April 23, 1963 V. L. PRICE 3,086,562

COIL WINDING MACHINE

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FIG. 8

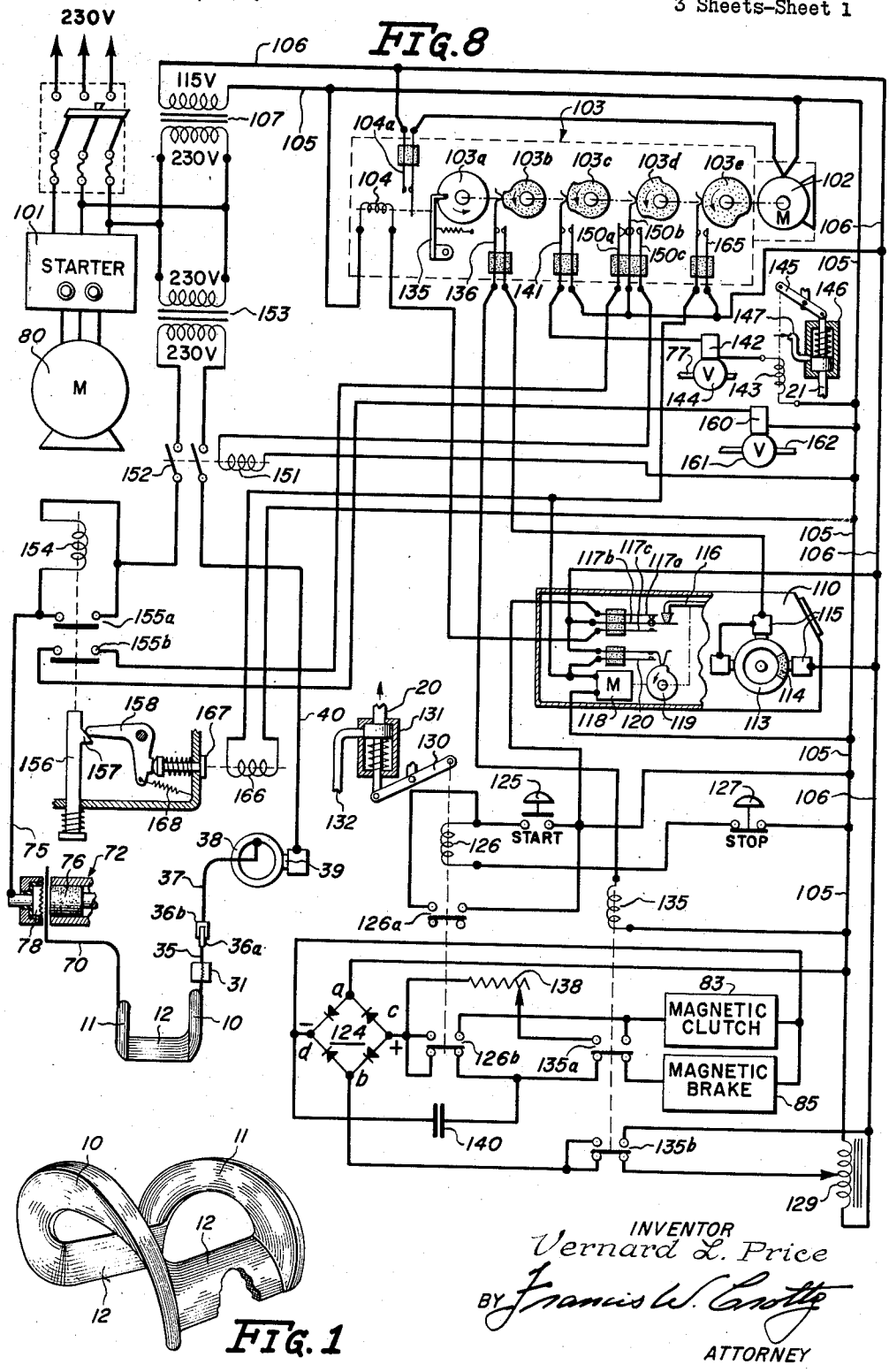


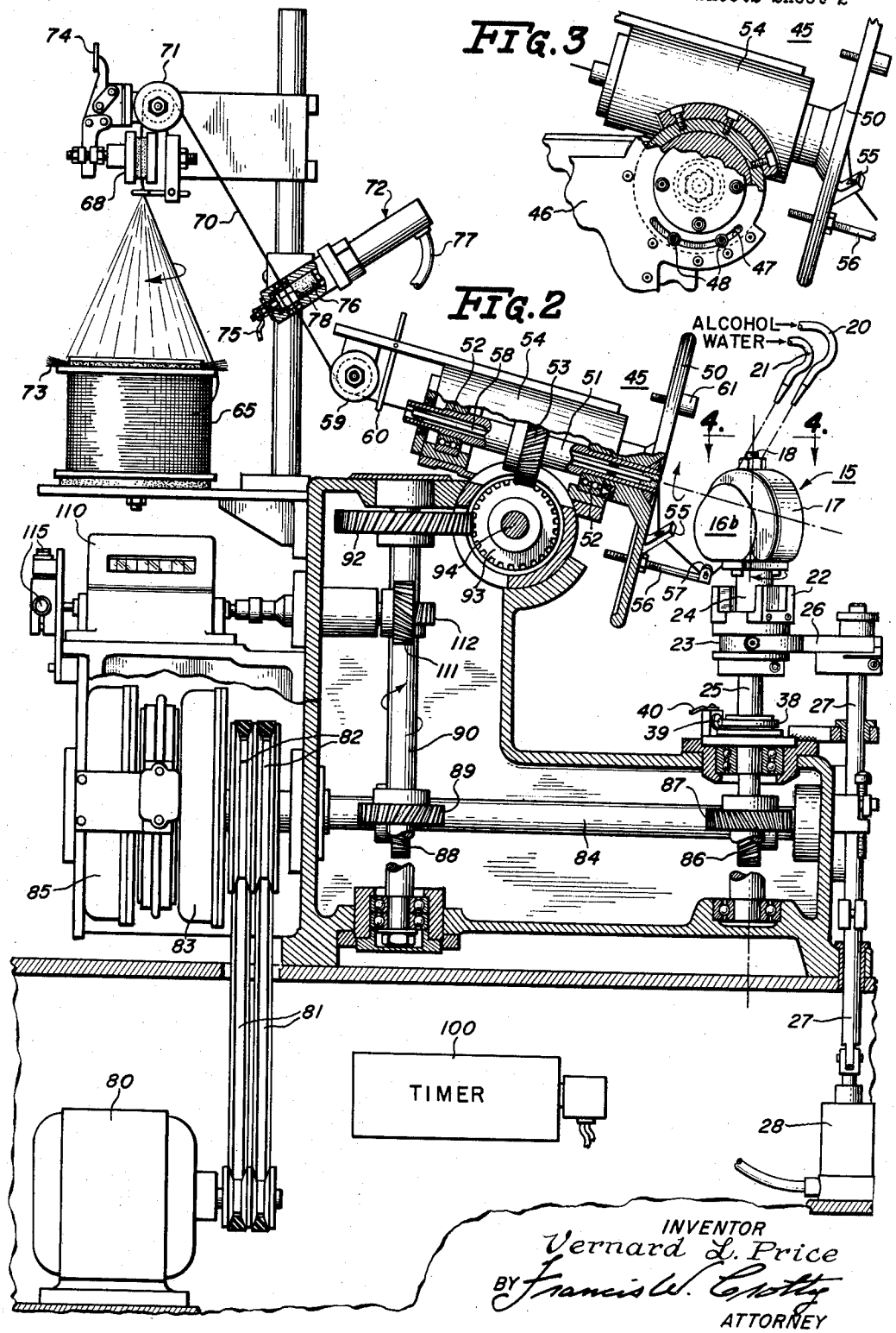
FIG. 1

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FIG. 5

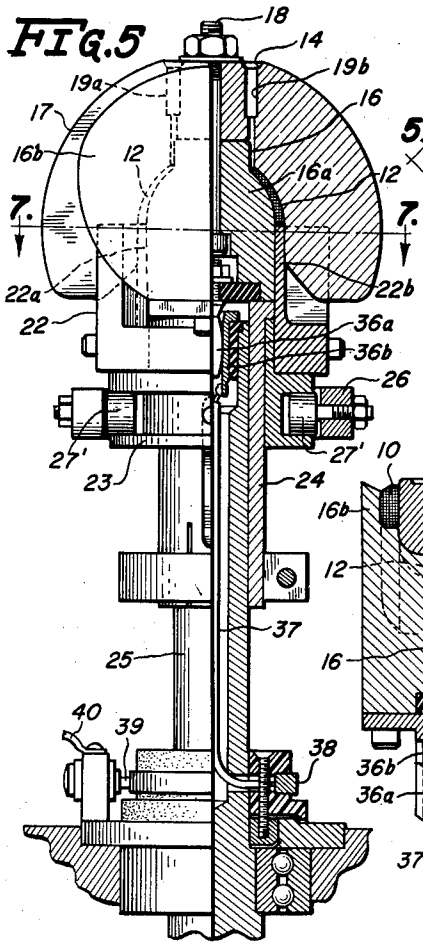


FIG. 4

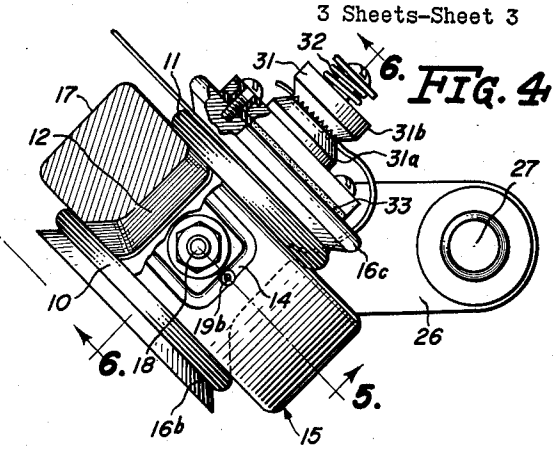


FIG. 6

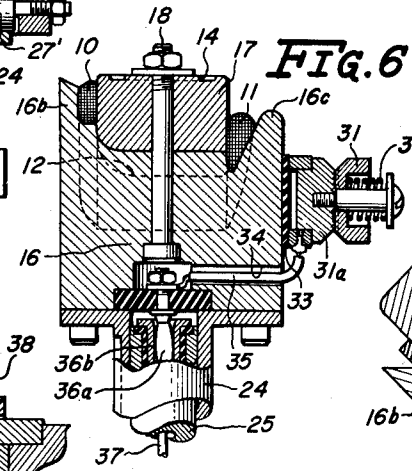


FIG. 7

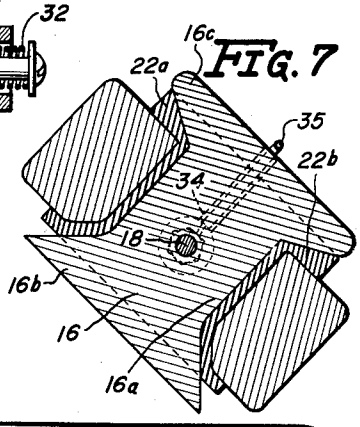
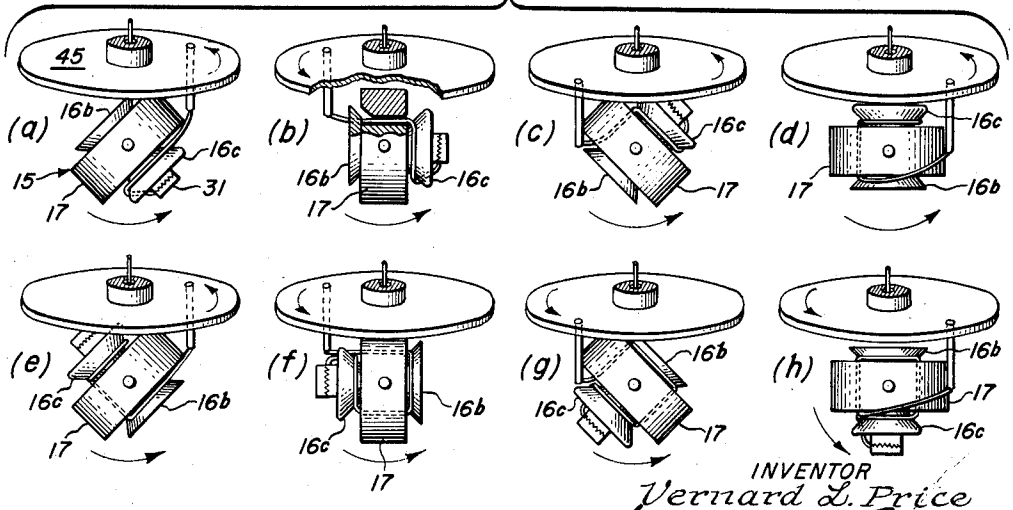


FIG. 9



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3,086,562

COIL WINDING MACHINE

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Filed Nov. 10, 1958, Ser. No. 772,989
10 Claims. (Cl. 140—92.2)

The present invention is directed to coil-winding machines and is particularly concerned with a machine for fabricating deflection coils employed to effect scansion of the electron beam in cathode-ray type devices.

Beam scansion in such devices is usually accomplished by a magnetic yoke assembly having two pairs of deflection coils in quadrature geometrical relationship so that the scanning field contributed by one pair is in space quadrature relationship to the field contributed by the other. Generally, one such field is horizontally disposed and the other is vertical.

The position of the deflection yoke upon the tube structure determines what is referred to as the center of deflection and it is desirable that this center be located forwardly of the neck portion of the tube toward the conical portion thereof. This is especially true where the angular excursion of the beam in traversing the tube screen in the horizontal or vertical direction is 90° or more. For such wide-angle deflection, the location of the center of deflection down in the neck of the tube causes undesirable electron shading and other distortion effects. Consequently, it is the practice to adopt a coil configuration which permits the yoke assembly to be mounted partially encompassing the conical section and partially encompassing the neck section of the tube. This usually results in a coil that has a forward lobe of large dimension and a rearward lobe of smaller dimension, viewed in the direction of the screen of the tube. This unsymmetrical coil configuration has created difficult fabricating problems in the art.

In accordance with one prior method the deflection coils have been formed by winding a flat or uniplanar coil which is then heated and introduced to forming dies and deformed to the desired configuration. This has the distinct disadvantage of imposing undue stresses on the winding turns and presents a definite possibility of interturn shorts.

Another approach to this problem contemplates the use of a winding mandrel which has a recess conforming to the desired configuration of the coil, and a family of cams carefully disposed with respect to the recess cooperate with a winding head to lay the wire into the recess to form successive coil turns. It is necessary to effect relative rotation of the winding head and the cams so that the laying down of the wire may be accomplished by the camming action. This winding process causes the tension of the winding conductor to vary undesirably in the formation of each winding turn and also requires a family of precisely shaped cams in addition to the mandrel. It is desirable to avoid the use of such a family of cams in directing the coursing of the winding conductor.

Still another process employs a complex mechanical movement having both reciprocatory and oscillatory motions. A linear section of the wire may be laid down on a linear traverse of a winding head and a following arcuate displacement of the winding matrix may form one lobe of the coil turn but the winding head is usually held stationary during this oscillatory movement of the matrix. Such a complex mechanical motion precludes the high-speed operation which is highly desirable and which is attainable if the machine employs continuous rotary movements. Hence, apparatus of this type is not capable of achieving the production rate and uniformity of coils that may be realized by the apparatus presently to be described.

It is an object of the present invention, therefore, to provide a coil-winding machine which avoids one or more of the aforementioned deficiencies and limitations of prior apparatus.

It is a principal object of the invention to provide an improved machine for winding coils of unsymmetrical configuration featuring continuous rotary motions and substantially constant tension of the winding conductor.

It is a specific object of the invention to provide an improved coil-winding machine for forming coils to be employed in deflection yoke assemblies of magnetically deflected cathode-ray tubes.

A coil-winding machine constructed in accordance with the invention comprises a mandrel supported for rotation about a first axis and having a recess defining a predetermined coil pattern for receiving a continuous wire and for forming that wire into consecutive coil turns having a shape corresponding to the pattern of the recess. There is a winding head rotatable about a second axis which intersects the mandrel and this winding head has a wire-feeding station which revolves about the recess of the mandrel as the winding head rotates. The machine includes means for feeding a winding conductor from a supply station to the feeding station of the winding head, as well as means for concurrently rotating the mandrel and the winding head at preselected relative speeds.

In accordance with one aspect of the invention, the axis of the winding head intersects the geometrical center of the winding recess of the mandrel and the winding head rotates at twice the speed of rotation of the mandrel.

The foregoing and other objects of the invention, together with further advantages and benefits thereof, will be more clearly understood from the following description of a particular embodiment thereof taken in conjunction with the annexed drawings in the several figures of which like components are designated by similar reference characters and in which:

FIGURE 1 is a perspective view of a deflection coil to be formed by the coil-winding machine;

FIGURE 2 is an elevation view, partly in section, of a coil-winding machine embodying the present invention;

FIGURE 3 is a detail of the mechanism enabling adjustment of the angular relation of the winding head to the mandrel in the machine of FIGURE 2;

FIGURE 4 is a view taken as indicated by section line 4—4 of FIGURE 2, showing details of the winding mandrel;

FIGURE 5 is a further view of the winding mandrel, taken along section line 5—5 of FIGURE 4 but representing the forming die advanced into its operated position;

FIGURE 6 is a further sectional view of the winding mandrel taken on section line 6—6 of FIGURE 4;

FIGURE 7 shows still another view of the winding mandrel taken along section line 7—7 of FIGURE 5;

FIGURE 8 is a schematic representation of the control circuitry incorporated in the winding machine of FIGURE 2; and

FIGURE 9 comprises a series of functional drawings used in explaining the cooperation of the mandrel and winding head in forming a coil turn.

GENERAL DESCRIPTION

Referring now more particularly to FIGURE 1, the coil there represented is the product of the machine to be described in detail hereinafter. It is one of a pair of identical coils which are assembled in a deflection yoke, arranged in mirror-image relation and electrically connected in series and energized to establish one of the deflection fields, for example, the horizontal field within a cathode-ray tube. Each coil terminates in semicircular lobes 10 and 11 interconnected by a two part linear sec-

tion 12. Lobe 10 is the larger and is shaped to fit the conical section of the tube enevelope adjoining its neck section while the remaining lobe is shaped closely to embrace the neck section. This permits the yoke assembly to be positioned forwardly of the neck section of the tube properly to locate the center of deflection. The coil is one continuous winding wound to constitute a succession of coils turns of generally similar configuration.

The machine for forming such a coil has certain major components including a winding mandrel, a winding head, a common drive for effecting concurrent relative rotation of the mandrel and winding head, and a timing and control system to assure that the several winding steps take place in a desired prescribed sequence. These several components will be considered seriatim.

WINDING MANDREL

The winding mandrel 15 is supported for rotation about a first axis, specifically a vertical axis, and has a recess defining a predetermined coil pattern for receiving a continuous wire and for forming the wire into consecutive coil turns having a shape corresponding to the pattern of the recess. Details of this mandrel are revealed in FIGURES 4 to 7, inclusive.

The mandrel includes a first portion 16 having the general configuration of a saddle with a linear central section 16*a* terminating in enlarged flanges 16*b* and 16*c* at its opposite ends. The mandrel further includes a U-shaped second portion 17 which is removably secured to the first portion intermediate its flanges 16*b*, 16*c* by means of a mounting bolt 18. The confirmation of these two portions of the mandrel, their specific dimensions and shapes, define a winding recess the pattern of which imposes a definite shape to a coil constructed by forming continuous winding turns in that recess. The section represented in FIGURE 6 shows the coil constructed by the laying of successive coil turns into the recess defined by mandrel portions 16 and 17. Lobe 10 which is specifically larger in diameter than lobe 11 results from the shaping of the saddle 16. The linear portion 12 of the coil appears in broken construction line in this figure.

A pair of channels 19*a*, 19*b* are formed in mandrel portion 17, entering into the recess of the mandrel to facilitate the introduction of certain fluids into the recess in particular parts of the coil-forming process. More specifically, it is contemplated that the coil will be formed of a winding conductor having an insulating coating, and a thermo-plastic cement coating, and a solvent introduced into the recess through one of these channels tends to soften and dissolve the cement so that the application of heat, subsequent thereto, cause the cement to coalesce and integrate the coil turns to one self-sustaining structure. Alcohol is a suitable solvent for the cement coatings and may be admitted into one of these channels through a tube 20, extending from a supply tank. Moreover, after the coil has thus been constructed into one integrated whole, it is proposed to introducing a coolant, such as water, through one of the channels as well as on lobes 10 and 11 to cause the coil structure to solidify or congeal preparatory to its removal from the coil recess. Tube 21 may extend from a water supply to one of these channels. The piping 20 and 21 is shown schematically in FIGURE 2 because the details of the connection from an alcohol and a water supply to the mandrel is of no great moment. Structures for connecting such supplies to the mandrel will be well understood by those versed in the art. In order to distribute the fluids through the winding recess, it is convenient to form a rectangular trough 14 in the upper surface of mandrel portion 17 and to have channels 19*a*, 19*b* lead therefrom.

While the recess of the mandrel imparts to the coil the general confirmation it is to have, it is desirable that the mandrel include a forming die movable into juxaposition with the winding recess accurately to form the coil turns therein to the desired pattern. A forming die 22 is movable axially of the mandrel between a normal or rest position represented in FIGURE 2 and an operated or actuated position represented in FIGURE 5. In plan view, the cross sectional configuration of the die matches or is complementary to the pattern of the winding recess as viewed looking upwardly of the mandrel into the cavity defined by its parts 16, 17. This is clearly represented in the sectional plan view of FIGURE 7 where the die portions 22*a* and 22*b* may be observed closing the spacing between mandrel portions 16, 17. The forming die is mechanically affixed to a yoke 23 which is slidable upon a collar 24 clamped and keyed to a shaft 25 supporting the mandrel to the end that the angular orientation of the die and mandrel portions 16, 17 is maintained fixed. The displacement of the forming die between its actuated and rest positions is accomplished by a bifurcated lever 26. While lever 26 is movable in a vertical plane, it does not accommodate rotation and therefore yoke 23 is provided with a race for receiving rollers 27' secured to the tines of lever 26. This lever is carried by a vertical shaft 27 supported by the framing of the coil-winding machine for reciprocal motion in a vertical plane. Its motion is under the control of an air cylinder 28 mechanically coupled to shaft 27 and comprising means for advancing the die into operating relation with respect to the winding recess of the mandrel.

Passing reference has been made above to the fact that a heating current is supplied to the coil as one step of the coil-winding process. This is achieved by means of circuitry which includes portions of the mandrel assembly. In particular, a clamp 31 is supported by mandrel portion 16, being affixed to the flange 16*c* thereof by means of mounting screws. The clamp is of well-known construction having two portions 31*a* and 31*b* provided with serrations or teeth on the surfaces which face one another. Clamp portion 31*a* is stationary but the other part 31*b* is rotatable and is axially movable although it is normally urged into clamping engagement with clamp 31*a* by means of a spring 32. This clamp may be manually opened by lifting part 31*b* against the force of its spring to admit the leading end of the winding conductor in order to anchor that end as required for the winding operation.

It is desirable that clamp 31 be one terminal of the heating circuit so that while it anchors the winding conductor it, at the same time, continues an electrical circuit to that conductor. An adequate electrical connection may be assured by turning clamp portion 31*b* in order to scrape the insulation off the section of the winding conduction that is secured within the clamp. Stationary clamp portion 31*a* is insulated from mandrel portion 16*c* by means of an insulating spacer 33 which appears in FIGURE 6. A channel way 34 cut into mandrel portion 16 accommodates a lead or connector 35 which connects clamp 31 to the terminal post of the male portion 36*a* of a banana plug having a mating portion 36*b* secured at the top of mandrel shaft 25 which has a central bore. The circuit in question is continued from plug connector 36 by means of a lead 37 to a contact ring 38 supported in the bearing block of mandrel shaft 25. A brush 39 engages contact ring 38 and receives a lead 40 for continuing the heater circuit to a power supply to be considered hereinafter.

WINDING HEAD

A winding head 45 cooperates with mandrel 15 in forming the coil turns. The winding head is rotatable about a second axis intersecting mandrel 15 along its axis and preferably at the geometrical center of the winding recess formed in the mandrel. Obviously, the specific physical dimensions and shape of the coil turns to

be wound are determined by the winding recess of the mandrel as indicated above and, therefore, it is contemplated that portions **16**, **17** of the mandrel be removable so that different pairs of mandrel sections may be selectively put into effect in accordance with the requirements of any particular winding operation. Therefore, it is desirable that winding head **45** be adjustable as to its angular orientation with respect to the mandrel axis to facilitate establishing the axis of the winding head to intersect at the geometrical center of the winding recess. Thus the winding-head assembly, as represented in FIGURE 3, is secured to a stationary portion **46** of the machine frame in a manner which permits angular adjustment of the winding head. The machine frame in this region is provided with an arcuate slot **47** to which the winding-head assembly is adjustably locked by machine screws **48** at a desired angle with respect to the axis of mandrel **15**.

The winding head comprises a circular plate **50** secured at the end of a hollow shaft **51** which shaft is rotatably supported in bearing blocks **52** of conventional construction. The shaft bearing blocks and its driven gear **53** are enclosed within a housing **54**. Plate **50** carries a guide **55** through which a winding conductor may be led to a wire-feeding station located on the winding head but displaced from the axis thereof to revolve about the winding recess of the mandrel as the winding head rotates. The wire-feeding station may be a needle type structure comprising a threaded shaft **56** carrying a wire-guide roller **57** at one end and engaging plate **50** at the other. This permits adjusting the axial spacing of guide **57** with respect to plate **50** and also with respect to mandrel **15**. Since the machine is to operate upon a wire conductor, the guides must be made of a material having a suitable hardness; they may conveniently be formed of carbide. In addition to guides **55** and **57**, it may be convenient to locate guides at the terminal portions of shaft **51** and, if desired, there may be a sleeve **58** included within shaft **51** as a covering and further guide for the wire.

The winding conductor is led into the shaft by means of a flanged roller **59** and a guide **60**. Obviously, needle **56** and guide **55**, unless counter-balanced, constitute an eccentric load on the winding head and establish an undesirable mechanical unbalance in the structure. This is avoided by using a counter weight **61** positioned on plate **50** at the appropriate distance but in the opposite direction from needle **56**.

A spool **65** represents the supply of winding conductor and the conductor feeds from that spool or other suitable container (buckets and drums) through a clamp **68** which applies a drag and some tension to the conductor **70**. From this clamp the wire leads over a pulley **71** through guides of another fixture **72** to pulley **59** leading to the winding head. All of this comprises means for feeding the wire conductor from a supply station to the feeding station of the winding head. The supply reel **65** may have radially extending bristles **73** which add further restraint on the wire and prevent overrunning of the reel. A thumb release mechanism **74** permits clamp **68** to be opened in order to facilitate leading the winding conductor from spool **65** to guide roller **71**.

One portion of the heating circuit for the coil formed within the mandrel has been outlined in discussing the mandrel and another part of that circuit may be conveniently considered at this juncture particularly with respect to the feed from supply reel **65** to the winding head. Intermediate guide pulleys **59** and **71**, there is a fixture **72** having guides in diametrically opposed portions of a cylindrical casing through which winding conductor **70** is threaded. One end of the fixture accommodates a terminal **75** to which a lead from the power supply for energizing the heater circuit may connect. Terminal **75** carries at the end which enters into the bore of fixture **72** a serrated plate **78** forming the end wall of an air cylinder and insulated therefrom. A piston **76**, having an insulated head and shaft, is included in that cylinder and may be displaced, upon the admittance of air via a supply tube **77**, to drive winding conductor **70** by an insulated member of cylinder against serrated plate **78** to extend an electrical connection from terminal **75** to the winding conductor.

DRIVE MECHANISM

The mandrel **15** and winding head **45** share a common drive system which constitutes means for concurrently rotating the mandrel and the winding head at preselected relative speeds. For the case under consideration, the winding head rotates at twice the speed of the mandrel.

The drive includes a motor **80** coupled through V-belts **81** to pulleys **82** which may be mechanically coupled through a conventional magnetic clutch **83** to a principal drive shaft **84**. This shaft is also provided at one end with a magnetic brake mechanism **85** of any conventional type.

Drive shaft **84** is supported by suitable journals and bearings from the frame of the machine and is gear coupled to shaft **25** of the mandrel. This coupling is afforded by a gear **86** on shaft **84** and a meshing gear **87** carried on the mandrel shaft. Suitable bearings for the mandrel shaft are represented in FIGURE 2.

The mechanical coupling from shaft **84** to shaft **51** of the winding head includes a gear **88** carried by shaft **84** and meshing with a gear **89** of a vertical intermediate drive shaft **90** likewise supported by suitable bearings for rotation about a vertical axis. Near the uppermost bearing this intermediate shaft carries a gear **92** meshing with a gear **93** carried on a horizontal intermediate shaft **94** and in turn coupled with driven gear **53** of winding head shaft **51**. Shaft **94** lies in the planes of gears **92** and **53** to permit the previously discussed angular positioning of the winding head. As indicated, the gear drives are proportioned to achieve a rotational speed of the winding head which is twice that of the mandrel.

TIMING AND CONTROL SYSTEM

The correlation of the several functions carried out by the mechanism is under the control of a timing and control system shown symbolically in FIGURE 2 by the block **100** and outlined further in FIGURE 8. Actually, the timer is made up of controlled circuits operated in timed relation with respect to one another through the agency of suitably shaped cams driven from a timing motor. The circuits are opened and closed by these cams in conventional fashion and cause the energization and de-energization of a plurality of controlled relays required to time the several functions of the winding machine.

The principal driving motor **80** connects through a starter mechanism **101** to a three-phase 230 volt supply system and it is contemplated that this motor will be connected to that supply to remain in operation for extended periods, reliance being placed on the operation of magnetic clutch **83** and brake **85** to effect winding operations at desired intervals. The timing and control system, per se, comprises a timing motor **102** for driving a cam shaft on which is mounted a cam assembly **103**. The several cams of this assembly have such cam sectors and such relative angular orientation on their shaft as to impose a desired programming or time sequence upon the controlled circuits. Timing motor **102** is normally de-energized because contacts **104***a* of relay **104** are normally open. Closure of these contacts connects the motor across a pair of busses **105**, **106** which are fed from the primary winding of one isolation transformer **107** energized from the three-phase supply.

Relay **104** may be energized by a contour **110** which counts the rotations of mandrel **15**. Referring to FIGURE 2, it is seen that this counter is mechanically coupled to the common driving system by means of gears **111** and **112** carried by a shaft of the counter and by intermediate shaft **90** of the driving system, respectively. No

novelty is predicated upon the structural details of this counter which may be of any well known form. For purposes of convenience, certain segment elements of the counter are illustrated schematically in FIGURE 8. It is represented as having an orienting device in the form of a ring **113** which is conductive except for a segment **114**. A group of three brushes **115** associated with ring **113** permit a circuit to be closed through the ring for all operating intervals, except when it assumes the angular aspect in FIGURE 8 presenting insulating segment **114** to the brush connected with bus **106**.

As is customary, the counter may be set to exert a control effect upon attaining a preselected count register. Accordingly, a lever **116** indicates the control device actuated by the counter at the time a desired count has been achieved. Actuation of this lever displaces movable contact **117***b*, opening a circuit at stationary contact **117***a* and completing a different circuit at contact **117***c*. The counter will further be considered as including a re-set motor **118** driving a cam **119** to control a pair of contacts **120** such that re-set, when achieved, presents the several components of the counter in a desired reference angular orientation so that the counter always commences the counting function from a fixed reference. Contacts **120** close a circuit to maintain motor **118** energized for a period of time required to accomplish re-set.

Magnetic clutch **83** and magnetic brake **85** of the coil-winding machine are D.C. operated from a rectifier bridge **124** having diagonal points *a*, *b*, *c* and *d*. Diagonals *a* and *b* connect to supply mains **105**, **106** and a D.C. output is attained at the opposing diagonals *c* and *d* with the polarity indicated on the drawing.

It is convenient to outline the circuitry of the control system of FIGURE 8 in conjunction with a recitation of the operation of the apparatus.

OPERATION

In describing the operation of the coil-winding machine, first consideration will be given to the many operating steps occasioned by the control system without regard to the details of laying consecutive turns of winding conductor **70** within the winding recess of mandrel **15**. The details of that aspect of the operation will be given hereinafter in a discussion of the functional views of FIGURE 9.

Machine Set-Up

It will be assumed initially that the machine has been set up with the conductor **70** threaded to the mandrel. This, of course, assumes that the mandrel and winding head are in their desired starting positions indicated in FIGURE 2. The winding conductor is led through clamp **68** by the operation of finger release **74** which parts the clamp for that purpose. Thereafter, it may be readily fed over guide roller **71** through the successive guides of clamp fixture **72**, and of the winding head to the needle of feeding station **57** thereon. Finally, it passes under portion **16** of the mandrel and is introduced between jaws **31***a*, **31***b* of clamp **31**. As these jaws are returned to normal position, the insulation of the anchored conductor is scraped away by turning jaw **31** or penetrated by the jaws to establish an electrical connection to the conductor as well as to anchor it securely against movement. Starting switch **125** is now momentarily depressed.

Start of Winding Process, Loading of Solvent Pump

A circuit is complete from bus **105** through the closed starting switch **125**, through a relay **126**, closed stop switch **127** to the alternate bus **106**. Energization of relay **126** closes its movable elements **126***a*, **126***b* to engage associated stationary contacts. Closure of contact **126***a* completes a hold circuit for relay **126**. At the same time, closure of contact **126***b* releases magnetic brake and applies operating potential from rectifier terminal *c* to magnetic clutch **83** and rectifier terminal *d*. It is apparent that diagonals *a*, *b* of the rectifier bridge are across bus **105** and a tap of a winding **129** which connects to bus **106**.

As relay **126** attracts its armature, it displaces a pivoted actuator **130** to retract the piston of a pump **131** downwardly to unblock an intake valve. A conduit **132** leads from a supply of solvent, such as alcohol, to this intake valve and the pump is thus charged or loaded so that when its piston is subsequently thrust vertically upwardly, it discharges a measured quantity of alcohol through a discharge duct **20** leading to trough **14** and channels **19***a*, **19***b* in the mandrel. Of course, the pump will be equipped with a check valve of known type (not shown), assuring that displacement of the piston forces the charge of solvent out conduit **20** rather than back into the supply through conduit **132**.

Operation of the clutch permits driving motor **80** to set the machine into operation, causing mandrel **15** to rotate at one speed and causing winding head **45** to rotate concurrently but at twice the speed of the mandrel. It also initiates operation of counter **110** through mating gears **111**, **112**.

The concurrent rotation of mandrel **15** and winding head **45** results in needle **57** coursing or gyrating about the winding recess formed within the mandrel. In this fashion, the winding conductor is, in effect, laid into the several parts of the winding recess as required to form a succession of coil turns. The details of this winding operation will be considered more particularly hereinafter in connection with a discussion of FIGURE 9. When the required number of coil turns has been formed, counter **110** will have attained a corresponding register and, in so doing, will have advanced its control lever **116** counter clockwise. This displaces movable contact **117***b* from engagement with contact **117***a* into engagement with contact **117***c*.

Completion of Winding Process, Actuation of Solvent Pump

Breaking the engagement of contacts **117***a* and **117***b* deenergizes relay **126** and its movable elements **126***a*, **126***b* fall from their upper to their lowermost positions, the latter being represented in FIGURE 8. As a consequence, the energizing circuit of clutch **83** is broken and the driven components of the winding machine are brought to rest. This is accomplished by means of magnetic brake **85** which is energized through a circuit from bridge terminal *c* through contacts **126***b*, contacts **135***a*, brake **85** to bridge terminal *d*.

At the same time, the release of its armature by relay **126** deflects control lever **130** in a clockwise direction and advances the piston of solvent pump **131** vertically upwardly. A measured quantity of solvent is thus discharged through duct **20** into mandrel **15**. The solvent enters the winding recess of the mandrel and spreads over the formed coil turns. The solvent chosen partially dissolves the thermo-plastic cement coating of the winding conductor, preparatory to the integration of the coil turns into a unitary whole under the influence of heat supplied through a circuit presently to be described.

Reset of Mandrel and Winding Head

Displacement of movable element **117***b* within timer **110** closes a circuit to effect energization of timing motor **102** which controls a cam assembly **103** for programming or establishing a sequence of other functions. In particular, a circuit is completed from bus **105** through relay **104**, contact pair **117***b*, **117***c* to bus **106**. Relay **104**, in attracting its armature, retracts a blocking lever **135** normally seated within a recess in cam *a* of cam assembly **103**. A contact pair **104***a* is closed at the same time, completing an obvious energization circuit for timing motor **102**. Thus, the timer is conditioned to execute one revolution of its cam assembly.

Cam *b* of assembly **103** is the first to operate movable contacts associated therewith. These contacts **136** are normally open but close as cam *b* rotates in a counter-clockwise direction. The closing of this contact pair extend a circuit from bus **106** through brushes **115** if conductive segment **113** of a ring included within and rotated concurrently with counter **110** permits. The circuit is completed through contact pair **136**, relay **135** to the other bus **105**. Relay **135** elevates its movable elements **135***a*, **135***b*. The first of these re-energizes clutch **83** from bridge terminal *c*, through a potentiometer **138**, contacts closed by element **135***a*, clutch **83** to the other side of the bridge at terminal *d*. The potentiometer **138** reduces the potential applied to the clutch to establish a slipping condition rather than a fully actuated condition so that motor **80** drives the apparatus slowly. At the same time, the voltage applied across the bridge is increased since switch element **135***d* connects bridge terminal *d* directly to bus **106** rather than through a tap of coil **129**. Full rectifier voltage is now applied from terminal *c* through contact **126***b* to a condenser **140** and terminal *d*, charging the condenser for a purpose to be considered presently.

For the described conditions, motor **80** effects slow rotation of the mandrel and winding head as well as counter **110**. This is accomplished in order to return the mandrel and winding head to a desired reference position established under the control of commutator **113**, **114** carried by the counter. When the commutator assumes the position represented in FIGURE 8, presenting insulating segment **114** to brush **115**, the circuit otherwise completed through contact pair **136** is interrupted.

Interruption of that circuit de-energizes relay **135** and restores movable elements **135***a*, **135***b* into engagement with the lower pair of associated fixed contacts as illustrated. This displacement of contact element **135***a* reinstates the energizing circuit of magnetic brake **85**. In this instance, however, the charge on condenser **140** energizes the brake with the higher voltage and arrests the machine immediately to retain the parts in the angular orientation corresponding to the positioning of insulating segment **114** of the counter commutator against brush **115**. Of course, condenser **140** effects sudden and complete braking action and the potential supplied to the brake from bridge terminals *c*, *d* retains the brake in its operated condition. With relay **135** de-energized and switch element **135***b* returned to the position represented, the bridge is again excited from the tap of coil **130** which is the low voltage condition first described.

Actuation of Clamp Fixture and Loading of Coolant Pump

The portion of cam *c* of cam assembly **103** serving normally to open contact pair **141** has such arcuate length as to retain this contact pair open until the described mechanism is able to restore the rotatable components of the coil-winding machine to their reference position following the fabrication of the desired number of conductor turns within the winding recess of mandrel **15**. Thereafter, cam *c* closes these contacts completing an obvious circuit from bus **106**, through contact pair **141**, a first valve operating relay **142** and a further valve operating relay **143** to bus **105**.

Operation of relay **142** causes a valve **144** in an air line **77** coupled to clamp fixture **72** to open admitting air under pressure thereto. The piston **76** is thrust forward, clamping winding conductor **70** between the end of the piston and the serrated portion **78** of terminal **75**. Of course, the leading end of the piston may likewise have serrations and the impact causes the serrations to penetrate the insulation of the winding conductor. Electrical connections are now complete at two points along the winding conductor; the first is made at clamp **31** of mandrel **15** and the second is made at fixture **72**. These contact points are at opposite sides of and in series relation with the several coil turns formed in the mandrel.

Relay **143** energized at the same time as relay **142** operates a lever **145** to lift the piston of a coolant pump **146**. This admits a measured amount of a coolant, such as water, from an intake conduit **147** to the pump chamber for subsequent discharge through tube **21** into trough **14** and channelways **19***a*, **19***b* of mandrel **15**. Pump **146** may be the same as pump **131**, and both are of any conventional design.

Heating of Coil Structure

Directly thereafter, cam *d* of assembly **103** permits movement of the middle or intermediate element **150***b* from engagement with a contact **150***a* into engagement with an alternate contact **150***c* completing an obvious circuit through a relay **151**. Operation of relay **151** closes a switch **152** and completes a heater circuit from one side of another isolation transformer **153**, through switch **152**, a relay **154**, through clamping fixture **72** to winding conductor **70**, through the formed coil within the confines of the winding recess of the mandrel, to clamp **31**, conductor **35**, plug **36***a*, **36***b*, conductor **37**, collector ring **38** and brush **39**, lead **40**, switch **152** and the other side of isolation transformer **153**. Energization of relay **154** lifts movable elements **155***a*, **155***b*. It also elevates a locking plunger **156** in a position in which its projection **157** rests on top of a bell crank **158**, locking contacts **155***a*, **155***b* in their closed positions. This, in effect, short-circuits relay **154** and locks the heating circuit to maintain a flow of heating current through the formed coil. Heating current is maintained for a sufficient period of time that its thermo-plastic insulating coating, which had previously been partially dissolved under the influence of alcohol admitted into the winding recess, welds itself into a unitary whole capable of retaining its own shape when removed from the mandrel. As a practical matter, the winding conductor is of the type having a double coating of insulation. The outer coat is a thermo-plastic cement which softens under the influence of the heating current. The inner insulating coating is not affected by the heating.

Although contact element **155***b* has been closed against its stationary contacts, the circuit in which it is located is open at contact pair **150***a*, **150***b* so that for the time being, closure of switch element **155***b* does not complete any circuit although it conditions one presently to be discussed.

Actuation of Conforming Die

After the desired heating period has transpired, cam *d* of assembly **103** displaces movable element **150***b* of switch bank **150** into engagement with its alternate contact **150***a*. The energizing circuit of relay **151** opens and interrupts the heating circuit. At the same time an obvious circuit is closed through contact pair **150***a*, **150***b*, contacts **155***b* and a valve operating relay **160**. The valve **161** controlled thereby is located in an air line **162** leading to air cylinder **28**. The piston contained within that cylinder is advanced vertically upwardly to elevate shaft **27**, lever **26** and conforming die **22**. Thus, the die is inserted or introduced into the recess of the mandrel, fitting in the space between portions **16** and **17** of the mandrel as indicated in FIGURE 7. The conforming die urges the coil turns within winding recess of the mandrel against the confining surfaces thereof to assure the desired confirmation of the coil.

Clamp Release and Cooling of Coil

Presently, cam *c* of assembly **103** opens its associated contact pair **141**. This de-energizes both valve actuating relays **142** and **143**. The first of these releases clamping fixture **72** and frees winding conductor **70** therefrom. De-energization of relay **143** restores the piston of water pump **146** to the position shown, discharging a measured quantity of water through conduit **21** into trough **14** and channels **19***a*, **19***b* of the mandrel. The admitted coolant quenches the coil form and, in effect, freezes it into the

shape imposed by the conjoint operation of the mandrel and the conforming die **22**.

Reset of Conforming Die and Counter

Finally, cam *e* of assembly **103** closes contact pair **165**, energizing an obvious circuit including relay **166**. When this relay attracts its armature **167**, belt crank **158** is permitted to be rotated counter-clockwise under the influence of a spring **168**. Lever **156** is released and restores elements **155***a*, **155***b* to the position shown in the drawing in which they are out of engagement with the stationary contacts that they are brought to bear against when relay **154** operates. The circuit broken due to the displacement of contact **155***b* includes valve operating relay **160**. As that valve is de-energized, the air supply to cylinder **28** is interrupted, permitting mechanism **26**, **27** to descend and withdraw forming die **22** from the bottom area of the winding recess formed in mandrel **15**.

It is also apparent that closure of contact pair **165** completes a circuit through a re-set motor **118** within counter **110**. This motor drives a re-set cam **119** which closes the contact pair **120**. Closure of contact pair **120** completes a circuit from bus **105**, through motor **118**, contact pair **120** to the other bus **106** and maintains the re-set motor in operation for one complete revolution. At the end of that time, cam **119** opens contact pair **120** and de-energizes the re-set motor. In the interim, control lever **116** within the counter will have been re-set to the position represented schematically in FIGURE 8. This, of course, re-sets the counters as well as the switch assemblies within mechanism **110** and prepares the control system for another cycle of operations. Thereafter, the recess of cam *a* in cam assembly **103** is presented to locking lever **135**. As this lever enters the recess, contact pair **104***a* open, timing motor **102** is de-energized and the cam assembly is locked against further rotation.

With the machine thus stopped, after the formation of a coil assembly, U-shaped portion **17** of mandrel **15** may be removed and the completed coil may be withdrawn. It is only necessary to return mandrel portion **17** into position and rethread winding conductor **70** through the mandrel as afore-described in order to prepare for the winding of the next coil.

WINDING DETAILS

The coil-winding machine described above, featuring cooperating and continuously rotating mandrel **15** and winding head **45**, permits rapid fabrication of multi-turn deflection coils in a process wherein there is substantially constant winding tension on the winding conductor throughout the formation of each winding convolution. This has the distinct advantage of uniformity in the winding, and minimized load on the machine and, in general, an improved structure. It results in large measure from the relative speeds of the mandrel and winding head and from the gyrations of the winding mandrel with respect to the winding recess of the mandrel. This is depicted functionally in the series of sketches of FIGURE 9.

The first position, shown in FIGURE 9*a*, is a convenient starting point to consider the formation of one winding turn assuming the mandrel and winding head to be rotating in the directions indicated by the arrows. The winding conductor at this juncture has completed the minor or smaller lobe **11** represented by the part of the winding recess adjacent flange **16***c*. In the next 45 degrees of rotation of the mandrel and the concurrent 90 rotational degrees of the winding head, the winding conductor is laid along the linear traverse of the mandrel recess in the direction from flange **16***c* to flange **16***b*. This will be considered a unit angular displacement because in the several remaining sketches of FIGURE 9, it is assumed that the rotatable parts have been advanced by the same amount compared with the immediately preceding showing.

As shown in FIGURE 9*c*, during the next unit of rotation, the winding conductor makes a vertical pass forming the start of the major lobe **10** of the coil. The next two rotational units represented in FIGURES 9*d*, 9*e* complete the formation of this major lobe. In the ensuing unit displacement, represented in FIGURE 9*f*, the conductor is laid in the alternate linear run of the winding recess in the direction from flange **16***b* to **16***c*. The formation of the minor lobe **11** is commenced with the vertical rise occasioned in the next unit of angular displacement, represented in FIGURE 9*g*, and is continued during the next unit of angular displacement, represented in FIGURE 9*h*, being completed as the cycle finishes with the mandrel and winding head assuming the initial relative positions of FIGURE 9*a*.

A principal advantage of the described machine is the avoidance of vibrations or pulsations in the winding conductor as the coil turns are formed. This enables and assures uniformity of results and faster winding operations without any material danger of breakage of the wire or damage to its insulation because of discontinuities in the winding tension. The desirable results attained flow directly from the fact that the winding conductor is essentially laid directly into the several portions of the winding recess as the mandrel and winding head are driven. This is in sharp contrast to prior practices wherein cam elements are employed to deflect a winding conductor from a normal feed path into a position from which it may enter the winding recess.

While particular embodiments of the invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects, and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. A coil-winding machine comprising: a mandrel supported for rotation about a first axis and having a saddle-shaped recess defining a predetermined coil pattern, having a window through which said first axis extends, for receiving a continuous wire and for forming said wire into consecutive coil turns having a shape corresponding to said pattern; a winding head rotatable about a second axis, intersecting said first axis at an angle of less than 90° and at the approximate geometrical center of said recess and having a wire-feeding station which revolves about said recess of said mandrel as said winding head rotates with said feeding station spaced radially of said second axis and located in its motion path at a point from which said wire extends directly in a substantially straight line into said recess; means for feeding said wire from a supply station through said feeding station of said winding head; and means for concurrently effecting continuous rotation of said mandrel and said winding head at a speed ratio of 1:2, respectively.

2. A coil-winding machine comprising: a mandrel supported for rotation about a first axis including a first portion having a linear central section terminating in enlarged flanges at its opposite ends and further including a U-shaped second portion secured to said first portion between said flanges thereof and constituting therewith a recess defining a saddle-shaped coil pattern, having a window through which said first axis extends, for receiving a continuous wire and for forming said wire into consecutive coil turns having a shape corresponding to said pattern; a winding head rotatable about a second axis, intersecting said first axis at an angle therewith of less than 90° and at the approximate geometric center of said recess, and having a wire-feeding station which revolves about said recess of said mandrel as said winding head rotates with said feeding station spaced radially of said second axis and located in its motion path at a point from which said wire extends directly in a substantially straight line into said recess; means for feeding said wire from a supply station through said feeding station of said winding

head; and means for concurrently effecting continuous rotation of said mandrel and said winding head at a speed ratio of 1:2, respectively.

3. A coil-winding machine comprising: a mandrel supported for rotation about a first axis including a first portion having a linear central section terminating in enlarged flanges at its opposite ends and further including a U-shaped second portion secured to said first portion between said flanges thereof and constituting therewith a recess defining a saddle-shaped coil pattern, having a window through which said first axis extends for receiving a continuous wire and for forming said wire into consecutive coil turns having a shape corresponding to said pattern; said second portion having at least one channel entering into said recess to facilitate the introduction of a fluid thereto; means for introducing a fluid into said channel; a winding head rotatable about a second axis, intersecting said first axis at an angle therewith of less than 90° and at the approximate geometric center of said recess, and having a wire-feeding station which revolves about said recess of said mandrel as said winding head rotates with said feeding station spaced radially of said second axis and located in its motion path at a point from which said wire extends directly in a substantially straight line into said recess; means for feeding said wire from a supply station through said feeding station of said winding head; and means for concurrently effecting continuous rotation of said mandrel and said winding head at a speed ratio of 1:2, respectively.

4. A coil-winding machine comprising: a mandrel supported for rotation about a first axis including a first portion having a linear central section terminating in enlarged flanges at its opposite ends and further including a U-shaped second portion secured to said first portion between said flanges thereof and constituting therewith a recess defining a saddle-shaped coil pattern, having a window through which said first axis extends, for receiving a continuous wire and for forming said wire into consecutive coil turns having a shape corresponding to said pattern; a winding head rotatable about a second axis, intersecting said first axis at an angle therewith of less than 90° and at the approximate geometric center of said recess, and having a wire-feeding station which revolves about said recess of said mandrel as said winding head rotates with said feeding station spaced radially of said second axis and located in its motion path at a point from which said wire extends directly in a substantially straight line into said recess; means for feeding said wire from a supply station through said feeding station of said winding head; means for concurrently effecting continuous rotation of said mandrel and said winding head at a speed ratio of 1:2, respectively; a forming die movable into said recess to conform coil turns therein to the pattern of said recess; and means for advancing said die into said recess.

5. A coil-winding machine comprising: a mandrel supported for rotation about a first axis including a first portion having a linear central section terminating in enlarged flanges at its opposite ends and further including a U-shaped second portion secured to said first portion between said flanges thereof and constituting therewith a recess defining a predetermined coil pattern for receiving a continuous wire and for forming said wire into consecutive coil turns having a shape corresponding to said pattern; said second portion having at least one channel entering into said recess to facilitate the introduction of a fluid thereto; a winding head rotatable about a second axis intersecting said mandrel and having a wire-feeding station which revolves about said recess of said mandrel as said winding head rotates; means for feeding a winding conductor having an insulating coating from a supply station to said feeding station of said winding head; means for concurrently effecting continuous rotation of said mandrel and said winding head at preselected relative speeds; and means admitting a solvent for said coating into said channel after a predetermined number of coil turns have been formed in said recess.

6. A coil-winding machine comprising: a mandrel supported for rotation about a first axis including a first portion having a linear central section terminating in enlarged flanges at its opposite ends and further including a U-shaped second portion secured to said first portion between said flanges thereof and constituting therewith a recess defining a predetermined coil pattern for receiving a continuous wire and for forming said wire into consecutive coil turns having a shape corresponding to said pattern; said second portion having at least one channel entering into said recess to facilitate the introduction of a fluid thereto; a winding head rotatable about a second axis intersecting said mandrel and having a wire-feeding station which revolves about said recess of said mandrel as said winding head rotates; means for feeding a winding conductor having an insulating coating from a supply station to said feeding station of said winding head; a clamp affixed to said first portion of said mandrel for anchoring one end of said winding conductor and for making an electrical connection thereto; means for concurrently effecting continuous rotation of said mandrel and said winding head at preselected relative speeds; means admitting a solvent for said coating into said channel after a predetermined number of coil turns have been formed in said recess; and means for completing a heater circuit through said winding conductor at a given time interval following the admission of solvent to said channel.

7. A coil-winding machine comprising: a mandrel supported for rotation about a first axis including a first portion having a linear central section terminating in enlarged flanges at its opposite ends and further including a U-shaped second portion secured to said first portion between said flanges thereof and constituting therewith a recess defining a predetermined coil pattern for receiving a continuous wire and for forming said wire into consecutive coil turns having a shape corresponding to said pattern; said second portion having at least one channel entering into said recess to facilitate introducing a fluid thereto; a winding head rotatable about a second axis intersecting said mandrel and having a wire-feeding station which revolves about said recess of said mandrel as said winding head rotates; means for feeding a winding conductor having an insulating coating from a supply station to said feeding station of said winding head; a clamp affixed to said first portion of said mandrel for anchoring one end of said conductor and for making an electrical connection thereto; a conforming die movable into said recess; means for concurrently effecting continuous rotation of said mandrel and said winding head at preselected relative speeds; means admitting a solvent for said coating into said channel after a predetermined number of coil turns have been formed in said recess; means for maintaining a flow of heater current through said winding conductor for a preselected interval following the admission of solvent to said channel; and means for advancing said die to said recess at the end of said interval.

8. A coil-winding machine comprising: a mandrel supported for rotation about a first axis and having a saddle-shaped recess defining a predetermined coil pattern, having a window through which said first axis extends, for receiving a continuous wire and for forming said wire into consecutive coil turns having a shape corresponding to said pattern; a winding head rotatable about a second axis, intersecting said first axis at an angle of less than 90° and at the approximate geometrical center of said recess, and having a wire-feeding station displaced from said second axis to revolve in a circular path about said recess of said mandrel as said winding head rotates with said feeding station spaced radially of said second axis and located in its motion path at a point from which said wire extends directly in a substantially straight line into said recess; means for feeding said wire from a supply station through said feeding station of said winding

head; and means for concurrently effecting continuous rotation of said mandrel and said winding head at constant speeds and at a speed ratio of 1:2, respectively.

9. A coil-winding machine comprising: a mandrel supported for rotation about a first axis and having a saddle-shaped recess defining a predetermined coil pattern, having a window through which said first axis extends, for receiving a continuous wire and for forming said wire into consecutive coil turns having a shape corresponding to said pattern; a winding head rotatable about a second axis, intersecting said first axis at an agle therewith of less than 90° and at the approximate geometric center of said recess, and having a wire-feeding station which revolves about said recess of said mandrel as said winding head rotates with said feeding station spaced radially of said second axis and located in its motion path at a point from which said wire extends directly in a substantially straight line into said recess; means for feeding said wire from a supply station through said feeding station of said winding head; means for concurrently effecting continuous rotation of said mandrel and said winding head at a speed ratio of 1:2, respectively; and means for automatically arresting said mandrel and winding head in predetermined relative angular positions after the formation of a preselected number of coil turns in said recess.

10. A coil-winding machine comprising: a mandrel supported for rotation about a first axis and having a saddle-shaped recess defining a predetermined coil pattern, having a window through which said first axis extends, for receiving a continuous wire and for forming said wire into consecutive coil turns having a shape corresponding to said patern; a winding head rotatable about a second axis, intersecting said first axis at an angle therewith of less than 90° and at the approximate geometric center of said recess, and having a wire-feeding station which revolves about said recess of said mandrel as said winding head rotates with said feeding station spaced radially of said second axis and located in its motion path at a point from which said wire extends directly in a substantially straight line into said recess; means for feeding said wire from a supply station through said feeding station of said winding head; means for concurrently effecting continuous rotation of said mandrel and said winding head at a speed ratio of 1:2, respectively; means for automatically arresting said mandrel and winding head after the formation of a preselected number of coil turns in said recess; and means for automatically establishing a predetermined relative orientation of said mandrel and said winding head preparatory to the formation of a preselected number of coil turns in said recess.

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