# United States Patent [19]

**Farnsworth et al.**

[11] **3,787,000**

[45] **Jan. 22, 1974**


[54] **WAVE FORM COIL WINDING MACHINE**


[75] Inventors: **Lemoyne E. Farnsworth,** Racine; **Bruce R. Pitt,** Wilwaukee; **John W. Wolf,** Colgate, all of Wis.

[73] Assignee: **Ro-Band Corporation,** Menomonee Falls, Wis.



[22] Filed: **May 19, 1971**

[21] Appl. No.: **144,752**

[52] **U.S. Cl.** ..... **242/1.1 R,** 29/205 D, 29/596, 29/605, 242/1.1 E

[51] **Int. Cl.** ..... **H02k 15/085**

[58] **Field of Search** ..... 242/1.1 R, 1.1 E, 4 R; 29/205 D, 596, 605



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*Primary Examiner*—Billy S. Taylor
*Attorney, Agent, or Firm*—Arthur L. Morsell, Jr.



[57] **ABSTRACT**

Apparatus for winding electrical coils with a wave form pattern into the slots of cores includes a support for a core, a wire feeding, rotatably indexible head which is reciprocable axially of the core, wire laying needles carried by the head, guiding fingers over which the wire is guided as the head is rotatably indexed, and axially movable retainer means for holding previously wound sequences of wire toward the bases of the core slots as additional sequences are being wound. The fingers and needles are radially adjustable toward the center of the core in preparation for subsequent winding. The wire supply is supported on a turntable positioned to rotate as the wire is withdrawn to prevent twisting during rotatable indexing of the head.


**11 Claims, 13 Drawing Figures**

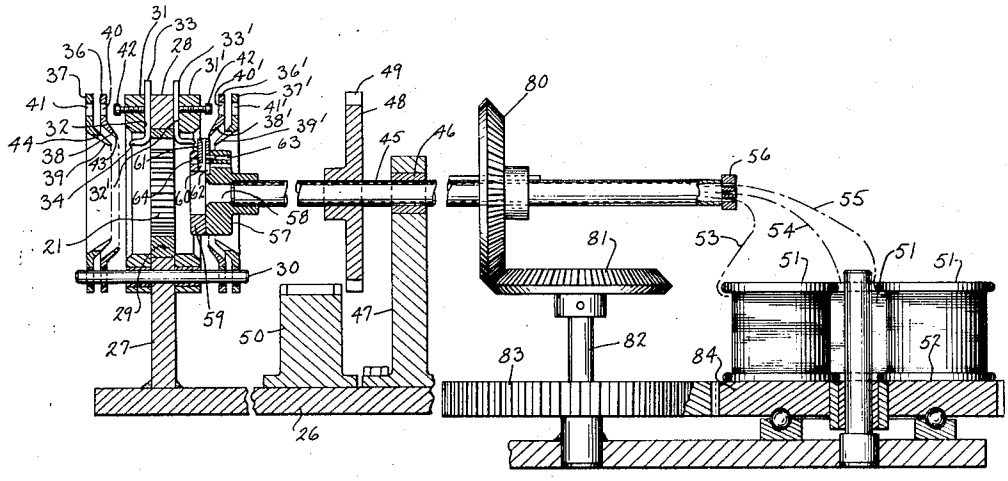


Fig. 1

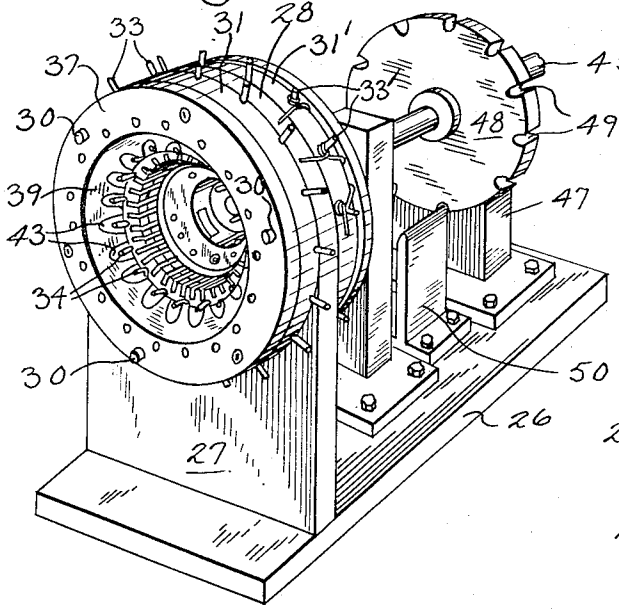



Fig. 2

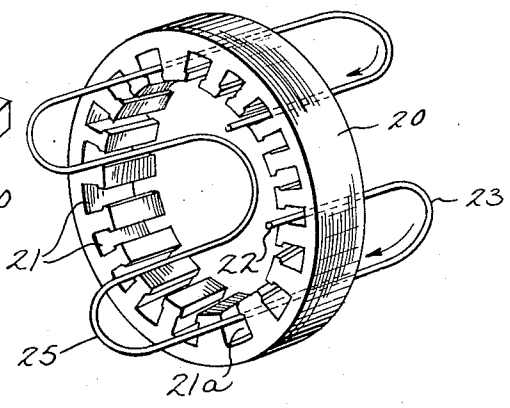



Fig. 3

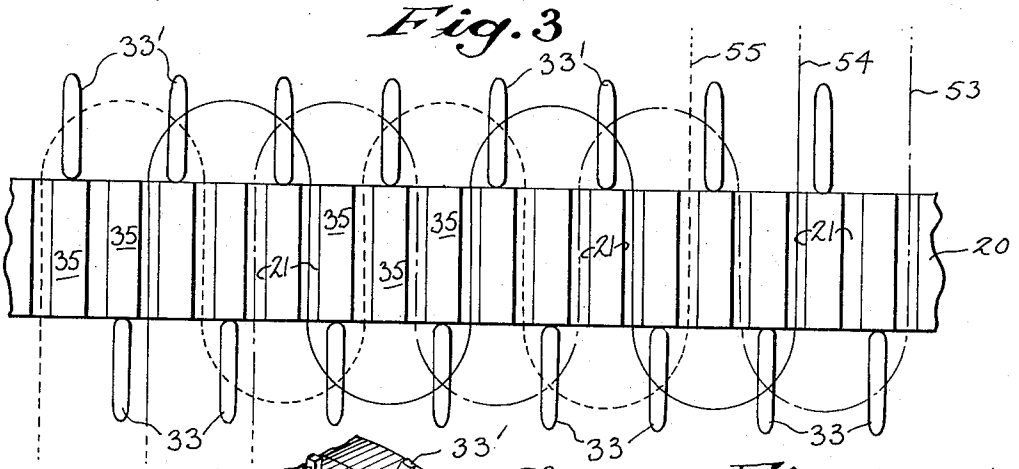



Fig. 4

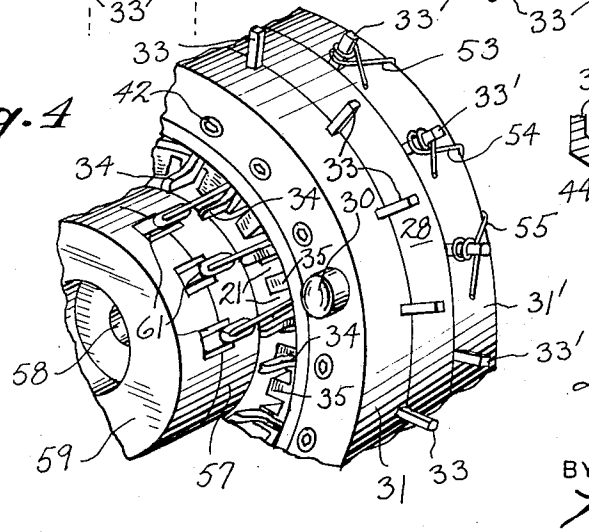
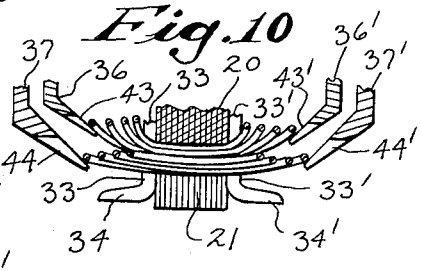



Fig. 10




INVENTORS
L. E. Farnsworth
Bruce R. Pitt
John W. Wolf
BY
Morsell & Morsell
ATTORNEYS

Fig. 5

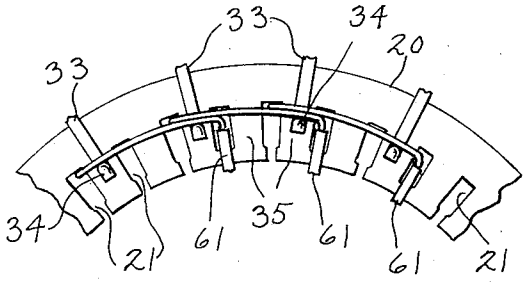



Fig. 6

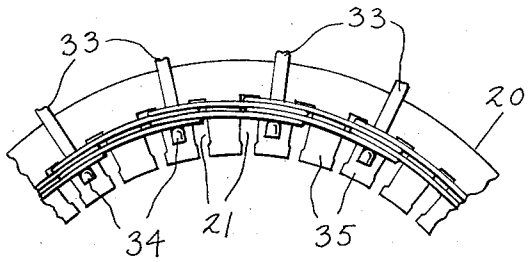



Fig. 7

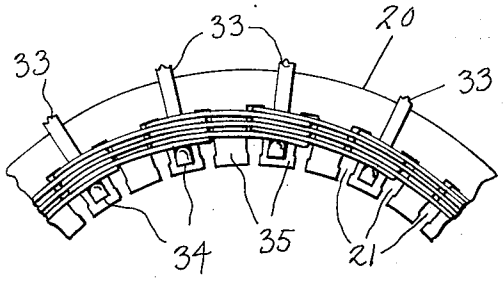



Fig. 8

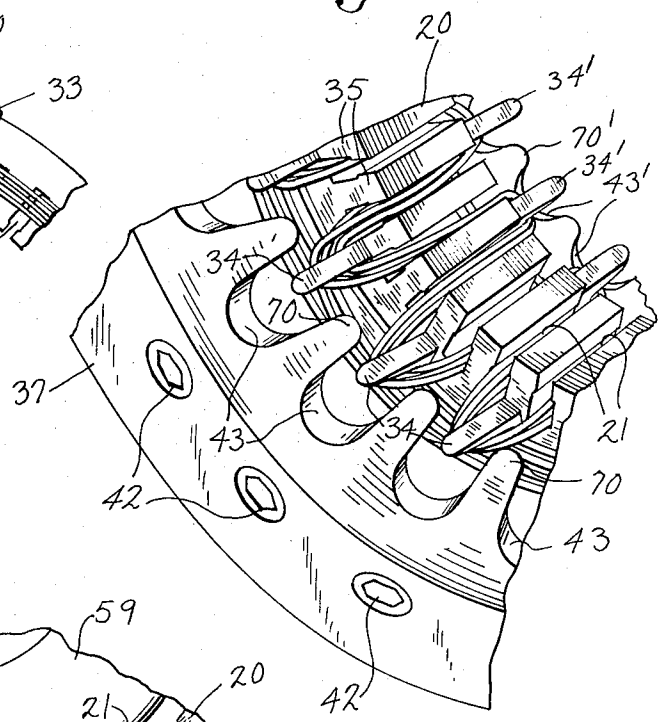
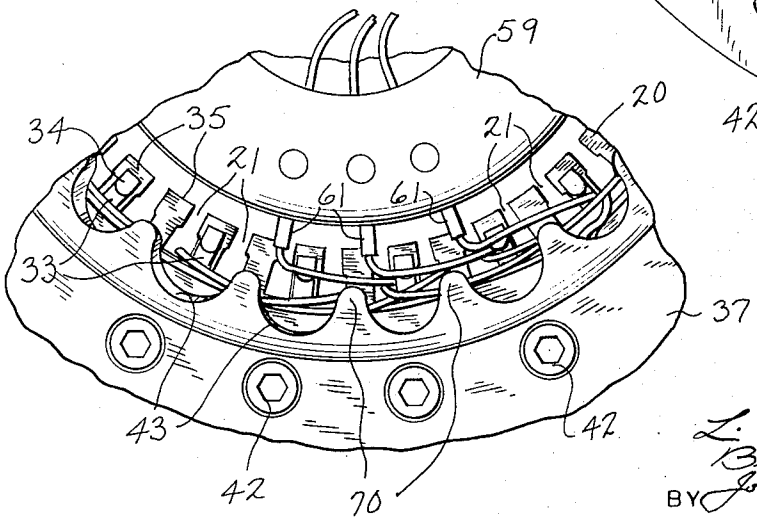



Fig. 9




INVENTORS
L. E. Farnsworth
Bruce R. Pitt
BY John W. Wolf

Morsell & Morsell

ATTORNEYS

Fig. 11

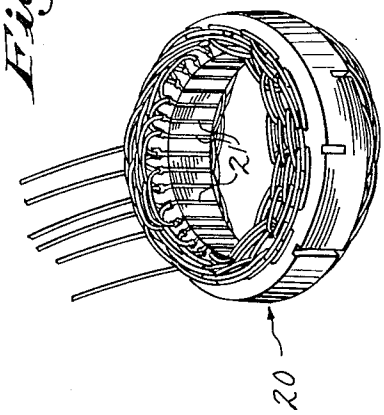



Fig. 12

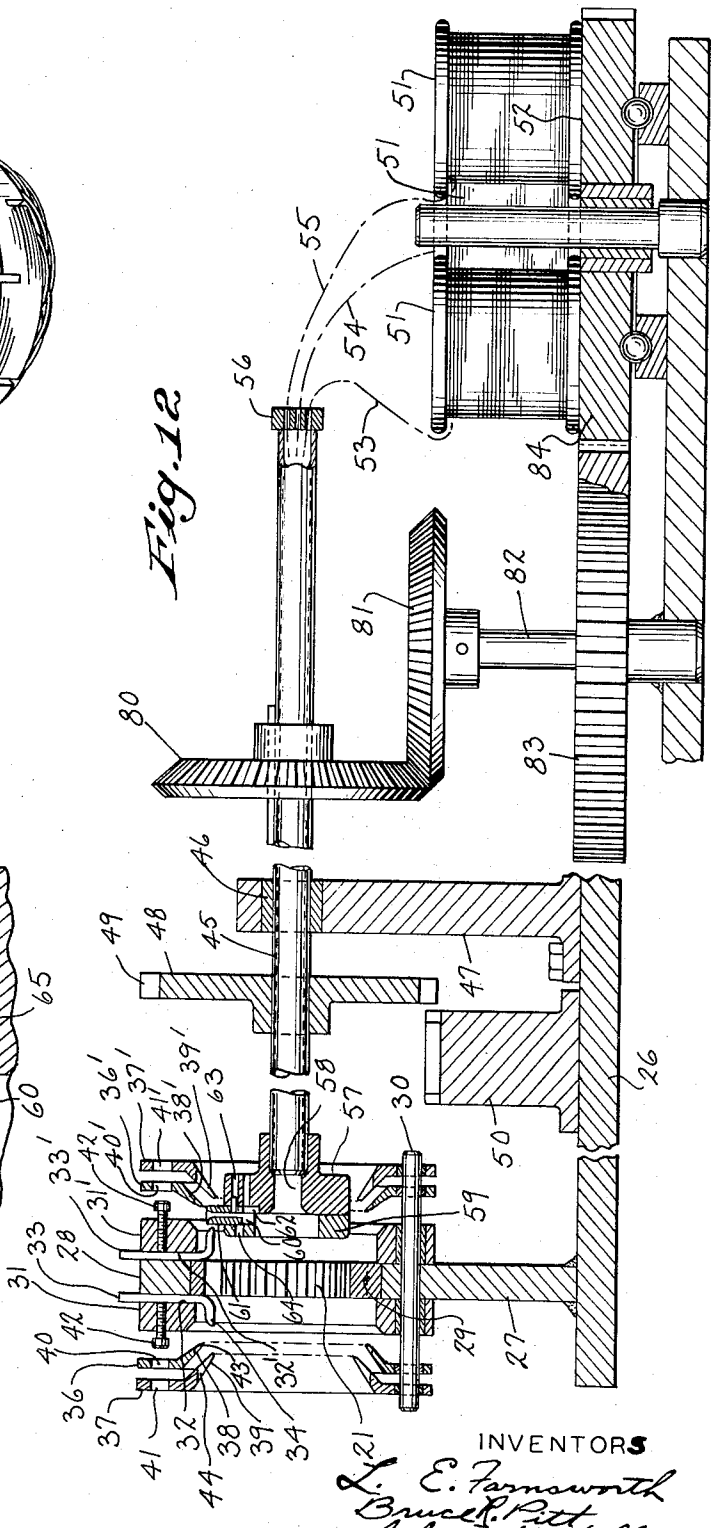
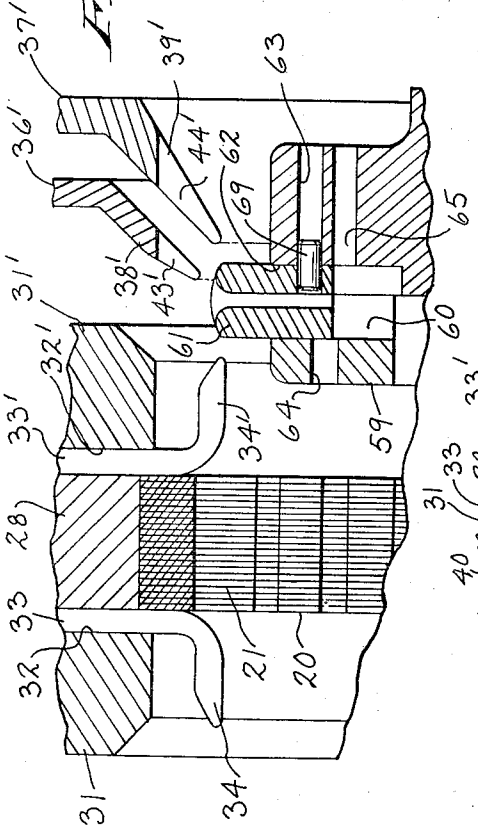



Fig. 13




INVENTORS
L. E. Farnsworth
Bruce R. Pitt
John W. Wolf
BY
Mosell & Mosell
ATTORNEYS

# WAVE FORM COIL WINDING MACHINE

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention pertains to apparatus for winding coils with a wave form pattern into the slots of cores of electrical devices such as into the slots of stators for alternators, electric motors or generators.

2. Description of the Prior Art

Cores are conventionally wound with a series of coils, each coil being wound through a pair of circumferentially spaced slots in the core. A completed motor comprises a series of such coils wound in a pattern depending upon the type of motor, the wire feeding head being alternately indexed in opposite directions in order to form the coil end loops of conventional winding. Wave form winding differs in that the wire progresses from slot to slot circumferentially around the core in a serpentine path, the completed winding consisting of several layers of this serpentine type winding. Wave form winding is advantageous in that it provides for better heat dissipation in use.

Apparatus for automatically winding the coils with conventional type windings has heretofore been proposed, and while wave form winding has heretofore been known, there have been no machines capable of taking care of the complicated winding sequences required.

Coil winding machines for winding coils in the conventional manner are disclosed in Frederick U.S. Pat. Nos. 3,082,966 and 3,227,382. If it were attempted to wind wave form coils by machines of the type shown in the above patents the wires would tend to concentrate on the sides of the slots in the core and would not build up from the bottoms of the slots toward the center of the core in a proper pattern to obtain efficient wave form winding. Therefore, winding machines as heretofore proposed have not been suitable for wave form winding.

## SUMMARY OF THE INVENTION

The present invention provides apparatus for winding coils with a wave form pattern which includes a wire feeding rotatably indexible head mounted for reciprocation axially of the core, the head having wire laying needles adjustably carried therein to provide for radial adjustment toward the center of the core as the winding progresses, and there being guiding fingers over which the wires are guided as the head is indexed which are also radially adjustable toward the center of the core. In addition there is movably supported retainer means for holding previously wound sequences of wires toward the bases of the core slots as additional sequences are being wound, and there is means for preventing twisting of the individual wires as they are fed to the machine.

A general object of the invention is to provide apparatus for efficiently winding coils with a wave form pattern.

A further object of the invention is to provide apparatus for winding coils with a wave form pattern wherein the head has a set of circumferentially spaced needles, such as three, which act to lay a plurality of strands simultaneously in different slots in a serpentine pattern.



A further object of the invention is to provide, in apparatus as above described, means for insuring that the wound sequences of wire start at the bases of the slots and progress toward the center of the core as the winding progresses to insure efficient filling of the slots.

A more specific object of the invention is to provide apparatus as above described in which the wire laying needles and wire holding fingers are radially adjustable toward the center of the core.

A further object of the invention is to provide, in a coil winding apparatus, movably mounted retainer means movable to positions to maintain previously wound sequences of wire toward the bases of the core slots as additional sequences are being wound.

A further object of the invention is to provide, in an apparatus as above described, turntable means for supporting the wire supply in a manner to compensate for the rotatable indexing movement of the needle head and to prevent twisting of the wire as it is being withdrawn for use.

A further object of the invention is to provide, in an apparatus as above described, an improved arrangement wherein the wire guiding fingers are supported over circumferentially spaced lands between slots, and wherein the fingers on one side of the core are staggered with respect to the fingers on the other side, whereby efficient wave form winding is accomplished.

With the above and other objects in view, the invention consists of the improved wave form coil winding apparatus, and all of its parts and combinations, as set forth in the claims, and all equivalents therof.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings, in which the same reference numerals designate the same or similar parts in all of the views:

FIG. 1 is a perspective view of the improved wave form coil winding machine;

FIG. 2 is a partially diagrammatic perspective view illustrating a wave form type of winding pattern;

FIG. 3 is a partially diagrammatic view showing the lower portion of the ID of a core laid out straight and illustrating the staggered position of the wire guiding fingers on the opposite sides of the core together with the path of the wave form wound wire as laid by three needles;

FIG. 4 is a fragmentary perspective view of the supported core showing the head just after it has passed through the core with three wires;

FIG. 5 is a fragmentary elevational view looking at the top of the apparatus with the retainer rings removed showing the wires after the head has been indexed clockwise from the position of FIG. 4;

FIG. 6 is a view similar to FIG. 5 showing two turns of wire in position in the first sequence;

FIG. 7 is a view like FIG. 5 showing the first sequence completed;

FIG. 8 is a fragmentary perspective view looking at a lower portion of the apparatus of FIG. 1 with a retainer ring in position holding the first sequence while additional wire is being laid for another sequence;

FIG. 9 is a fragmentary perspective view looking at a lower portion of the core holding part of the machine of FIG. 1 showing the winding of the first turn of the second sequence;

FIG. 10 is a fragmentary sectional view through the bottom of a supported core showing both retaining

rings axially adjusted to a position to retain two sequences in position;

FIG. 11 is a perspective view of a wound core after it has been removed from the winding machine;

FIG. 12 is a longitudinal, vertical sectional view through the apparatus of FIG. 1, also showing the turntable support for the wire supply; and

FIG. 13 is an enlarged fragmentary sectional view showing the adjustable mounting for the needles and showing fragments of associated parts, the dotted lines showing the maximum extended position of the needle as it passes through a core slot.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring more particularly to the drawing, first to FIG. 2, the numeral 20 illustrates a laminated core of the general type with which the present invention is concerned, which core is used in electrical machines such as for the stator of an electric motor or alternator. The core is ring-shaped and there are slots 21 projecting radially inwardly from the ID and extending in circumferentially spaced relationship therearound. In convntional winding the wire is threaded axially through one slot from a first side, then looped around and positioned for return through another slot, spaced circumferentially from the first slot, back to the first side, and then looped back to the first slot. The winding is continued with repeated revolutions to form a coil in the pair of slots, with the ends of the coil projecting from the front and rear faces of the core in the form of loops. A completely wound core consists of a series of these coils circumferentially spaced from one another and arranged in a pattern which depends upon the particular type of motor or electrical apparatus. Wave form winding with which the present invention is concerned is illustrated diagrammatically in FIG. 2 by the path of a single wire. Here the wire enters a slot 21 on the front face of the core as at 22, continues through the slot to the other side, is looped around as at 23, then through another slot 21*a* which may be spaced several slots away from the first slot, is then looped around in a clockwise direction as at 25, and progresses circumferentially around the core in the serpentine path illustrated diagrammatically in FIG. 2. A completed winding will consist of several sequences, and each sequence comprises a plurality of turns, each turn comprising a 360° travel around the ID of the core. FIG. 2 shows one turn substantially completed with a single wire. A complete winding may comprise a plurality of sequences, such as three, each sequence having three or four or more turns. With the present invention, as will appear hereinafter, instead of one wire being laid as in FIG. 2, the improved machine is designed to lay a plurality of wires, such as three, simultaneously in different slots which are circumferentially spaced from one another.

Referring more particularly to FIGS. 1 and 12, the improved apparatus comprises a suitable base 26 having a cradle 27 projecting upwardly therefrom, the cradle supporting a core holder ring 28 for removably receiving a core 20 which is to be wound. Extending transversely through the holder ring, preferably 120° apart, are rods 30. The intermediate portions of these rods are fixed in the holder 28. Slideably mounted on the rods on one side of the holder is a tooling ring 31 having a plurality of radially extending slots 32 in its inner face for radially adjustably receiving guiding fingers 33. Slideably mounted on the opposite side of the core holder 28 is another tooling ring 31' having a plurality of slots 32' for fingers 33'. The inner ends of the fingers are bent into L-shape hooks as at 34 and 34'. When the tooling rings 31 and 31' are in the assembled position of FIG. 12 the guiding fingers may be radially adjusted to vary the distance of the bent ends 34, 34' from the center of the core being wound. In FIG. 12, for purposes of clarity, only one pair of fingers 32, 32' is illustrated. It is, however, to be understood that in the embodiment illustrated there is a finger for every other land 35 between the core slots 21, as is clear from FIGS. 5–8, inclusive. The position of the fingers on the tooling ring 31', however, is staggered with respect to the position of the fingers on the tooling ring 31, as is clear from FIG. 3, and this is important in order to carry out the wave form winding pattern. It is important that the spacing of the finger slots 32, 32' be such as to bring the fingers over lands 35 between core slots when the core is assembled as in FIG. 12, and when the machine is ready for operation. Also slideably mounted on the supporting rods 30 are retainer rings 36, 37 and 36', 37'. The retainer rings 36, 36' have angularly inwardly projecting annular flanges 38, 38', and the rings 37, 37' have angularly inwardly projecting flanges 39, 39' which are positioned radially inwardly from the portions 38, 38'. The rings 36, 36' have a circle of holes 40, 40', and the rings 37, 37' have a circle of holes 41, 41' which are positioned to allw passage of the heads of set screws 42 when the retainer rings are adjusted inwardly. There is a set screw 42 for each of the fingers 33, 33' which may be manipulated to hold the fingers in a selected position of radial adjustment. The angularly inwardly extending flanges 38, 38' of the holding rings 36, 36' have scalloped edges to provide recesses 43, 43' for clearing the inner portions of the fingers 32, 32', and the angularly inwardly extending portions 39, 39' of the outer retainer rings are similarly scalloped to provide recesses 44, 44' (see FIG. 10). The recesses of the retainer rings at one end of the apparatus (see FIG. 8) are staggered with respect to the recesses of the retainer rings at the opposite end because of the staggered relationship between the fingers at opposite ends of the apparatus. The flange portions between recesses provide sequence holding elements 70. These recesses are also clear from FIGS. 8 and 9 where it is apparent that there is one recess for each of the guiding fingers 33, 33'.

A tubular spindle 45 is suitably supported in a bearing 46 at the upper portion of a standard 47 for rotation as well as for axial movement. The spindle may carry an indexing disk 48 in fixed position thereon having circumferentially spaced peripheral notches 49 one of which may be made to engage a fixed indexing key 50 when the spindle 45 is moved axially to the left (referring to FIG. 12). Wire may be supplied from spools 51, three in number in the preferred embodiment illustrated, which are mounted on a rotatably supported turntable 52. The three wires 53, 54 and 55 from the spools 51 enter a fitting 56 with three holes at the end of the tubular spindle 45. These wires continue through the spindle where they enter a head 57 carried by the inner end of the spindle, the head having a central wire passageway 58. The head has a readily removable inner ring portion 59 which has openings 60 for needles 61, each needle being received in a recess 62 of the main

portion of the head, and in a complementary recess 60 of the needle clamping ring 59. Each needle has a laterally projecting pin 69 which may be fitted into an adjustment hole 63 of the head for maximum height of the needle, into an adjustment hole 64 of the inner ring 59 for intermediate adjustment, or into an adjustment hole 65 on the head for lowest adjustment, depending upon the distance it is desired to have the needle project considering the stage of the winding operation (see FIG. 13). The needle clamping ring 59 may be removably clamped to the head, by bolts or other suitable means, to clamp the needles in a predetermined position of adjustment.

## OPERATION

In use, the core 29 is mounted in the core holder 28 while the tooling ring 31 and retainer rings 36 and 37 are removed. Then the core is inserted in such a position that the fingers 33, 33' are opposite lands 35 between slots, as is clear from FIG. 3, the position of the tooling rings 31, 31' on the supporting rods 30 being such that the fingers of the tooling ring 31' are staggered with respect to the fingers of the tooling ring 31, as is clear from FIG. 3. Next the tooling rings 31 and 31' are removably bolted to the core holder 28 and the fingers 33 and 33' are adjusted to substantially the position of FIGS. 12 and 13 with the hooked portions 34, 34' relatively close to the bottoms of the slots 21 of the core being wound. Also the three needles 61 in the head are adjusted to the maximum outwardly extending position 63, as shown in FIG. 12. The circumferential relationship of the three needles with respect to one another is shown in FIG. 4. Then the wires are threaded through the spindle 45, through the bore 58 of the head 57, and one wire is threaded through the bore of each needle to emerge from the outer end thereof.

At the start of a winding operation the ends of the three wires 53, 54 and 55 may be suitably anchored to the tops of three fingers by being wound therearound as in FIG. 4. The head 57 is then indexed to the desired starting position by moving the spindle to the left (referring to FIG. 12) with a selected indexing recess 49 of wheel 48 engaging the key 50. The spindle is then moved axially to push the head 57 through the core from the position of FIG. 12 to the position shown in FIG. 4. This pulls the three wires through three slots, being three alternate slots as shown in FIG. 3, the wire 53 passing through one slot, the wire 54 through a second slot away from the slot for the wire 53, and the wire 55 through the second slot away from the slot for the wire 54, as is illustrated in FIG. 3. As the needles come through to the opposite side of the core as in FIG. 4 there will be a guiding finger 33 opposite the land which is just beyond the slot, in a clockwise direction, for each wire.

Next the spindle 45 is pushed axially sufficiently far so that it may be clear of the key 50, permitting indexing one notch in the wheel 49. This indexing is in a clockwise direction, referring to FIG. 4, carrying each wire over two of the finger hooks 34. The position of the wires after indexing is illustrated in FIG. 5. Thereafter the needle head 57 is drawn back through the core while the indexing wheel 48 is held in its second indexed position with respect to the key 50. Back on the first side, the head 57 is again indexed in the same direction (clockwise looking at FIG. 4) and the wires are passed back through the core, the loop of each strand being passed over two of the finger hooks 34', as is clear from the pattern of FIG. 3. This procedure then continues for 360°, which completes the first turn. The procedure then continues around for more turns until the desired number of turns for the first sequence have been laid. FIG. 6 shows the completion of two turns of the first sequence, and FIG. 7 shows the completion of the first sequence. It is to be noted that the adjusted position of the needles and fingers has been such as to lay the wires of the first sequence closely adjacent the bottoms of the core slots 21.

With the present invention the fingers will now be readjusted to bring their hooked ends 34, 34' closer to the center of the core so that there is room for winding another sequence on top of the first sequence, with the turns of the second sequence progressively farther out in the slots 21 toward the open ends thereof. To accomplish this the needles 61 are adjusted inwardly to the second position (64 of FIG. 13) so as to conform to the new position of the hooks 34, 34'. However, if this were performed without any further provision there would be danger of the first-laid sequence working outwardly in the slots to interfere with the next sequence to be laid. Accordingly, with the present invention, before the fingers 33, 33' are adjusted to the new position, the inner retainer rings 36, 36' are moved inwardly to the position shown in FIG. 10 so that the holding projections 70 of the flanges 38, 38' engage the loop ends of the first sequence to hold said sequence closely toward the bottoms of the slots as in FIG. 10. At this time the outer retainer rings 37, 37' are in an outward position on the rods 30 (instead of in the position of FIG. 10) so that they do not interfere with the winding of the next sequence.

The winding of the several turns of the next sequence is now carried out in the same manner heretofore described in connection with the first sequence. When this has been completed the retainer rings 37, 37' are moved into position of FIG. 10 to engage loop ends of the second sequence to hold them in a position closely against the first sequence. The fingers 33, 33' are then adjusted to a third position to bring the hook portions 34, 34' to the position shown in FIG. 10 ready for the winding of a third sequence. FIG. 8 shows the retainer ring 36 holding the first sequence while wire is being laid for another sequence, and FIG. 9 shows the wires at the start of the first turn of the second sequence after the head has been indexed.

After the third sequence has been wound in the same manner heretofore described in connection with the first two sequences, the core of FIG. 11 is complete and may be removed from the machine.

During winding, as the wires are pulled off of the spools 51, the rotatable indexing of the head, always in the same direction during the wave form winding, would normally cause objectionable twisting of the three wires. By having the spools 51 mounted on a turntable which is driven in sequence with the head 57 at the same speed the turntable will rotate as the head 57 is being indexed, and the rotation of the turntable will compensate for the rotation of the head and prevent the objectionable twisting. This desirable feature is accomplished by having the turntable 52 rotate at a 1:1 ratio with the head 57 in order to unwrap wire automatically from the spools 51 at a rate which is in sympathy with the rotation of the head 57 when the latter is rotatably indexed. This may be accomplished in various

ways. In the drawing there is a bevel gear **80** splined to the spindle **45** and in mesh with a bevel gear **81** on a jack shaft **82**, the latter carrying a gear **83** on its opposite end which meshes with a gear **84** at the bottom of the turntable **52**. As a result, whenever the spindle **45** is rotatably indexed a predetermined number of degrees the turntable will be rotated an equal number of degrees.

If it were attempted to wind wave form coils having the pattern of FIGS. **2** and **3** by winding apparatus of the type used for conventional core winding, the wires would tend to concentrate on the sides of the slots and would not build up from the bottoms of the slots towards the open ends thereof. Thus proper winding for a wave form pattern could not be carried out. As a result, winding of cores with a wave form pattern has heretofore been done by hand.

With the present invention it is entirely practical to have winding sequences, each with a selected number of turns, and to have each sequence positioned progressively farther outwardly in the slots to provide for efficient filling of the slots with wire from the bases of the slots outwardly. The results of the present invention are made possible by the novel combination of radially adjustable needles, radially adjustable guiding fingers, and retainer rings arranged in a novel manner to hold sequences in proper position while subsequent sequences are being wound, the retainers being of novel form so that they do not interfere with such subsequent winding.

While the present invention has been shown as manually operable, it is obvious that the apparatus may be power driven and that the sequences may be programmed for automatic operation in accordance with the requirements for the particular core being wound.

It is to be understood that we do not desire to be limited to the exact details of construction shown and described, for obvious modifications will occur to a person skilled in the art.

What we claim is:

**1.** In an apparatus for winding wire in wave form into the slots of a circular core wherein there is supporting means for a core to be wound and wherein there is a wire feeding head mounted for rotatable indexing movement and for reciprocable movement axially of the core, the improvement comprising wire laying needles, means mounting said needles for radial adjustment in the periphery of said head for movement from a position in which the wire is laid close to the bases of the slots of the core to positions progressively closer to the center of the core, guiding fingers, means mounting said fingers for radial movement on the core-supporting means whereby they may be adjusted to conform to the position of the needles and thereby provide for progressive winding of wire sequences from the bases of the slots toward the open ends thereof, retainer means, means mounting said retainer means for movement toward and away from an end of the core-supporting means, said retainer means having portions positioned for engagement with the looped ends of wound sequences of wire to maintain said sequences toward the bases of the slots while additional sequences are being wound.

**2.** Apparatus as claimed in claim **1** in which the retainer means is a ring, and in which said ring has a circle of holding elements positionable to engage the looped ends of wound sequences of wire to maintain said sequences toward the bases of the core slots while additional sequences are being wound.

**3.** Apparatus as claimed in claim **1** in which the retainer means is ring-shaped, and in which said retainer means portions are angularly, inwardly projecting to provide wire retaining elements positioned for engagement with the looped ends of the wound sequences of wire.

**4.** Apparatus as claimed in claim **2** in which the wire holding elements are portions of an annular angularly, inwardly projecting flange and are separated by peripherally spaced slots which are located to accommodate the guiding fingers when the retainer means is in a retaining position.

**5.** Apparatus as claimed in claim **4** in which there are two retainer rings supported adjacent an end of said core supporting means, one of said rings having an angularly, inwardly extending flange positionable concentrically within the angularly, inwardly extending flange of the other ring, whereby one retainer ring may hold the looped ends of a first sequence of wire and whereby the other retainer ring may hold the looped ends of a second sequence of wound wire.

**6.** Apparatus as claimed in claim **5** in which there are two retainer rings supported adjacent each end of said core supporting means.

**7.** Apparatus as claimed in claim **1** in which the supporting means for the core has transversely extending rods projecting therefrom, and in which the retainer means is slideably supported on said rods for movement toward and away from the core.

**8.** Apparatus as claimed in claim **1** in which there are guiding fingers at each end of the core supporting means with the fingers at one end mounted in staggered position with respect to the fingers at the other end.

**9.** Apparatus as claimed in claim **8** in which the retainer means is a ring, in which said ring has an angularly, inwardly projecting annular flange with a circle of holding elements positioned to engage the looped ends of wound sequences of wire to maintain said sequences toward the bases of the core slots while additional sequences are being wound, in which said guiding fingers have hooked ends positioned over the lands between slots of the core, and in which there are circumferentially spaced recesses between said holding elements which are positioned to allow the hooked ends of the guiding fingers to project therethrough when the retainer means is in retaining position, the recesses of the retainer ring at one end being staggered with respect to the recesses of the retainer ring on the other end.

**10.** In an apparatus for winding wire in wave form into the slots of a circular core wherein there is supporting means for a core to be wound and wherein there is a wire feeding head mounted for rotatable indexing movement and for reciprocable movement axially of the core, the improvement comprising tubular wire laying needles, means mounting said needles for radial adjustment in the periphery of said head for movement from a position in which the wire is laid close to the bases of the slots of the core to positions progressively closer to the center of the core, guiding fingers, means mounting said fingers for radial movement on the core-supporting means whereby they may be adjusted to conform to the position of the needles and thereby provide for progressive winding of wire sequences from the bases of the slots toward the open ends thereof, a tubular spindle, means mounting the

head on said tubular spindle, a rotatably supported turntable supporting a supply for feeding plural wires to said tubular needles in the head, and means responsive to rotatable indexing of the head for rotating the turntable to compensate for said indexing movement and prevent twisting of the wire.

11. Apparatus as claimed in claim 10 in which the turntable supports a plurality of spools of wire.

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