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CONTINUOUS WINDER SYSTEM AND METHOD

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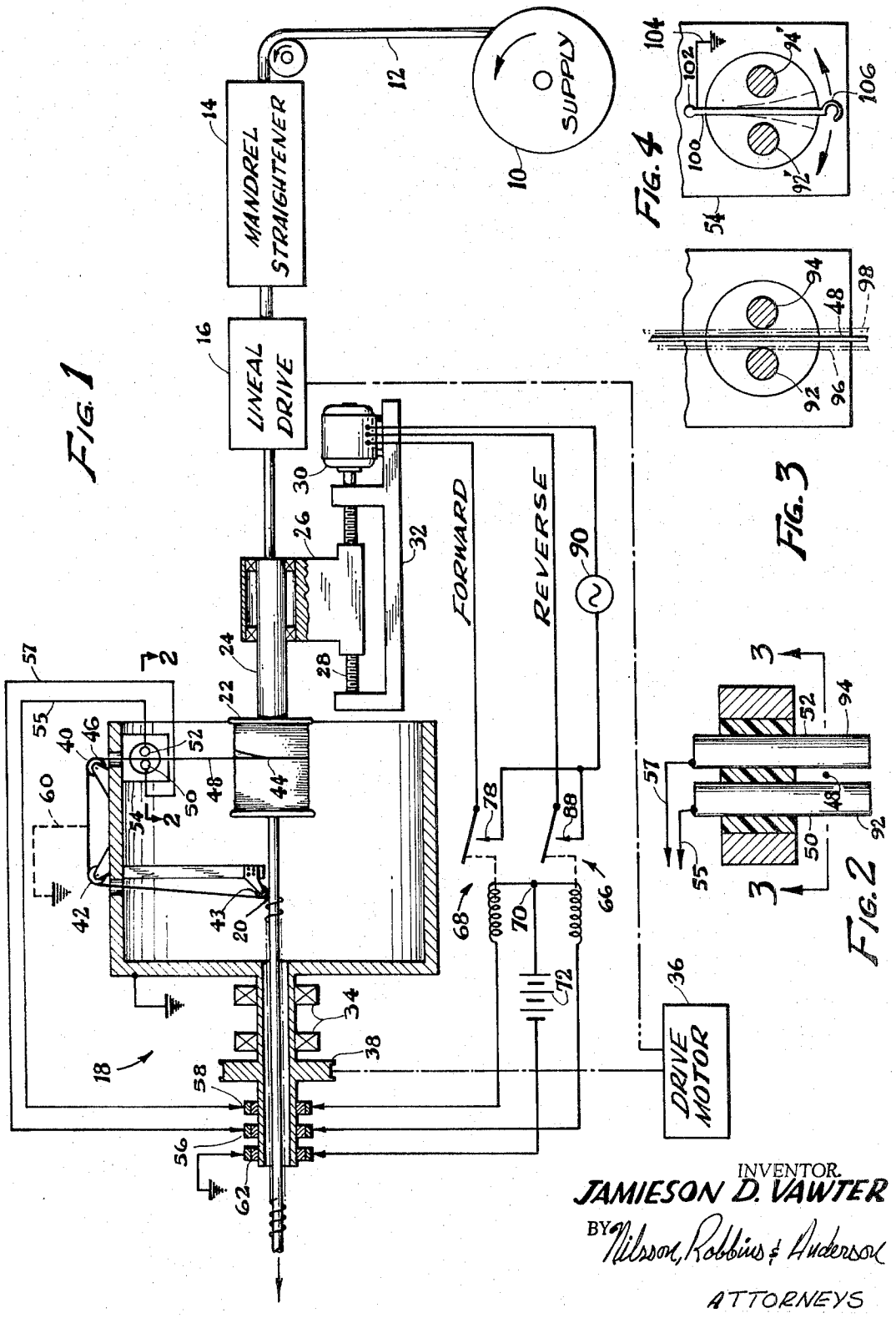



FIG. 1



FIG. 4



FIG. 3



FIG. 2

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# CONTINUOUS WINDER SYSTEM AND METHOD

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## ABSTRACT OF THE DISCLOSURE

Electrical conductor is unwound from a supply spool onto a mandrel fed axially through said spool by means of a driven winding cage that includes contacts adjacent the unwinding path of the conductor which are electrically connected to a motor to reciprocate said spool axially relative to said winding cage to maintain the unwinding angle substantially constant.

This invention relates generally to improved apparatus and methods for winding a coil of strand material upon a continuous core mandrel.

Although the present invention finds particularly useful application in the field of machinery and techniques for producing wire wound coils, resistors, and the like for electrical elements and components, and although in the cause of brevity and clarity, much of the following discussion of an example of the invention is directed theretoward, it is expressly to be understood that the advantages of the invention are equally well manifest in other fields wherein it is desired to wrap or wind, at high speed and with precision, a continuous core element with strand material.

In the field of providing such electrical devices which include a coil of strand material, such as insulated or non-insulated conductive (including "resistive") wire, wound over a mandrel to form, for example, a resistance element as for a variable resistor, it is highly desirable, for precision repeatability between different components as well as for their economic mass production, that the coils be continuously wound over a very long or continuous mandrel. The long coil is then parted into the desired individual, wire wound components. With such a general technique, it is possible in accordance with the features of the present invention to manufacture, at very high speed, resistance elements having precisely constant parameters, and therefore electrical resistance characteristics, over their entire lengths. Thusly to wind a coil continuously over a mandrel requires, however, either that the mandrel be rotated while a source of strand material, such as a spool of resistance wire, is moved, relatively, along the length of the mandrel in a manner to create and control the winding pitch while maintaining a predetermined tension in the wire, or that the winding mechanism itself, including the spool of source, be rotated around the mandrel while one or the other is translated longitudinally to provide the pitch in the resultant winding.

Attempts in the past to achieve such continuous winding have typically been directed toward a lathe-type machine which spins the mandrel as a workpiece and carries a spool of resistance wire on the tool-holder carriage at a fixed longitudinal rate with respect to the angular velocity of the mandrel to determine thereby the pitch of the coil. Such techniques can be made to provide relatively precise components.

The lathe-type winding process cannot, however, be a truly continuous one unless a source of the mandrel material is also being spun; and means is provided for axially moving the mandrel past the spool of resistance wire. Furthermore, as a practical matter, such techniques can provide a length of coil which is no longer than the permissible travel of the tool holder carriage along the bed of the machine. A further disadvantage of spinning mandrel-type machines is that at usefully high speeds of operation there is always some lateral flipping of the spinning elongated mandrel which deleteriously varies the tension in the winding wire, and consequently the diameter or pitch, or both, of the resultant coil.



Other typical prior art attempts to achieve continuous coil winding have been directed toward the development of machines in which the mandrel is rotationally stationary while a winding mechanism carrying the spool of resistance wire is rotated thereabout. The mandrel may in such cases be truly continuously fed past the winding mechanism. However, the required centripetal forces for the revolving winding mechanism even when dynamically balanced, generally limit the process to a relatively low speed. Typically in such systems, the reservoir spool of resistance wire is made to have a small diameter so that the system may have a minimum effective moment of rotational inertia and will require a minimum of centripetal forces to hold the mechanism together. However, this necessitates making it longer in order to provide it with a practical capacity for the strand material.

Making the spool longer seriously aggravates another problem in this type of machine; namely, that of removing the strands from the spool at high speeds. There must effectively be a single output point for the strand to leave the reservoir assembly. This output point generally must have a fixed axial relationship with respect to the winding point where the strand is applied to the mandrel. As the strand is pulled from the spool and conveyed to the output point, it is pulled from a wide range of directions; that is, from the different ends of the spool. This range of directions is measured by the angles subtended at the output point by the opposite effective ends of the spool.

Since the lineal velocity of the strand between the reservoir spool and the mandrel is constant, and since the distance the strand must travel to arrive at the output point from the spool varies due to the axial motion of the point of unwinding of the material from along the length of the spool, it follows that the angular velocity of the unwinding spool must vary as the point of unwinding moves from one end of the spool to the other. It may be considered that this relative longitudinal motion of the point of unwinding alternately adds and subtracts a component of velocity to the lineal motion of the strand. The relative magnitude of this component compared to the total lineal strand velocity determines the amplitude of oscillation or variation of the angular velocity of the unwinding spool and is proportional to the magnitude of the range of directions between the spool and the output point; that is, the greater the change of direction suffered by the strand in reaching the output point from various points on the spool, the greater is the required variation in the rotational velocity of the spool.

This variation in angular unwinding velocity of the strand spool results in variations and tension and, consequently, in geometric and electric parameters of the strand as it is wound upon the mandrel. In addition the same phenomenon may cause fouling in the spool at high speeds. Furthermore, the variation and tension and the longitudinal pulling of the strand at the point of unwinding, particularly at points axially most remote from the output point, causes additional fouling as adjacent loops of the strand are rolled over each other.

When the output point can be removed radially from the vicinity of the spool the range of angle or direction change of the strand is reduced; however, attempts in the prior art so as to remove the output point have resulted in increased rotational inertia or unbalance or both.

Another general approach towards solving these problems has been directed toward providing a programmed

longitudinal oscillation of the spool with respect to the output point, either by moving the spool or by mechanically moving the output point, so that the unwinding point remains axially fixed with respect to the output point. However, the resultant prior art solutions and mechanisms developed toward that end have heretofore been either impractically bulky and complex or have employed formidably complex programming and controls because, for example, the frequency of the longitudinal oscillation of the spool must vary with the varying effective diameter of the unwinding spool, and these rates of change depend upon the strand size itself.

It is therefore an object of the present invention to provide a continuous coil winder machine system and method which are not subject to these and other disadvantages of the prior art.

It is another object to provide such apparatus in which the mandrel does not rotate and may be truly continuous.

It is another object to provide such a coil winding system in which the strand always leaves the reservoir spool substantially at right angles thereto.

It is another object to provide such an apparaus in which the output point of the reservoir assembly is at an axially fixed point which is radially contiguous to the spool.

It is another object to provide such a coil winding machine which may wind with high precision and repeatability at angular rates of several thousands of revolutions per minute without submitting the winding strand to appreciable tension or to variations therein.

It is another object to provide such a continuous coil winding machine which mechanically is simple, rugged and reliable.

Briefly, these and other objects and advantages are achieved in accordance with the structural aspects of an example of the invention which includes means for linearly driving a continuous length of mandrel core stock along a given path at a predetermined velocity. A winding cage is disposed about the mandrel path and is driven at high angular velocity concentrically about the core axis. The winding cage includes means for receiving power at an axially fixed point, the strand to be wound about the core and for feeding the strand to an axially stationary winding point adjacent the core. The axial position of the winding cage may be considered to be fixed with respect to a base, supporting structure and is rotatably driven by power means also carried by the base structure. This power means is also coupled to the mandrel lineal drive means to provide a predetermined desired pitch producing relationship between the lineal drive and the angular velocity of the winding cage.

Also carried by the base structure is a reservoir spool carriage which supports a spindle for the reservoir spool. This spool mounted on the carriage is, in this example, adapted to be disposed within and concentric with the winding cage.

The winding mechanism is "threaded" by removing the end of the strand from the spool, passing the strand though the receiving means on the winding cage, carrying it through the feeding means to the winding point, and affixing it to the mandrel.

The spool carriage is axially movable and is driven back and forth axially, in this example, by an electric motor so that the strand unwinding point on the reservoir spool is maintained axially in alignment with the strand receiving means on the winding cage.

The control system for the carriage drive motor comprises a pair of closely spaced wire sensing elements carried by the winding cage at the wire receiving point and between which the strand passes as it is pulled from the reservoir spool. The wire sensing elements are axially spaced and positioned so that when the spool unwind point is axially aligned with the strand receiving means on the winding cage, neither sensing element is contacted by the wire and there is no energizing current supplied through the carriage drive motor. When, however, the spool unwind point is not aligned with the strand receiving point on the winding cage, one or the other of the sensing elements is contacted by the wire and an appropriate signal is generated to cause energization of the carriage drive motor in a direction and for a period of time to cause a continually maintained alignment between the spool unwind point and the winding cage receiving point as sensed continuously by the sensing elements.

By operation automatically of these means, the spool supporting carriage is driven forth and back in a manner to provide the desired alignment. It may be considered, in this connection, that the motion added to the spool by the carriage drive motor exactly compensates for that component of the wire velocity, otherwise occurring due to the axial movement of the spool unwind point.

Further details of these and other novel features of the invention including details of an example of the carriage and its driving motor as well as an example of the sensing elements briefly described above and their principles of operation as well as additional objects and advantages of the invention will become apparent and be best understood from a consideration of the following description taken in connection with the accompanying drawing which is presented by way of an illustrative example only and in which:

FIGURE 1 is a schematic and simplified longitudinally sectioned view of an example of a continuous coil winding machine system constructed in accordance with the principles of the present invention;

FIGURE 2 is a sectional view of the sensing element portion of the structure shown in FIGURE 1 taken along the reference lines 2—2 thereof;

FIGURE 3 is a cross-sectional view of the structure of FIGURE 2 taken along the reference lines 3—3 thereof; and

FIGURE 4 is a view, like that of FIGURE 3, of a portion of an alternative example of the invention.

With specific reference now to the figures in detail, it it stressed that the particulars shown are by way of example and for purposes of illustrative example only and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and structural concepts of the invention. In this regard no attempt is made to show structural details of the apparatus in more detail than is necessary for the fundamental understanding of the invention, the description taken with the drawing making it apparent to those skilled in the arts of winding and wrapping machines and systems how the several forms of the invention may be embodied in practice. Specifically the details shown are not to be taken as a limitation upon the scope of the invention which is defined by the appended claims forming, along with the drawing, a part of this specification.

In FIGURE 1, the example of the continuous winder system illustrated includes a supply **10** of core stock material **12** which is drawn from the source and through an appropriate mandrel straightener **14** by a lineal drive mechanism **16**. The mandrel stock **12** is then moved longitudinally along the axis of a winding cage assembly **18**, past a winding point **20** therewithin, and out of the winding part of the machine at its left hand end as shown. To permit the indicated passage of the continuous mandrel, the winding cage assembly is provided with a hollow axial bore of adequate diameter to clear the mandrel along the entire length of assembly **18**.

Also similarly bored and supported concentrically about the mandrel axis and disposed within, in this example, the open right hand end of the winding cage assembly **18** is a wire reservoir spool **22** and a spindle **24** for the spool. The spindle supports the spool and is, in turn, carried by a carriage assembly **26**. The carriage assembly is provided with a longitudinal freedom of motion and coupled to a lead screw **28** in a manner such that actuation of the lead screw **28** in either of two senses of rotation causes the

carriage assembly and the spool **22** to move axially in a corresponding fashion either to the left or right. These two senses, whether in referring to the lead screw rotation or the axial translation of the spool, may be denoted "forward" and "reverse" respectively. The forward sense is taken to be that which moves the carriage assembly in the direction of travel of the mandrel stock.

The lead screw **28** is connected, in this example, to a reversing electric motor **30**. It may be noted that the motor **30**, the lead screw **28**, its supporting base **32**, and the winding cage assembly **18** are all fixed as regards longitudinal movement with respect to a stationary support structure, not shown.

The winding cage assembly is rotatably supported by the same stationary support through a set of bearings **34**. A drive motor **36** also carried by the stationary support is rotationally drivingly coupled to a gear or pulley member **38** affixed to the winding cage assembly **18**.

The drive motor **36** is shown coupled to the lineal drive mechanism **16** to indicate that a desired, predetermined relationship between the angular velocity of the winding cage and the lineal velocity of the mandrel stock is maintained to provide the desired winding pitch of the strand upon the mandrel stock.

The winding cage assembly **18** includes, in this example, a set of wire directing pulleys **40**, **42**, **43**, shown schematically, for directing the wire from an unwind point **44** on the spool **22**, to a wire receiving point **46** on the winding cage, to the winding point **20** on the mandrel.

As the wire strand **48** is fed from the unwind point **44** to the receiving point **46**, it passes between a pair of wire contact sensing elements **50**, **52**. In this example, the sensing elements are polished, conductive posts mounted electrically insulatively on a support member **54** which is in turn carried by the winding cage. The sensing elements **50**, **52** are spaced to permit the strand **48** to pass between them without necessarily contacting either one, and they are disposed axially astraddle of a point in alignment with the wire receiving point **46**. By this means, as described more fully below, the wire strand **48** does not contact either of the posts of the sensing elements when the spool unwind and wire receiving points **44**, **46** are in axial alignment. When, however, the unwind point **44** is relatively forward, the post of the sensing element **50** is contacted by the wire strand **48**; and, conversely, when the unwind point **44** is relatively rearward, the post of the sensing element **52** is contacted.

The sensing element **50** is connected, in this example, through a lead **55** to an insulated slip ring **56**; and the sensing element **52** is connected through a lead **57** to a slip ring **58**. The conductive wire strand **48** is effectively grounded to the winding cage assembly frame as indicated by the dashed connection **60**. Similarly a third slip ring **62** is grounded to the winding cage frame as shown.

Each of the slip rings **56**, **58** is connected, as by a brush, to a coil terminal of a respective one of a pair of relays **66**, **68**. These relay coils, in this example, are connected to have a common terminal **70** which is connected through a relay energizing battery **72** to the third, grounded, slip ring **62**. The relay contacts **78**, **88**, respectively, are normally open and are connected, or connectable, in a single-pole, double-throw arrangement to the "forward" and "reverse," respectively, leads through a current source **90** to the terminals **92** of the spindle positioning motor **30**.

With reference to FIGURE 2, the smooth, conductive posts **92**, **94** of the wire contact sensing elements **50**, **52** are illustrated with the conductive wire strand **48** disposed symmetrically therebetween. Each of conductive posts is again shown connected to its respective leads **55**, **57**.

In FIGURE 3 the posts **92**, **94** are shown in cross section with the conducting strand **48** in elevation therebetween. The dashed lines **96** indicate the position of the strand **48** when the spool **22** is disposed too far forwardly; and the dashed lines **98** indicate its position when the spool is too far to the rear.

In operation, with the wire strand in its central, proper position as shown in FIGURES 1 and 2 and the solid lines of FIGURE 3, neither relay is connected to the coil energizing source **72**; and both sets of relay contacts **78**, **88** remain open so that the spool positioning motor **30** is not energized. When, however, the spool is too far forward for the required alignment between the unwinding point **44** and the wire receiving point **46**, the wire strand **48** may assume the position of the dashed lines **96** in FIGURE 3, the conductive post **92** of the sensing element **50** is consequently grounded causing energization of the coil of the relay **66**, the contacts **88** close to connect the source **90** to the "reverse" lead of the motor **30** whereby the motor is energized and rotates the lead screw **28** to cause a movement of the spindle carriage **26** in the direction to remove the strand **48** from contact with the sensing element **50**.

In the same manner, when the winding strand contacts the sensing element **52** indicating that the spool is disposed axially too far to the rear, the lead **55** is grounded causing energization of the relay **68** which closes the contacts **78** to cause energization of the positioning motor in the "forward" direction.

Thusly the electrical contact and positioning drive system disclosed provides continual adjustment, as needed, of the reservoir supply spool **22** so that the wire strand is always removed from the spool at a fixed, known angle with respect thereto. In this manner, the angular speed of the spool and hence the tension in the strand **48** need not undulate due to a fluctuation in the take-off angle of wire from the spool.

Referring to FIGURE 4 an example of the invention is illustrated which is particularly adapted for utilization with a non-conductive strand or an insulated strand. In this example a conductive switch arm wire follower member **100** is affixed at a pivot point **102** to the support member **54**. The pivoted switch arm member is grounded, as indicated by the connection **104** to the winding cage structure through its connection thereto at the pivot point **102**. The end of the arm member **100** is formed, in this example, to include a strand encircling loop portion **106** at its end opposite from the pivot point **102**. For purposes of clarity, the size of the eye of the loop portion **106** is exaggerated and the strand is omitted from the figure. In practice, the loop portion is designed to be only slightly larger than the strand diameter whereby when the strand is received therethrough axial motion of the strand causes a corresponding following displacement of the arm member **100** with a minimum of backlash or delay.

In this manner, as in the previous example, a predetermined displacement of the strand causes a grounding of a particular one of the conductive posts **92'**, **94'** thusly generating the control signal for moving the carriage assembly **26** to correct the angular displacement of the unwind point **44** with respect to the receiving point **46**.

There have thus been disclosed and described a number of illustrative aspects of an example of a continuous coil winder system which exhibits the advantages and achieves the objects set forth hereinabove.

What is claimed is:

**1.** In a winding machine for removing, by unwinding, a strand of material from a reservoir spool thereof and winding the strand on a core mandrel moving longitudinally through the center of said spool along a predetermined winding axis, apparatus for maintaining the angle at which said strand in unwinding leaves said spool within predetermined limits with respect to said predetermined winding axis of said spool, said apparatus comprising:

(A) carriage means axially reciprocally movable over a distance equal approximately to at least the length of said spool,

(1) said carriage means being adapted to receive and support said spool in rotatable relationship about said axis;

(B) bidirectional power means connected to said carriage means for reciprocally moving the same in an axial direction, the sense of which is controllable;

(C) sensing means positioned adjacent said strand adapted to determine variants of said strand from said angle and to initiate a signal indicative of said variance and the sense thereof; and

(D) control means interconnecting said sensing means and said power means for causing said power means to move said carriage means responsive to said signal in a direction to return said angle with respect to said variance thereof to within said predetermined limits.

2. Apparatus as defined in claim 1 wherein said carriage means includes a hollow spindle member through which said mandrel core passes and upon which said spool is received, an axially translatable support member upon which said spindle member is carried, and drive means connected between said axially translatable support member and said power means for reciprocally moving said axially translatable support member.

3. Apparatus as defined in claim 1 wherein said strand is electrically conductive material and in which said sensing means is a pair of electrical conductors, one positioned on each side of said strand whereby a first signal is generated when said strand varies from said angle in a first direction and a second signal is generated when said strand varies from said angle in the opposite direction.

4. Apparatus as defined in claim 1 which further includes:

(A) rotatable winding cage means disposed concentrically about said axis and having strand unwinding means carried thereby for said removing of said strand from said spool, said unwinding means defining a strand receiving point between which and the strand unwind point on said reservoir spool, the unwinding strand is suspended;

(B) said sensing means comprising a pair of conductive members insulated from each other carried by said winding cage means contiguously to said strand receiving point and disposed effectively forwardly and rearwardly in relation to said suspended strand whereby when said angle is within said predetermined limits the strand is disposed non-contactingly between said conductive members and is disposed in contact with a predetermined one thereof when said unwind point of said reservoir spool is axially displaced in a predetermined sense causing said angle to be not within said predetermined limits, and is in contact with the other of said conductive members when said unwind point is displaced in the opposite sense to cause said angle to be not within said predetermined limits.

5. Apparatus as defined in claim 4 in which said strand is conductive and which further includes electrical connection means for coupling each of said conductive members and said conductive strand to said control means.

6. Apparatus as defined in claim 4 in which said strand receiving point of said strand unwind means is disposed in axial alignment with the axial midpoint between said forwardly and rearwardly disposed conductive members, and said predetermined limits of said angle straddle 90°.

7. Apparatus as defined in claim 1 in which said bidirectional power means comprises a reversible motor and an elongate lead screw coupled mechanically between said motor and said carriage means.

8. In the process of removing, by unwinding, a conductive strand from a rotatable, axially translatable spool reservoir thereof and winding the strand upon a core mandrel moving longitudinally through the center of the spool along a predetermined winding axis, the method for maintaining the angle with respect to said winding axis at which said strand in unwinding leaves said spool within predetermined limits comprising the steps of:

(A) passing said conductive strand between an insulated pair of effectively rearwardly and forwardly spaced conductors as it leaves said spool during said unwinding whereby when said angle is within said predetermined limits, said strand does not contact either of said conductors and when said angle is not within said limits in one direction, one of said conductors is contacted by said conductive strand, and when said angle is not within said limits in the other direction the other of said conductors is contacted by said conductive strand;

(B) generating a correction electrical signal indicative of which of and when said strand is in contact with either of said conductors;

(C) utilizing said correction electrical signal to translate axially said spool reservoir in the proper sense of axial direction as needed to maintain said angle within said predetermined limits.

9. The invention as defined in claim 1 in which said sensing means includes a pair of axially spaced sensing elements and a strand following member adapted to receive said strand and move axially therewith toward different ones of said sensing elements in accordance with the latter's angular excursions, in different senses, from said predetermined limits.

10. Apparatus as defined in claim 1 wherein said sensing means includes a pair of axially spaced electrical conductors and a strand follower conductive member disposed pivotally therebetween for engaging said strand and being of the character to contact one of said electrical conductors when said angle varies from said predetermined limits in one axial sense and to contact the other of said electrical conductors when said angle varies from said predetermined limits in the opposite axial sense.

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