed one coöperating with the strand in one direction of winding of a helix, and the other coöperating with the strand when a helix is being wound in the opposite direction. These circuit-controlling arms are preferably movable in unison with the guide-sheave 13 and the feed-nut 14, they being illustrated as mounted on a bracket, 58, supported to travel back and forth on the feed-screw with an intermittent movement and suitably guided, as by means of a depending arm, 59, working in a guide, 60. On the bracket or slide 58 are mounted, in this case, two insulated circuit-controlling arms or switches, 61 and 62, the former of which is coöperative with the strand *s* when the winding is proceeding in the direction shown in Fig. 3, and the other of which is coöperative with said strand when the winding is in the opposite direction. Here each of these arms 61 and 62 carries an antifriction roller, 63 or 64, to be engaged by the tensioned strand *s*, each of these being of sufficient length to coöperate properly with the strand both at the beginning of the winding of the magnet and when the winding is about finished. Each arm 61 and 62 also carries a contact, such as 65 or 66, adapted to engage an insulated and preferably adjustable contact, 67 or 68, on the bracket or slide 58. The antifriction roller 63 is engaged by the strand and moved to the left when the angle of lag of the strand becomes excessive during the winding in the direction of Fig. 3; while the contact-arm 31 is moved in the opposite direction by a corresponding action of the tensioned strand on the antifriction roller 64 when the winding is proceeding in the reverse direction. These circuit-controlling arms are connected here in parallel branches of a controlling circuit through the electromagnet 55 from a suitable source of energy, and whenever the tensioned strand forces either of these circuit-controlling arms sidewise far enough to bring either the contact 65 into engagement with the contact 67 or the contact 66 into engagement with the contact 68 a circuit will be closed from a source of energy, such as 70, through the electromagnet 55. In the case of the controlling-arm 61, the circuit is from the battery 70 through conductor 71, contacts 67 and 65, switch-arm 61, conductor 73′, magnet 55, conductor 73 and conductor 74 back to the battery. In the case of the switch-arm 62, the course is substantially the same except that from conductor 71 the current passes by way of conductor 75, contacts 68 and 66, and switch-arm 62 to the conductor 73′. Whenever contact is made at either of the points 67 or 68 and the magnet 55 is energized the escapement will release the feed-screw and permit it to be turned instantly a single rotation by the motor 16, which will result in a single forward movement of the feed-nut 14 and the guide-sheave 13 along the feed-screw. As often as the winding of the coils on the mandrel causes an excessive lag in the portion of the tightly tensioned strand between the winding point and the guide-point of

the sheave 13 the sidewise pull of said strand will cause this feed movement to take place, and each time that it does take place the strand will be automatically shifted away from the antifriction roller 63 or 64 with which it is in engagement and it will also be withdrawn from its coöperating contact, thus breaking the circuit through the magnet 55.

Whenever the winding strand arrives substantially at the end of the mandrel its movement is intended to be reversed also in this case through the action of suitable electrical controlling means. The reversing means shown comprises a reversing switch, 76, for the electric motor 16, the action of which reversing switch may be controlled by an electric circuit including circuit-controlling arms similar to those shown at 61 and 62. The means illustrated comprises two switch-arms 77 and 78, mounted on suitable uprights and having near their free ends antifriction rollers, 79 and 80, and contacts, 81 and 82, corresponding to those of the switch-arms 61 and 62. A pair of contacts, 83 and 84, also preferably adjustable, coöperate with the contacts 81 and 82 on said switch-arms 77 and 78, said contacts 83 and 84 being also suitablv supported on the main base. Conductors 85 and 86 connect the contacts 83 and 84 respectively with the conductor 71 leading to one side of the battery 70, while conductors 74 and 88 and 89 and 90 are shown as connecting the battery through a pair of solenoids 91 and 92 with the respective switch-arms 78 and 77. A common core, 93, properly insulated is shown as connected to the reversing switch 76 and controlled by both of the solenoids 91 and 92.

The parts described are so combined and coöperate with the strand in such a manner that when the strand arrives at the left-hand end of the helix being wound in Fig. 3 it will, at the proper point, engage the antifriction roller 79 and shift the same to the left to bring the contact 81 of the switch-arm 77 into engagement with the contact 83; whereupon the circuit will be closed from the battery through conductors 71, 85, contacts 83, 81, switch-arm 77 and conductor 90, to the solenoid 92, the opposite side of which is connected through conductor 89 to said battery. When thus energized the solenoid 92 shifts the reversing switch 76 in the usual manner to reverse the direction of flow of the current through the motor 16 and thereby reverse the direction of rotation of the armature-shaft and feed-screw 15 in a manner well understood. If the tensioned traveling strand is at the opposite end of the mandrel it will, of course, shift the switch-arm 78 instead of 77, and will close contact at the points 82 and 86, whereupon the current will flow from the battery through conductors 71 and 86, contacts 84 and 82, switch-arm 78 and conductor 88 through the solenoid 91, the return circuit being by way of conductors 74 and 89. This will of course result in the energization of the solenoid 91 and the shifting of the reversing switch 76 in the opposite direction to cause a flow of current through the motor 16 in the reverse way to bring about a reversal of the direction of rotation of the armature shaft and feed-screw 15.

At the begining of the operation of winding a layer or helix, it will be necessary to give to the strand to be wound a suitable lag. This is preferably accomplished automatically with each layer after the first, that is to say, by the action of the machine itself, and means are shown herein for this purpose. The means employed may be of any proper construction, but is preferably connected with the reversing switch 76 so as to be governed thereby. By referring to Fig. 3 it will be seen that the feed-screw 15 is connected with the armature shaft by a pin-and-slot connection, 94, which permits a slight longitudinal movement of the feed-screw and parts carried thereby. The shifting of said feed-screw and parts is shown as brought about by a shifting-lever, 95, working in the groove of a collar, 96, secured to said feed-screw and connected by a link, 97, to the electrical reversing switch 76. It will be clear that on the movement of the reversing switch in the one direction or the other the connections just described will serve to shift the feed-screw end-wise in a corresponding manner the desired distance. The feed-screw should of course be held in this position to which it is shifted until the end of a new layer is reached and the parts are to be shifted again. For this purpose I have shown a double cam-wheel, 98, secured to the feed-screw, the circumference of which cam-wheel is substantially V-shaped and which coöperates with a spring-pressed rock-arm, 99, the pressure of a spring, 100, serving through an antifriction roller, 101, to hold said cam-wheel and feed-screw in either extreme position to which they may be shifted. The construction of the arm 99 is such that the movement of the feed-screw to its extreme position in either direction will cause the wheel 101 to ride over the high point or neutral point of the periphery of the cam-wheel 98 to the opposite cam face upon which it will exert pressure in the proper direction for maintaining said feed-screw in either position to which it is shifted. These devices constitute an automatic means for setting the feed-screw with its guide-sheave 13 in position to give the guide-point of said sheave a lag with respect to the winding point of the mandrel in each direction of winding.

The manner in which the tension on the

strand is varied automatically both at the point of supply and at the winding point, and the manner in which the feed mechanism operates to lay the successive coils of the winding strand in close contact with one another will be clear from the foregoing. It will also be seen that by combining the tensioning and feeding means described there results a very sensitive control of the movements of the traveling strand both in the direction of its length and sidewise or crosswise thereof. The degree of tension on the strand largely controls the amount of the sidewise pull of said strand, which in turn controls the action of the electrical means for governing the movements of the traverse device and the angle of lag of the strand; while the movements of the traverse device and the angle of lag of said strand in turn directly affect the tension on said strand. Because of this there is not only a very sensitive control of the tension by the tensioning means and of the feed by the feed mechanism, but there is also an exceedingly sensitive interdependent control of the tensioning and feeding means each by the other, which results in a correspondingly sensitive and positive control of the winding action under all conditions of operation.

It will of course be obvious that while a simple type of machine is herein illustrated having but a single tensioning unit and a single unit for controlling the feeding of the strand to vary the angle of lag thereof, multiple coils may be wound on a plurality of mandrels carried by the same or different shafts by employing the desired number of tensioning and feeding units, no change whatever being required in the mechanism in multiple winding on multiple winding arbors, and only such changes as are well-known in the art being required for multiple winding on a single winding mandrel while maintaining thorough control of the tension of each strand and of the lateral feed movement thereof.

What I claim is:

1. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of the turning mandrel, and means controlled by the strand for laying a coil on said mandrel.

2. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, and intermittently movable means controlled by the strand for laying a coil on said mandrel.

3. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, and automatic means controlled by the winding and including a source of power other than the strand being wound for positively locating the winding point of the strand and laying each coil of the tension strand on the mandrel in close contact with the last preceding coil from end to end of a helix.

4. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, and automatic means controlled by the lag of the tensioned strand being wound for laying a coil on the mandrel in close contact with the last preceding coil.

5. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, and automatically operated traversing means having a positive power action controlled by the strand for laying a coil on the mandrel.

6. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, and automatically - operated traversing means controlled by the transverse pull of the tensioned strand for laying a succeeding coil in close contact with the last coil wound.

7. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, and an automatic traverse device movable in parallelism with the axis of said mandrel and the guide-point of which is located by positive power action and at times has a lag with respect to the winding point of the coil being wound.

8. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, and automatic intermittently movable traversing means the guide-point of which at times has a lag with respect to the winding point of the coil being wound.

9. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, and automatic traversing means including a source of power other than the strand being wound the guide-point of which is positively located by power from said source

and at times has a lag with respect to the winding point of the coil being wound.

10. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, and automatic traversing means for laying successive coils on the mandrel, said means having a positive variable progressive traverse movement from a source other than said strand.

11. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, and automatic traversing means for laying successive coils on the mandrel, said means having an intermittent traverse movement.

12. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, and automatic traversing means for laying successive coils on the mandrel, said means having normally no movement and also having means controlled by the tensioned strand for imparting traverse movement.

13. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, an automatic traverse device for laying successive coils on the mandrel the guide-point of which device normally has a lag with respect to the winding point of the coil being wound, and means controlled by the tensioned strand for intermittently reducing said lag.

14. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, automatic traversing means for laying successive coils on the mandrel, and electrical controlling means governing said movement and governed by said strand.

15. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, automatic traversing means having a variable traverse movement and operative for laying successive coils on the mandrel, and electrical controlling means governing said movement and governed by said strand.

16. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, a power-operated device for laying a coil on the mandrel, and means controlled by the strand being wound for governing the movement of said power-operated device.

17. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, a power-operated device for laying a coil on the mandrel, and a controlling device mounted on said power-operated device and operable by the strand being wound for governing the movement of said power-operated device.

18. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, a power-operated device for laying a coil on the mandrel, and electrical controlling means including a yielding contact mounted on said power-operated device and operable by the tensioned strand being wound for governing the movement of said power-operated device.

19. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, a reciprocatory power-operated device for laying on the mandrel coils of helices running alternately in opposite directions, and a pair of controlling devices operable alternately by the tensioned strand being wound for governing the movement of said power-operated device.

20. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, a traverse device mounted to move back and forth for winding successive helices in opposite directions, and electrical reversing means for said traverse device, said reversing means being controlled by the tensioned strand.

21. In a winding machine, the combination with a winding mandrel, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying the rate of travel of said strand, a traverse device mounted to move back and forth for winding successive helices in opposite directions, and electrical reversing means controlled by the tensioned strand for reversing the direction of movement of said traverse device at each end of the range of movement thereof.

22. In a winding machine, the combination with a winding mandrel and with

means for supplying a strand, of a motor for turning said mandrel, electrically-controlled means for regulating the rate of travel of the strand, said means embodying an element controlling said rate of travel and a second element controlled by the tension of the strand, and automatic means including a source of power other than the strand being wound for laying each coil of the tensioned strand on the mandrel in close contact with the last preceding coil.

23. In a winding machine, the combination with a winding mandrel and with means for supplying a strand, of a motor for turning said mandrel, means controlled by the tension of the strand being wound for varying its rate of travel at the point of supply, and automatic means controlled by the winding and including a source of power other than the strand being wound for positively locating the winding point of the strand and laying each coil of the tensioned strand on the mandrel in close contact with the last preceding coil.

24. In a winding machine, the combination with a winding mandrel and with means for supplying a strand, of a motor for turning said mandrel, means controlled by the tension of the strand between the point of supply and the mandrel for varying the speed of said motor, and automatic means controlled by the winding and including a source of power other than the strand being wound for positively locating the winding point of the strand and laying each coil of the tensioned strand on the mandrel in close contact with the last preceding coil.

25. In a winding machine, the combination with a winding mandrel and with means for supplying a strand, of a motor for turning said mandrel, circuit-controlling means governed by the tension of the strand between the point of supply and the mandrel for varying the speed of said motor, and automatic means controlled by the winding and including a source of power other than the strand being wound for positively locating the winding point of the strand and laying each coil of the tensioned strand on the mandrel in close contact with the last preceding coil.

26. In a winding machine, the combination with a winding mandrel and with means for supplying a strand, of a motor for turning said mandrel, an automatic tension device controlled by the tension of the strand for varying the rate of travel of said strand, and automatic means controlled by the winding and including a source of power other than the strand being wound for positively locating the winding point of the strand and laying each coil of the tensioned strand on the mandrel in close contact with the last preceding coil.

27. In a winding machine, the combination with a winding mandrel and with means for supplying a strand, of a motor for turning said mandrel, a take-up device for controlling a loop in the strand between the point of supply and the winding point, means controlled by said take-up device for varying the rate of travel of the strand, and automatic means controlled by the winding and including a source of power other than the strand being wound for positively locating the winding point of the strand and laying each coil of the tensioned strand on the mandrel in close contact with the last preceding coil.

28. In a winding machine, the combination with a winding mandrel and with means for supplying a strand, of a motor for turning said mandrel, a take-up device for controlling a loop in the strand between the point of supply and the winding point, electrical controlling means governed by said take-up device for varying the rate of travel of the strand, and automatic means controlled by the winding and including a source of power other than the strand being wound for positively locating the winding point of the strand and laying each coil of the tensioned strand on the mandrel in close contact with the last preceding coil.

29. In a winding machine, the combination with a winding mandrel and with means for supplying a strand, of means controlled conjointly by said mandrel and supplying means for regulating the rate of travel of the strand, and automatic means controlled by the winding and including a source of power other than the strand being wound for positively locating the winding point of the strand and laying each coil of the tensioned strand on the mandrel in close contact with the last preceding coil.

30. In a winding machine, the combination with a winding mandrel and with means for supplying a strand, of means controlled conjointly by said mandrel and supplying means for maintaining a substantially constant tension upon the strand, and automatic means controlled by the sidewise pull of the lagging strand being wound and operative from a source of power outside said strand for laying each coil of the tensioned strand on the mandrel in close contact with the last preceding coil.

Signed at New Haven in the county of New Haven and State of Connecticut this 13th day of November, A. D. 1913.

CHARLES R. UNDERHILL.

Witnesses:

MARY A. MURPHY,

EVA M. VISEL.