United States Patent

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[54] **COIL WINDER BELT GUIDE SHUTTLE SYSTEMS**
9 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **242/4**
[51] **Int. Cl.** **H01f 41/08**
[50] **Field of Search** 242/4, 5, 6

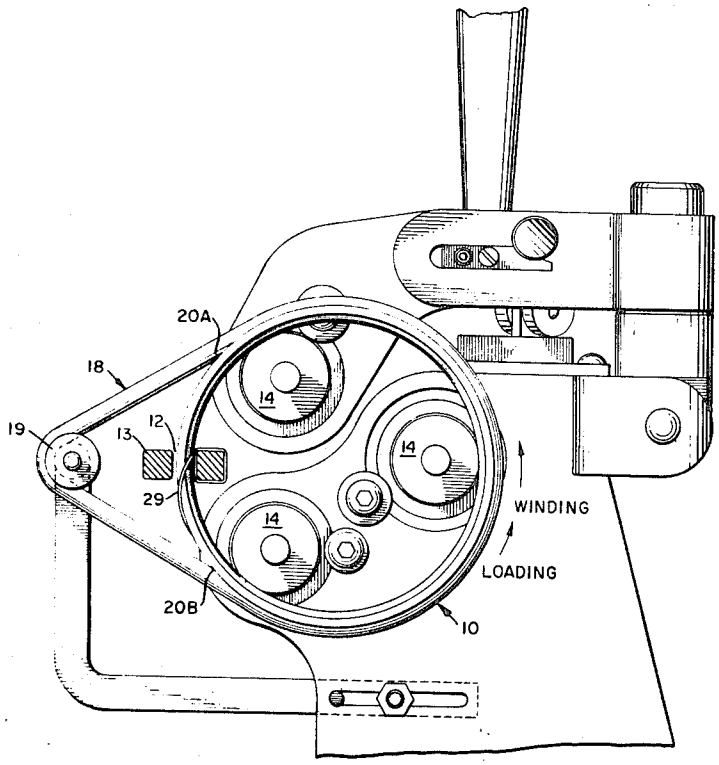
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ABSTRACT: Methods and apparatus for winding electrical conductor wire of moderate to heavy sizes on small and miniature toroidal cores utilizing a sliderless shuttle having storage coil of wire wound in a peripheral groove and held therein by a belt encircling a substantial part of the shuttle groove periphery. To permit mounting, loading and coil winding operations, the belt diverges from the shuttle periphery at the point where it passes through the toroidal core. Loading and winding rotation of the shuttle occur in the same direction, significantly minimizing flexure and bending distortion of the conductor wire as it is drawn from the shuttle groove.



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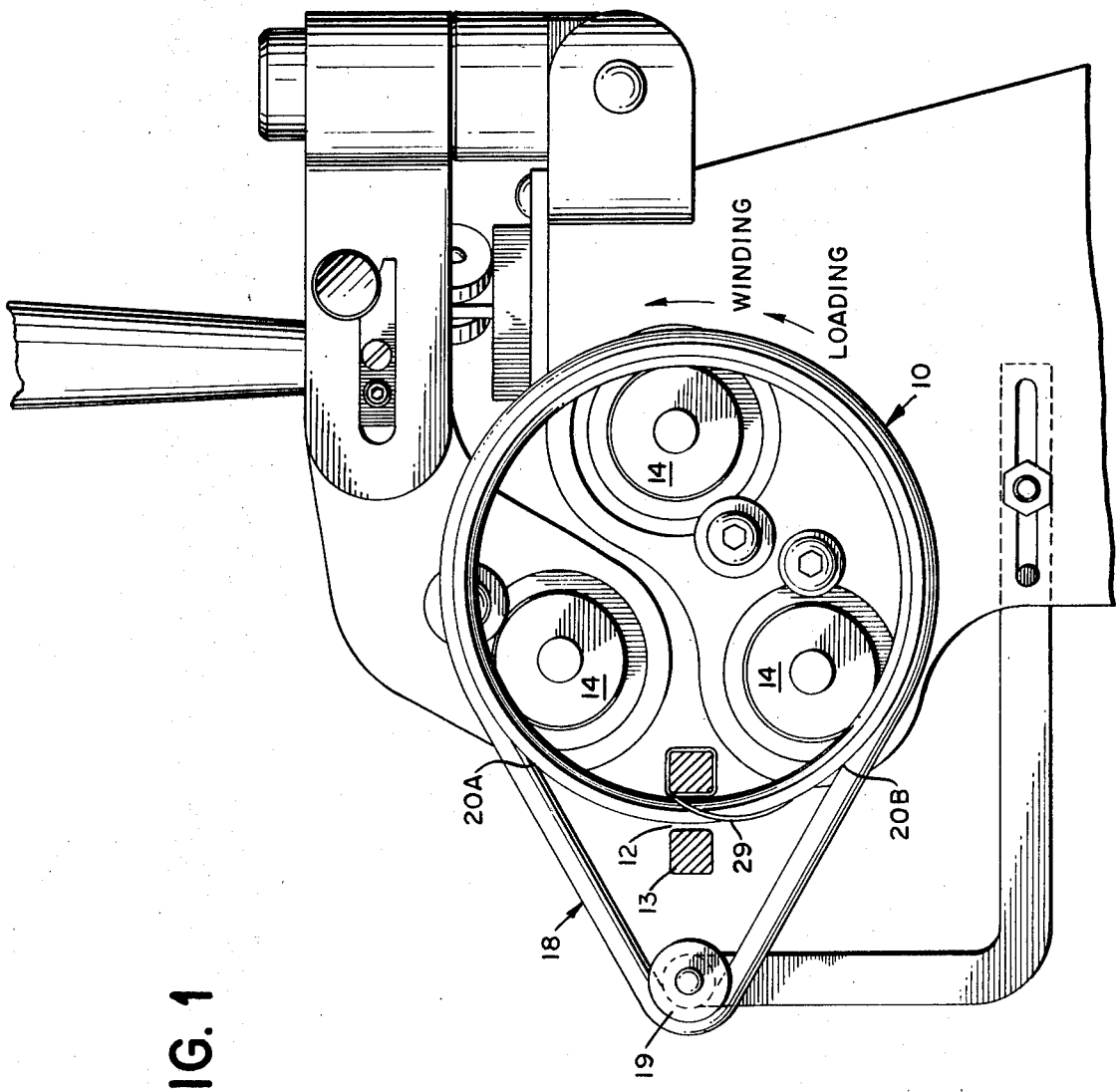


FIG. 1

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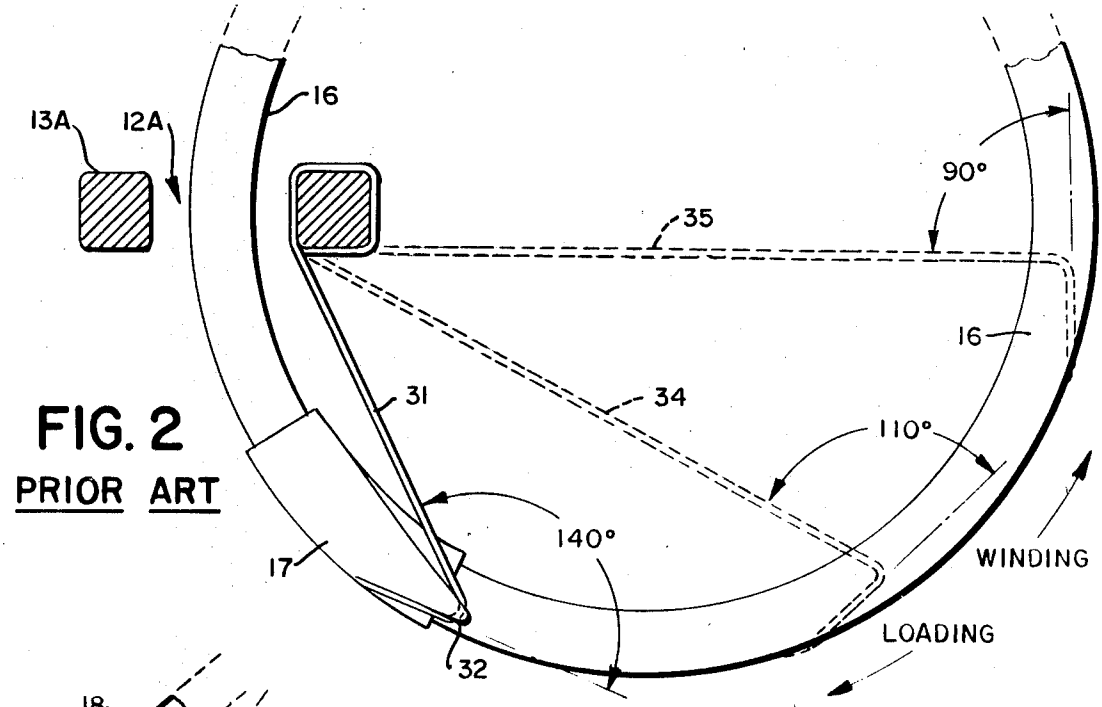


FIG. 2
PRIOR ART

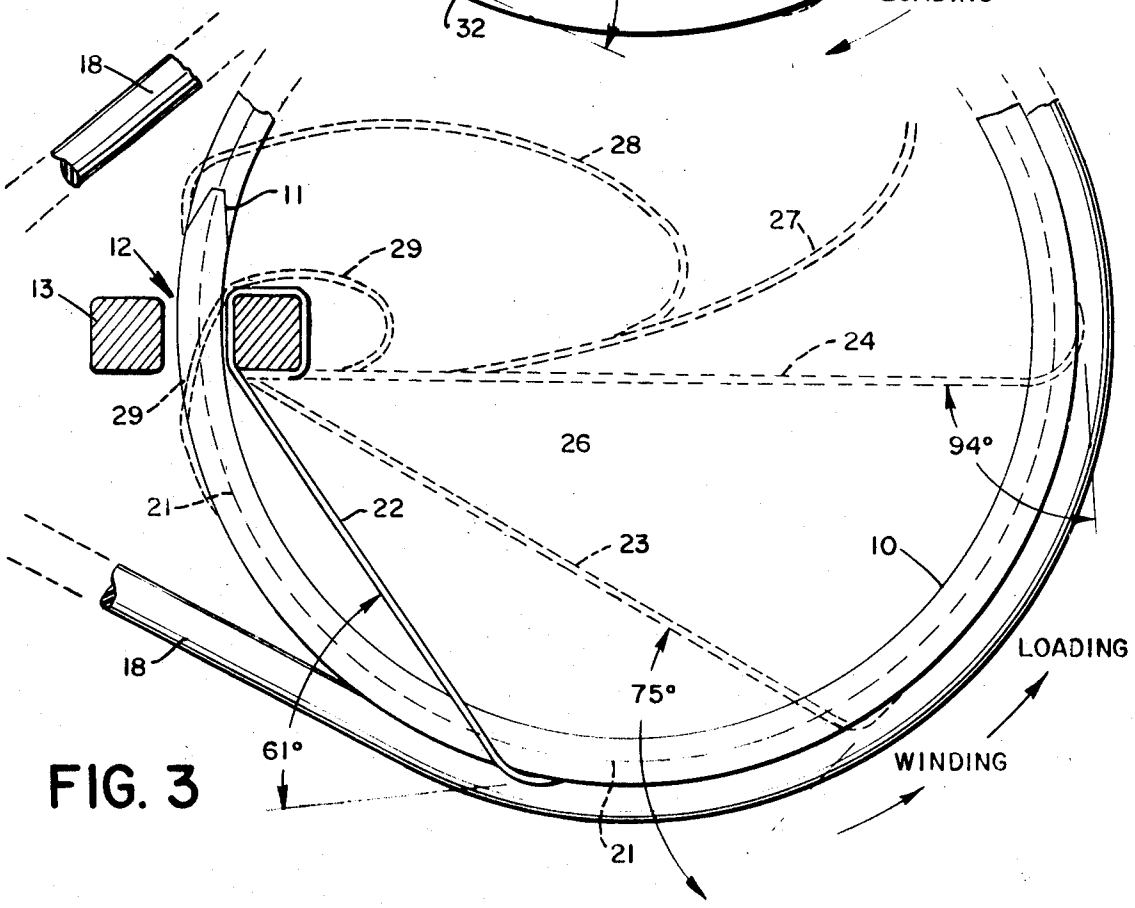


FIG. 3

COIL WINDER BELT GUIDE SHUTTLE SYSTEMS

This invention relates to toroidal core winding methods and apparatus, and particularly to novel techniques utilizing a sliderless shuttle on which wire is loaded and unwound in the same rotational direction, with conductor wire being stored in the peripheral groove encircling the shuttle, and being held therein by a partially encircling adjustable band or belt.

BACKGROUND OF THE INVENTION

Conventional coil winding machines customarily employ a slider which is frictionally engaged for relative sliding rotation around a ring-shaped shuttle, such as the slider **169** on shuttle **22** shown in FIG. **10** of McIntosh et al. U.S. Pat. 3,400,894, or the slider **82** on shuttle **40**, shown in FIGS. **1** and **5** of Stevens U.S. Pat. No. 2,656,124. Alternatively, a ring-shaped bent wire slider **81** designed to move slidingly within the peripheral groove of a shuttle **45** is shown in the drawings of Clarke U.S. Pat. No. 2,793,818, and a ring gear shuttle driven by heavy pinion gear drive is shown in Werth U.S. Pat. No. 2,427,079, with an internal sliding magazine **76** mounted for sliding relative movement inside the periphery of an outer groove in the shuttle **75**.

All of these prior art shuttle assemblies have proved inadequate to the task of winding heavy wire on very small toroidal cores. The bulk and cross-sectional size of a slider mounted on the side of a shuttle ring requires a certain minimum core aperture in order to pass through the center of the toroidal core. Conventional shuttle-slider assemblies simply cannot be used with cores of small diameter.

In addition, sliders possess small but significant mass and inertia, producing successive hammering shock loads during high-speed winding operations as each successive turn of wire is drawn off the shuttle with a jerk of the slider. These shock loads are conveyed to the winding wire, and often break the wire.

The sharp flexure of wire passing through a bending reversal of nearly 180° as it travels form a storage coil wound on a conventional grooved shuttle past the sharp bend of a conventional slider imposes high stress on these fine conductor wires and on their insulating coatings, frequently damaging the wire or the coating.

Finally, toroidal coil winding machines are customarily operated by semiskilled personnel, and even skilled operating personnel occasionally deflect the conductor wire inadvertently in such a way that a spill results, dispensing many shuttle turns of conductor wire over the work station in a tangled mass before the machine's operation can be halted.

As a result of the foregoing factors, the largest conductor wire which can ordinarily be wound automatically on a small toroidal core by conventional coil winding machines is a **30** gauge wire, and hand-winding has become necessary in many such winding operations. With the methods and apparatus of the present invention, conductor wire as large as **22** gauge can be wound in even, uniform, closely-spaced coils on extremely small diameter toroidal cores.

SUMMARY OF THE INVENTION

This invention concerns TOROIDAL COIL WINDING, SHUTTLES, SLIDERS AND TOROIDAL CORES.

The methods and apparatus of the present invention employ a peripherally grooved shuttle, separable at a scarf joint for insertion through the center aperture of a small toroidal core, and supported on customary drive sheaves of a toroidal coil-winding machine. An elongated conductive wire, generally provided with an insulating coating of polymer, varnish or similar flexible material, is laid and wound peripherally in a n externally facing groove encircling the outermost part of the ring-shaped shuttle.

In the techniques of this invention, as shown in the drawings, this coil of conductive wire is laid into the shuttle groove during rotation of the shuttle in a counterclockwise

direction as its scarf joint passes downward through the central core aperture to revolve rearward, upward and forward during each rotation cycle. Accordingly, the final free end of the wound conductor extending from the loaded shuttle protrudes upwardly from the front of the shuttle groove through the core aperture when the shuttle is stopped to conclude the loading operation. This free end is suitably clamped or secured to begin the winding operation, and the shuttle is then placed in rotation in the same direction, rotating counterclockwise as viewed from the right-hand side of the winding operation in the figures, drawing the free end of the wire taut between the rear side of the core aperture and the lower rim of the shuttle.

The major part of the periphery of the shuttle groove is encircled by an overlying band, such as an elastic rubber belt, spanning the shuttle groove and maintaining the wound turns of conductor wire in place therein. This retaining belt diverges from the shuttle rim at a point above the core and passes around an idler sheave, returning to the shuttle rim below the toroidal core. While the belt can be used as a drive belt, it is preferred to utilize a freely rotating low-friction idler so that the belt merely moves along its path of travel in synchronism with the revolving shuttle, which is driven in the conventional manner preferably by internal drive sheaves, one or more of which is provided with drive torque which it delivers to the shuttle.

Accordingly, a principal object of the present invention is to provide methods and apparatus for the winding of small toroidal cores with conductor wire of moderate or heavy gauge in uniform, closely laid turns.

A further object of the invention is tor provide such methods and apparatus avoiding spills, wire breakage and other disadvantages of conventional coil winding machines while permitting heavier gauge wire to be wound on smaller cores than can be handled by conventional coil winding machines.

Other and more specific objects will be apparent from the features, elements, combinations and operating procedures disclosed in the following detailed description and shown in the drawings. THE DRAWINGS

FIG. **1** is a schematic side elevation view showing the shuttle driving head and coil winding work station a of a coil winding machine incorporating the principles of the present invention;

FIG. **2** is a fragmentary enlarged schematic side elevation view of a conventional shuttle slider assembly showing successive stages in the coil winding operation; and

FIG. **3** is a corresponding enlarged fragmentary schematic side elevation view of a core and shuttle assembly incorporating the principles of the present invention, likewise showing successive stages in the coil-winding operation.

As shown in FIGS. **1** and **3**, the core and shuttle assembly of the present invention comprises a ring-shaped scarf-jointed shuttle **10** having a scarf joint **11** permitting it to be interfitted for interlinked relationship passing through the central aperture **12** of a small toroidal core **13**. These toroidal cores may be as small as ½ inch in external diameter, for example, with the methods and apparatus of the present invention. The cross-sectional configuration and area of the shuttle **10** is limited solely by the size of the central aperture **12** through which the shuttle must revolve, and also by the requirements of shuttle rigidity and stiffness, which must be sufficient to maintain the shuttle in its closed, ring-shaped condition, withstanding the deformation introduced by the torque and support functions of the drive and support sheaves **14**.

Prior art shuttles such as the shuttle **16** shown in prior art FIG. **2** must likewise possess sufficient rigidity, but must also support the slider **17** in moving engagement for sliding relative rotation around the periphery of the shuttle **16**. Therefore the size, shape and cross-sectional area of the slider **17** and of the shuttle **16** must both pass together through the central aperture **12A** of the toroidal core **13A** utilized with such prior art coil winding machines. For this reason the cores **13A** are considerably larger, with much larger apertures **12A**, than the

corresponding cores 13 which can be wound by using the techniques of the present invention.

The retainer belt 18 preferably encircles about half of the periphery of shuttle 10 in the systems of the present invention, and the belt 18 may encircle considerably more than half of the periphery of shuttle 10 in the systems of the present invention, and the belt 18 may encircle considerably more than half, and as much as three quarters or more, of the external periphery of the shuttle 10, generally the rearmost portion of the shuttle. The frontmost portion of the belt 18 preferably departs at an approach point or a tangent point 20A from the shuttle 10 as it approaches aperture 12 in core 13, and belt 18 diverges and passes over a low-friction idler sheave 19, thence returning to rejoin shuttle 10 at a return point on the opposite side of the core 13 such as tangent point 20B beneath the aperture 12 of core 13. Belt 18 remains firmly engaged overlying the wire in groove 21 of shuttle 10 from this rejoining point of tangency 20B beneath core 13 rearwardly and upwardly around the entire path of travel of the revolving shuttle 10 until the belt returns again to the point of departing tangency 20A above core 13 as the shuttle approaches its aperture 12 during the course of its continuing revolution.

Both loading and winding operation of shuttle 10 occur during counterclockwise revolution of the shuttle as indicated in FIG. 3. The free end of conductor wire is first secured through a suitable small side-facing aperture in the shuttle communicating with the groove 21, and the wire is then guided from a storage reel over supply sheaves to be wound on shuttle 10 during rapid revolution thereof counterclockwise as shown in FIG. 3 until a sufficient number of conductor turns have been laid in groove 21 in the periphery of shuttle 10. The wire may then be severed from the supply reel, leaving a free end extending tangentially upward from the front portion of the groove 21 and passing upward through aperture 12 of core 13. This free end may then be secured to form a winding terminal of the final wound coil, and thereafter each revolution of shuttle 10 wraps one turn of conductor wire 22 around the toroidal core 13.

Successive stages in the coil winding operation are schematically in FIG. 3, and comparable successive stages in a conventional coil winding operation utilizing a shuttle-slider assembly are likewise shown in the corresponding view of FIG. 2.

As the previous turn of wire 22 is drawn tight around the toroidal core 13, the tightening of this turn draws the wire 22 in tension, producing a taut length 22A of wire stretching from the aperture 12 of core 13 downward and rearwardly to the rim of shuttle 10 where the supply coils of wire 22 are stored in the groove 21. Rearward revolution of this portion of shuttle 10 adds further tension to the wire 22, causing the wire to be rolled outwardly over the side rim of groove 21, thus supplying a sufficient length of wire to provide the next turn of wire around the toroidal core 13. This dispensing rollover movement of the stored wire in groove 21 over the near edge of the groove to supply additional length to the wire 22 allows this taut segment 22A of wire to comprise a longer length of wire, as shown by the successive wire lengths 23 and 24 of FIG. 3, and this rollover dispensing motion is resisted by the retainer belt 18 overlying the groove 21. The belt 18 is preferably dimensioned in cross section to extend inwardly within the outward facing groove 21, placing it in traction contact with the coils of conductor wires stored in the groove 21. In this manner, belt 18 effectively retains these stored coils of wire within the groove.

As taut wire segment 22A is further tightened by counterclockwise revolution of shuttle 10 as indicated in FIG. 3, a length of conductor wire corresponding to the cross-sectional circumference of the core 13 is thus dispensed over the rim of groove 21, squeezing out between the groove rim and the overlying retainer belt 18, which is sufficiently flexible to be displaced by this dispensing length of wire. All the remaining turns of wire 22 are continuously retained in groove 21 by the encircling retainer belt 18 which is displaced only at the exact peripheral point on shuttle 10 at which the new length of dispensed wire emerges.

Dispensing continues from the tautening position 22A, where the wire stretches diagonally downward and rearward from core 13 to rim of shuttle 10, through out a first portion of the shuttle revolution cycle, which carries the wire rearward and upward to a substantially diametral position 24. At this point the wire 24 encounters and passes between a central traction shoe 26 and a traction anvil 26A shown in FIG. 1, frictionally retarding the unlaid length of wire 24 as the shuttle 10 continues its revolution carrying the dispensing point upward and forward to return downward through aperture 12 of core 13.

As the loop of wire 27 is drawn forward and downward through successive positions 28 and 29 through aperture 12, it is gradually tightened around core 13 to form a fresh winding turn. When this turn is laid firmly and tightly on core 13, the remaining length of wire assumes the position 22 and is placed in tension by the continuing revolution of shuttle 10 to repeat the winding cycle. The cooperation of the retainer belt 18 with the traction shoe 26 and anvil 26A enables the shuttle 10 to operate smoothly and rapidly to lay numerous turns of wire side-by-side in close uniform succession about the entire periphery of core 13, forming one or several overlying layers of conductive electrical windings thereon.

A significant advantage of the coil winding methods and apparatus of the present invention is demonstrated by a comparison of FIG. 3 with FIG. 2, the prior art shuttle-slider winding assembly. It will be noted in FIG. 3 that as the fresh wire 22A is initially placed in tension by the advancing revolution of shuttle 10, the wire begins its rollover, emerging dispensing movement between the rim of shuttle groove 21 and retainer belt 18 at a point where it is bent smoothly and gently across the shuttle rim through an angle of approximately 60°. As the shuttle 10 continues to advance rearwardly, drawing additional wire from the rim of shuttle groove 21 in this rollout dispensing operation, the flexing angle through which the wire is bent gradually increases to about 75° at the position 23 and to about 90° at the rearmost position 24. It should be noted that the maximum tension is placed on the wire during the initial dispensing operation between positions 22 and 23, since the greatest portion of the dispensing operation occurs between these two positions, leaving only a small length of the dispensed portion of the wire to be drawn through flexure over the edge of shuttle groove 21 and between shuttle 10 and retainer belt 18 as the wire moves from position 23 toward the rearmost position 24. Thus during the high tension portion of the dispensing operation, the flexure angle through which the wire is bent is relatively small, being between 60 and 75°, for example. It should also be noted that the wire 22 is not sharply bent but is drawn progressively at a gentle smooth "rollover" pace across the smooth rim of shuttle groove 21, avoiding kinking or sharp bending of the wire even at this low flexure angle of between 60 and 75°. It will thus be seen that when the entire dispensed portion of the wire has been contributed from the stored turns of wire 22 to the new length of wire at position 24, the maximum flexure angle has progressed only as high as about 94°, as shown in FIG. 3. Continuing revolution of shuttle 10 relaxes all the tension on the free loop of wire through positions 27, 28 and 29, since there is no tension and no flexural dispensing of wire between the shuttle and the retainer belt as the wire loop travels through these positions.

This smooth, rollover dispensing of wire in the methods and apparatus of the present invention, flexing the wire through gentle flexure angles, is in sharp contrast to the bending stress and deformation which conductor wires normally suffer in conventional coil winding operations. As shown in FIG. 2, a prior art shuttle and slider assembly applies initial tension at point 31, drawing the wire sharply through a bending angle of about 140°, more than double the flexure angle produced in the techniques of the present invention. Moreover, this sharp flexure angle occurs about the sharp point 32 of slider 17 and applies the entire tensile load of wire segment 31 to slider 17

through its point **32** in an amount sufficient to overcome the sliding friction of slider **17** on shuttle **16**. Thus slider **17** is forced to move clockwise with a sharp jerk relative to the advancing shuttle **16** in order to dispense the new length of wire required to supplement the taut wire length **31** as this length extends through the successive positions **34** to the maximum dispensed wire length **35**. During the high tension portion of this dispensing operation over which the principal length of newly dispensed wire is drawn through its sharp bend past point **32** of slider **17**, the flexure angle is initially high, being in the neighborhood of 140°, and slowly declines through successive angles, finally reaching the neighborhood of 90° at the diametral point where the fully dispensed wire length **35** is now available to form the next turn of wire about the toroidal core **13A**.

Thus, by comparing FIG. **2** with FIG. **3**, it will be noted that the initial sharp flexure angle of 140° diminishes slowly and remains a very substantial high flexure angle with an extremely sharp apex at the guiding point **32** of the slider **17** in conventional prior art shuttle-slider assemblies. During the corresponding high tension portion of the wire-despensing operation in the coil winding methods and apparatus of the present invention, as shown in FIG. **3**, the smooth, gentle flexing of the wire **22A** during the gentle, rollover dispensing avoids the sharp crimping or bending of the wire, and the maximum flexure angle encountered at the highest tension portion of the cycle in the present invention appears to be in the neighborhood of only 60°, less than half the flexure angle of the prior art techniques.

In the methods and apparatus of the present invention, it will thus be seen that uniform radial retaining force is applied by the retainer belt **18** to the stored turns of wire in grooves **21** of shuttle **10**. Sharp bending deformation stress at a slider is entirely eliminated, and flexure angles less than half of the conventional wire dispensing flexure angles are produced in the methods of this invention. Sharp jerky movements of sliders imposing additional shock loads on the fine winding wire caused by the inertia of the slider **17** and sharp flexure angles of the tightened dispensed wire are all eliminated in the systems of the present invention. Furthermore, the retainer belt **18** effectively contains all stored turns of wire within the groove **21**, avoiding inadvertent spills and tangled twisted masses of conductor wire at the work station. Finally the use of a shuttle without a slider passing through core aperture **12** permits heavy wire to be wound on very small cores, providing significant economies of automated winding operation.

Since the foregoing description and drawings are merely illustrative, the scope of the invention has been broadly stated herein and it should be liberally interpreted so as to obtain the benefit of all equivalents to which the invention is fairly entitled.

We claim:

1. A toroidal coil winding shuttle assembly incorporating

A. a scarf-jointed ring-shaped shuttle adapted to be interlinked in relative rotatable engagement with a toroidal core and having a wire storage groove facing radially outward formed around its periphery,

B. supporting means positioning the shuttle for relative rotational interlinked movement through the central aperture of the toroidal core,

C. idler means supported adjacent to the interlinked position of the core,

D. and a continuous and uninterrupted retainer belt having a substantial portion of its length encircling a substantial portion of the periphery of the shuttle overlying the wire storage groove, and diverging from said shuttle to pass along a path around said adjacent idler means, thence converging directly to rejoin said shuttle, with the interlinked toroidal core being supported for rotation at a point near the idler means between the converging and diverging portions of the retainer belt,

E. and shuttle-engaging drive means providing driving torque causing said shuttle to rotate about its axis whereby the continuous, encircling retainer belt is retained thereon and tractively driven with and by the shuttle,

2. The toroidal coil winding shuttle assembly defined in claim **1**, wherein the supporting means comprises a plurality of rotatable sheaves supporting the shuttle by virtue of mutually counteracting radial forces, said drive means comprising at least one of said sheaves drivingly rotated to supply rotational torque as a tangential traction force to said shuttle.

3. The assembly defined in claim **2**, wherein said sheaves are mounted for rotation on axes passing through the ring-shaped shuttle.

4. The assembly defined in claim **2**, wherein said idler means are adjustably supported for variable positioning movement toward and away from said shuttle, providing tension adjustment for the retainer belt.

5. The toroidal coil winding shuttle assembly defined in claim **1**, wherein the retainer belt is elastically resilient and deformable.

6. The method of winding wire on a toroidal core comprising the steps of

A. providing a scarf-jointed ring-shaped shuttle adapted to be interlinked in relative rotatable engagement with a toroidal core and having a wire storage groove facing radially outward formed around its periphery,

B. supporting said shuttle for relative rotational movement interlinked through the central aperture of a toroidal core,

C. supplying wire to said shuttle while simultaneously loading said wire into the groove of said shuttle by rotating said shuttle in a first direction,

D. subsequently rotating said shuttle in the same first direction to wind said wire from said shuttle groove around said core, while

E. encircling a portion of the periphery of said shuttle with a continuous retainer belt overlying the shuttle groove to retain the wire therein,

F. diverting a portion of said retainer belt from the periphery of said shuttle at an approach point adjacent to said core, and

G. returning the diverted portion of said belt directly to said shuttle at an return point on the opposite side of the core.

7. The toroidal coil winding method of claim **6**, further including the step of securing a free end of a length of said wire, loaded into the groove of said shuttle, fixed in an initial turn on said toroidal core, before initiating winding rotation of said shuttle in the same first direction.

8. The toroidal coil winding method defined in claim **6** wherein the segment of wire delivered during each winding revolution of the shuttle in said first direction squeezes between the rim of the shuttle groove and the encircling overlying retainer belt by deforming the belt to force it away from the shuttle at successive points along their engaged peripheral portions.

9. The assembly defined in claim **1** wherein the continuous retainer belt travels along an uninflected path around said shuttle and around said idler means.