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(54) **Improved winding apparatus for winding gap-less cores for magnetic devices**

(57) An improved winding apparatus for winding a length of an element onto a form includes: a first retention cylinder which in a first position retains a first end of the length of element against a first backstop cylinder; a second retention cylinder which in a first position retains a second end of the length of element against a second backstop cylinder; means for driving the retention and backstop cylinders to rotate the length of element in a first direction through the form; means for alternately, successively moving one of the first and second retention cylinders to its second, retracted position to release the innermost loop of element to cause it to be wound onto the form as the length of element rotates; and means for returning the moved retention cylinder to its first position after the innermost loop of element is released to retain the remaining loops of element.

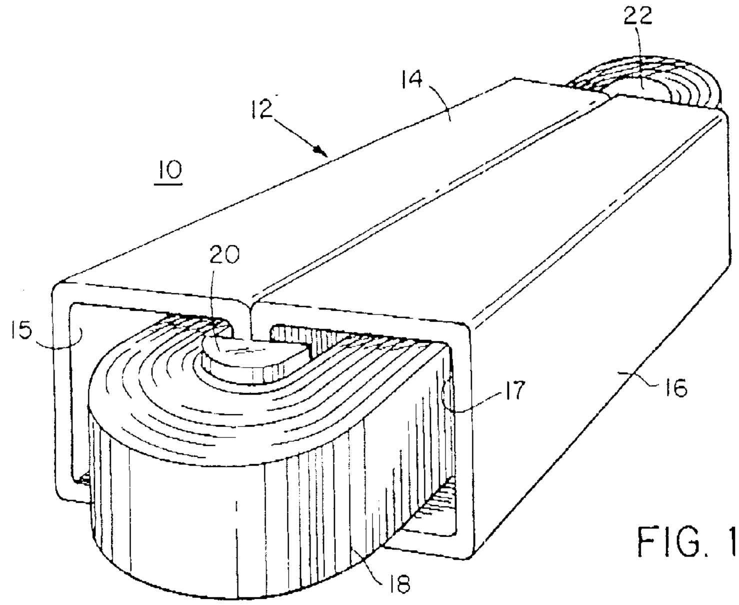

FIG. 1

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Description

FIELD OF INVENTION

This invention relates to an improved winding apparatus for winding gap-less cores for magnetic devices.

BACKGROUND OF INVENTION

Constructing cores for magnetic devices such as transformers presents certain manufacturing difficulties. One method of manufacture involves assembling individual laminar core sections or segments of transformer steel to form a core that fills the opening in and surrounds one or more transformer inductance coils. However, this method is complicated and does not permit rapid assembly of transformers. In addition, this method results in the construction of transformers that are bulky, relatively noisy, and exhibit comparatively large electrical losses. Moreover, cores made of individual lamination pieces necessarily have one or more gaps in each layer of core material. In order to fit into the inside of a coil and also to surround its outside perpendicular to the direction of the coil's conductor material necessitates a core structure of at least two pieces for each layer of core material. In many transformers each layer of core is comprised not just of two pieces but of three, four, five or more individual pieces of material. The lateral fitting together of these pieces leaves microscopic gaps between all adjoining pieces. These gaps impede the propagation of the magnetic field in the core when voltage is applied to the surrounding conductor coil. Overcoming this reluctance to magnetization requires additional power that does not contribute to driving the load of the transformer, but rather is lost as heat in the core and is called "core loss", with its magnitude expressed in Watts. Core loss is of a fixed magnitude, wholly independent of the load of the transformer. Core loss contrasts with "load loss", the power wasted as heat in the coils of the transformer due to the conductor material resistance to current flow. Load loss is independent of the core loss; it varies with the magnitude of the load and is subject to the I^2R phenomenon - doubling the load current quadruples the load loss.

Gap-less transformer cores constructed by winding a ribbon of transformer steel into the shape of a ring or a squared "O" offer certain advantages over transformer cores assembled from individual laminar construction. Gap-less cores avoid the losses specifically attributable to core gaps, and such cores are quieter in operation, more compact, and fundamentally more economical than conventional laminar cores. The manufacture of gap-less core inductive devices bypasses the metal-stamping or cutting processes necessary for conventional lamination and replaces manual core assembly with a rapid semi-automatic process involving little labor.

One winding apparatus, disclosed in U.S. Patent No. 4,655,407, for producing gap-less transformer cores uses retention roller assemblies disposed about the inside of a loop of transformer core material to successively release the inner-most layer of core material when tension on that layer exceeds a predetermined threshold. Each roller assembly responds to the tension by raising and separating its roller pair to physically release the layer which is then wound about the form under tension in an inside-out manner. This apparatus, especially the design of its roller assemblies, is relatively complex in construction and its speed is limited by the response time of the roller assemblies. In addition, since the loop of core material is driven from the outside, the inner layers are eventually shortened and tightened. This significantly increases the tension on the inner-most layer and the roller assemblies which eventually causes the apparatus to seize.

Another apparatus for producing gap-less transformer cores, disclosed in U.S. Patent No. 4,752,042, utilizes a plurality of magnetic carrier units to wind a core of transformer ribbon about a form such as one or more transformer coils. This apparatus, however, cannot easily accommodate a range of transformer core ribbon widths as each of the individual magnetic carrier units are of a fixed width. Thus, this apparatus is not capable of accommodating a transformer core ribbon width greater than the size of the carrier unless each of the many carrier units are replaced with wider units. Moreover, this apparatus is relatively complex in construction.

SUMMARY OF INVENTION

It is therefore an object of this invention to provide an improved apparatus for winding gap-less cores for magnetic devices which is less complex than prior winding devices.

It is a further object of this invention to provide such an improved apparatus for winding gap-less cores for magnetic devices which is capable of assembling gap-less core devices faster than prior devices.

It is a further object of this invention to provide such an improved apparatus for winding gap-less cores for magnetic devices which propels the core ribbon from the inside thereby avoiding the gradual tightening of the core ribbon layers that can lead to a seizing of the machine.

It is a further object of this invention to provide such an improved apparatus for winding gap-less cores for magnetic devices which can easily accommodate a wide range of core ribbon widths.

It is a further object of this invention to provide such an improved apparatus for winding gap-less cores for magnetic devices which is capable of producing single or three-phase magnetic devices having a number of coils and which are capable of operating at power ratings up to 1000 KVA with voltage ratings in the multiple kilovolt range.

This invention results from the realization that a truly reliable, efficient and uncomplicated winding apparatus for tightly winding a gap-less core of ribbon onto one or more magnetic device coils can be achieved by providing two pairs of retention and backstop cylinders located at and retaining opposite ends of a length of core ribbon to be wound onto the magnetic device coil(s) and driving each of the retention and backstop cylinders to rotate the length of core ribbon through the magnetic device coil(s) such that the length of core ribbon is driven from the inside or from both the inside and outside and by alternately, successively moving one of the retention cylinders to a second, retracted position to release the innermost loop of core ribbon to cause it to be wound onto the magnetic device coil(s) as the length of core ribbon rotates.

This invention features an improved winding apparatus for winding a length of element onto a form. The apparatus includes a first retention cylinder which in a first position retains a first end of the length of element against a first backstop cylinder and a second retention cylinder which in a first position retains a second end of the length of element against a second backstop cylinder. There are means for driving the retention and backstop cylinders to rotate the length of element in a first direction through the form. There are also means for alternately, successively moving one of the first and second retention cylinders to its second, retracted position to release the innermost loop of element to cause it to be wound onto the form as the length of element rotates.

In a preferred embodiment the element may be a core ribbon and the core ribbon may be formed of transformer steel. The core ribbon may be formed of an amorphous metal, nickel alloy or a ferrite. The form may include at least one magnetic device coil.

The first retention cylinder and first backstop cylinder may be affixed to one of a stationary module and a moveable module and the second retention cylinder and second backstop cylinder may be affixed to the other of the stationary module and the moveable module. There may further be included a platform positioned between and interconnected with the stationary and moveable modules for supporting the form. There may further be included means for moving the moveable module with respect to the stationary module. There may further be included means for adjusting the length of the platform to accommodate various size forms. The platform may include a first set of incorporating tines proximate one of the moveable and stationary modules and a second set of incorporating tines proximate the other of the moveable and stationary modules; the tines may be moveable with respect to each other as the moveable module moves with respect to the stationary module to enable the length of the platform to be adjusted. There may further be included means for adjusting the height of the platform to ensure proper travel of the element through the form. The platform may include means for securing the form to the platform. The means for securing may include a pair of spring loaded jaws which enable lateral movement of the form. The means for driving may include means for driving the retention and backstop cylinders to rotate the element in a second direction, opposite the first direction, through the form to load onto the apparatus the length of element to subsequently be wound onto the form. There may further be included a plurality of feed belt means for propelling the length of element in the first and second directions through the form. The feed belt means may include means for magnetically attracting the element to the feed belt means to propel the element as the feed belt means are moved. There may further be included means for winding the innermost loop of element onto the form to a predetermined tension. The means for alternately, successively moving may include means, responsive to the means for winding, for initiating movement of the next retention cylinder to its second, retracted position after the released innermost loop of element is wound onto the form to the predetermined tension. The form may be mounted on a moveable platform and the means for winding may include switch means which activate the means for initiating when the form is laterally moved a predetermined distance by the force of the innermost loop of element being wound onto the form to the predetermined tension. The means for winding may include clamp means for holding a portion of the innermost loop of element against the form until the innermost loop of element is wound onto the form to the predetermined tension. The means for clamping may include means for forcing the portion of the innermost loop in the direction of rotation. There may further be included means for returning the moved retention cylinder to its first position after the innermost loop of element is released to retain the remaining loops of element. The means for returning may include means for determining when the innermost loop of element has traveled a predetermined distance toward the form to initiate return of the moved retention cylinder to its first position. The first and second retention cylinders may include two cylinder portions. The means for alternately, successively moving may include means for separating the cylinder portions to cause the release of the innermost loop of element. The means for separating may include means for raising one of the cylinder portions above the innermost loop of element and lowering the other of the cylinder portions below the innermost loop of element. The stationary and moveable modules may each have a surface on which the element travels as it is wound onto the form. There may further be included means for holding the length of element against the surfaces of the stationary and moveable modules as the coil of element is rotated. There may further be included restraining means for imparting a force on the innermost loop of element to hold it against the remaining loops of the length of element until the tension on the innermost loop exceeds the force when the restraining means releases the innermost loop. The restraining means may include a plurality of paddles spaced about the circumference of the innermost loop; each paddle may include a concave portion for receiving the tip of another paddle to impart lift on the paddle as the other paddle is forced upward as it releases the innermost loop. The form may include at least one previously completed core of magnetic material and the element may include electrically conductive material.

This invention further features an improved winding apparatus for winding a length of core ribbon onto one or more magnetic device coils. The apparatus includes a first retention cylinder which in a first position retains a first end of the length of core ribbon against a first backstop cylinder. There is a second retention cylinder which in a first position retains a second end of the length of core ribbon against a second backstop cylinder. There are means for driving the retention and backstop cylinders to rotate the length of core ribbon through the magnetic device coils. There are means for alternately, successively moving one of the first and second retention cylinders to its second, retracted position to release the innermost loop of core ribbon to cause it to be wound onto the magnetic device coils as the length of core ribbon rotates. There are means for returning the moved retention cylinder to its first position after the innermost loop of core ribbon is released to retain the remaining loops of core ribbon. There are means for winding the innermost loop of core ribbon onto the magnetic device coils to a predetermined tension. The means for alternately, successively moving includes means, responsive to the means for winding, for initiating the movement of the next retention cylinder to its second, retracted position after the innermost loop of core ribbon is wound onto the magnetic device coils to the predetermined tension.

In a preferred embodiment the magnetic device coils may be mounted on a moveable platform and the means for winding may include switch means which activate the means for initiating when the magnetic device coils are laterally moved a predetermined distance by the force of the innermost loop of core ribbon being wound onto the magnetic device coils to the predetermined tension. The means for winding may include clamp means for holding a portion of the innermost loop of core ribbon against the magnetic device coils until the innermost loop of core ribbon is wound onto the magnetic device coils to the predetermined tension. The means for clamping may include means for forcing the portion of the innermost loop in the direction of rotation.

DISCLOSURE OF PREFERRED EMBODIMENT

Other objects, features and advantages will occur to those skilled in the art from the following description of a preferred embodiment and the accompanying drawings, in which:

Fig. 1 is a perspective view of a magnetic device capable of being produced by the apparatus according to this invention;

Fig. 2 is a perspective view of the apparatus according to this invention;

Fig. 3 is a top schematic view of the apparatus of Fig. 2;

Fig. 4 is a partial top schematic view similar to the view of Fig. 3 illustrating the core stacking/winding process;

Fig. 5A is a side view of one set of retention and backstop cylinders with the retention cylinder in the extended position;

Fig. 5B is a view similar to Fig. 5A with the retention cylinder in the retracted position located within the retention cylinder housing;

Fig. 6A is a top plan view of the view shown in Fig. 5A;

Fig. 6B is a top plan view of the view shown in Fig. 5B;

Figs. 7A and B are side views of the core ribbon with the innermost loop of core ribbon being released by the retention paddles;

Fig. 8 is a partially broken away front elevational view of the apparatus of Fig. 2;

Fig. 9 is a left end view of the apparatus shown in Fig. 8;

Fig. 10 is a right end view of the apparatus shown in Fig. 8;

Fig. 11A is a top schematic view of a retention cylinder in its housing interconnected with a pulley by a drive belt;

Fig. 11B is a side cross-sectional view of the retention cylinder of Fig. 11A;

Figs. 12A and 12B are side elevational views of an alternative retention cylinder illustrating its operation;

Fig. 13A is a side view of a clamp mechanism used for ensuring that the core ribbon is wound onto the coils to a predetermined tension;

Fig. 13B is an end view of the clamp mechanism of Fig. 12A;

Fig. 14A is a side view of the clamp mechanism depicting the first step of the clamping sequence;

Fig. 14B is a top plan view of the clamp mechanism of Fig. 13A;

Fig. 14C is a side view of the clamp mechanism depicting the second step in the clamping sequence;

Fig. 14D is a top plan view of the clamp mechanism of Fig. 13C; and

Fig. 15 is a flow chart illustrating the loading and stacking/winding operation of the apparatus according to this invention.

Fig. 16A and 16B are partial top schematic views similar to the view of Fig. 4 illustrating how the stacking/winding processes is terminated; and

Fig. 17 is a schematic cross-sectional view of an inductance core and a loading coil of conductor to be wound into an inductor on the core.

The system of this invention is capable of winding cores onto magnetic devices such as transformer 10 as shown in Fig. 1. Transformer 10 includes a form, such as coil set 12 consisting of, in this case, two individual annular coils 14 and 16 having inner spaces 15 and 17, respectively, through which an element, such as a length of transformer core ribbon, is stacked or wound in a plurality of loops to form core 18 about core bobbins 20 and 22. This type of magnetic device and its various configurations with one, two and three coils, are described in U.S. Patent Application Serial No. 08/495096, filed June 27, 1995, entitled "Magnetic Device Mounting System and Bobbin" and assigned to the same assignee as the instant application, can be constructed according to the present invention.

Improved winding apparatus 30, Fig. 2, for winding gap-less cores for magnetic devices according to this invention is capable of producing magnetic device 10, Fig. 1, or any similarly configured device with one, two or even three coils. Moreover, it is capable of forming such cores from core ribbons of various widths. Improved winding apparatus 30 includes stationary module 32 and mobile module 34 which is translatable along track 36 on rollers 35 towards and away from stationary module 32. Positioned securely between stationary module 32 and mobile module 34 is coil set 12 on cradle platform 38 which may be adjusted in the vertical direction to raise or lower coil set 12 for proper alignment during winding. The length of platform 38 is also adjustable as mobile module 34 is translated towards and away from stationary module 32 to accommodate different size coil sets.

Before the stacking/winding process is begun, a sufficient length of core ribbon 40, formed of transformer steel, amorphous metal, nickel alloy, ferrite, or other material customarily used in inductive magnetic devices, from core ribbon dispenser 42 is loaded onto core ribbon support platforms 44 and 46 so that a number of loops of core ribbon 40 can be wound onto coil set 12. Ribbon 40 is passed through first coil 47 of coil set 12, through the gap between backstop cylinder 48 and retention cylinder 50, through second coil 51 of coil set 12, and finally through the gap between backstop cylinder 52 and retention cylinder 54. For the loading process, the end of core ribbon 40 is temporarily taped to the inside of the portion of core ribbon 40 which is then being fed into first coil 47 of coil set 12 at location 55, for example.

Control panel 56 includes programmable controller 58, such as an SMC Corporation ECC50 programmable controller, and linear distance meter 60 which is programmed by an operator to load the necessary length of core ribbon 40 required for the magnetic device which is being formed by winding core ribbon 40 onto coil set 12. The length of core ribbon 40 is measured by linear distance meter 60 and this distance may be monitored on linear distance meter display 62 on control panel 56. When the proper length of core ribbon 40 has been provided to apparatus 30, programmable controller 58 stops the loading process and the operator cuts the core ribbon and tapes it to the outside of the core ribbon 40 which has already been loaded in system 30. There are a plurality of retention paddles 64, only two of which are shown, which position core ribbon 40 as it rotates about the surface of core ribbon platforms 44 and 46.

A top schematic view of system 30, Fig. 3, shows that cradle platform 38 includes a plurality of incorporating tines 66 which enable the length of platform 38 to be adjusted as mobile module 34 is translated towards and away from stationary module 32. This lengthwise adjustment of platform 38 enables the accommodation of various sizes of coil set 12. Coil set 12 is typically mounted on a frame, such as frame 68, as described in U.S. Patent Application Serial No. 08/495,096, filed June 27, 1994, entitled "Magnetic Device Mounting System and Bobbin", for example, which as a unit is secured between spring loaded jaws 70 and 72.

Feed belt channels 74a-d through which ribbon feed belts 76a-d rotate on feed belt pulleys 78a-d and 80a-d carry electromagnets 82a-d in order to magnetically attract core ribbon 40 and propel it in a counterclockwise direction during the loading procedure. During core ribbon loading backstop cylinders 48 and 52 and feed belts 76b and c are rotated in the clockwise direction while retention cylinders 50 and 54 and feed belts 76a and d are rotated in the counterclockwise direction to propel core ribbon 40 in the counterclockwise direction. Ribbon peel-off plates 84 and 86 direct core ribbon 40 toward the openings of coils 47 and 51, respectively. Core ribbon guides 88 and 90 are provided to ensure that core ribbon 40 forms oval or elliptical loops when it is loaded. Ribbon hold down bars 92 and 94 are provided to ensure that core ribbon 40 is propelled substantially flush along platforms 44 and 46 of mobile module 34 and stationary module 32. Proximity sensors 96 and 98 as well as microswitches 100 and 102 are used during the stacking/winding procedure which is described in detail below.

When the loading process is complete a length of element is present on top of apparatus 30 and is traversing coils 47 and 51 of coil set 12. The first end of core ribbon 40 is then affixed to core bobbin 22 by wrapping the end of core ribbon 40 about a dowel 105, for example, and inserting it into core bobbin trench 106. The stacking/winding process is then initiated to reduce the length of individual loops of core ribbon 40, one loop at a time from the inside loop out, from, for example, 10-15 feet to 1½ - 2 feet. The exact reduction depends on the length of core ribbon 40 required for a single loop around both retention cylinders 50 and 54 compared with the length of core ribbon 40 needed for a single loop through and around the coils such as coils 47 and 51 of coil set 12. While stacking/winding, core bundle 104 of core ribbon continually sheds its innermost loop 40a, loop by loop until each of the loops is stacked to form a gap-less core of a magnetic device such as device 10, Fig. 1.

The stacking/winding program of apparatus 30, activated by an operator through programmable controller 58, causes a reversal in the direction of rotation of ribbon feed belts 76a-d, retention cylinders 50 and 54 and backstop cylinders 48 and 52 to drive core bundle 104 in the clockwise direction, opposite its direction of rotation during the loading process such that it rotates in an oval or elliptical path. The inside of core bundle 104 is driven by retention cylinders 50 and 54 and the outside of core bundle 104 may additionally be driven by backstop cylinders 45 and 52.

At the start of the stacking/winding program retention cylinder 54 is positioned below the surface of ribbon support platform 44, whereas retention cylinder 50 is positioned above ribbon support platform 46 and is pressed against backstop cylinder 48 holding core bundle 104 tightly between itself and backstop cylinder 48. As core bundle 104 begins its clockwise rotation driven by retention cylinder 50 and backstop cylinder 48, the beginning of core ribbon 40 is prevented from participating in the rotation as it is affixed to core bobbin 22. This causes the innermost loop 40a of core ribbon 40 to be pulled to the right toward core bobbin 20. As the innermost loop of core ribbon 40a travels toward core bobbin 20 it passes over proximity sensor 96, such as a Veeder Root 672550-530 capacitive proximity sensor, thereby closing the switch within the sensor. Sensor 96 provides a signal to programmable controller 58 which forces retention cylinder 54 to rise above the surface of ribbon support platform 44 and into a position pressed against backstop cylinder 52, thereby holding the remaining loops of core bundle 104 between retention cylinder 54 and backstop cylinder 52. Innermost loop 40a loops from its fixed point on core bobbin 22 through coil 47 around core bobbin 20 through coil 51 to retention cylinder 50. The continuous clockwise rotation of core bundle 104 pulls on innermost loop 40a and with it the entire coil set 12 secured between spring-loaded jaws 70 and 72 is forced to the right as the jaws are compressed. The movement of jaw 72 closes microswitch 100, such as a Minarik DT2RV, which provides a signal to programmable controller 58. Programmable controller 58 in turn causes retention cylinder 50 to move to the left away from backstop cylinder 48 and to be retracted below the surface of ribbon support platform 46. This clears the way for innermost loop 40a proximate retention cylinder 50 to be pulled toward coil set 12 where it will lay down on the loop of core ribbon already positioned on core bobbin 22. By waiting to retract retention cylinder 50 until coil set 12 compresses spring loaded jaw 72 sufficiently to close microswitch 100 this ensures that innermost loop 40a is wound onto coil set 12 with a sufficient amount of tension. The distance coil set 12 compresses before closing microswitch 100 (and 102) can be varied to vary the tension that loop 40a is wound onto coil set 12, and core ribbons of different thicknesses (gauges) require winding to different tensions.

As innermost loop 40a traverses the space above proximity switch 98, the switch is closed and it provides a signal to programmable controller 58 which repositions retention cylinder 50 by forcing it above ribbon support platform 46 and against backstop cylinder 48 with core bundle 104 between it and backstop cylinder 48. The continuing clockwise rotation of core bundle 104 pulls coil set 12 to the left compressing the springs of spring-loaded jaw 70 which closes microswitch 102 to ensure that innermost loop 40a is wound onto coil set 12 with a sufficient amount of tension. The closing of microswitch 102 is sensed by programmable controller 58 which initiates the forward movement and descent of retention cylinder 54, thereby completing one cycle of the stacking process. These steps are repeated under control of programmable controller 58 until all but approximately 1½ loops remain in core bundle 104. The tail end of core ribbon 40 is then untaped and the remaining few feet inserted onto the coils by hand. Once the last loop has been wound, the tail end of core ribbon 40 is welded to the penultimate loop of core bundle 104 already wound onto coil set 12.

The retraction of the retention cylinders below the surface of the ribbon support platform is shown in Figs. 5 and 6. In these figures retention cylinder 54 is shown progressing from its extended position against backstop cylinder 52, Figs. 5A and 6A, to its fully retracted position below the surface of platform 44 within retention cylinder housing 106 in Figs. 5B and 6B. Paddles 64a-d are biased to restrain innermost loop 40a and hold it securely against core bundle 104 until innermost loop 40a is pulled with sufficient force such that it is pulled from core bundle 104. As the innermost loop 40a is finally pulled from the other loops of core bundle 104, paddles 64a-d temporarily give up their restraint, and they do so by virtue of their shape and their positions suspended from individual rotatable shafts 107a and b, Figs. 7A and 7B, above core ribbon 40. As the innermost loop 40a peels off the other loops of core bundle 104 it lifts the first paddle 64a. The tip of paddle 64a contacts a concave portion of paddle 64b, imparting a lift to this paddle. As innermost loop of ribbon 40a clears the tip of paddle 64a, this paddle's tip returns to ribbon support platform 44 and again restrains the remaining loops of ribbon 40 other than the innermost loop 40a. This loop continues its movement to the right and paddle 64b is lifted higher and drops back to ribbon support plate 44 as soon as the edge of innermost loop of ribbon 40a passes beyond the tip of paddle 64b.

The means by which movement of the various components of system 30 is effected is shown in Fig. 8. The positioning of mobile module 34 with respect to stationary module 32 is accomplished by means of drive screw 110 powered by gear motor 112. Screw 110 is linked by ball-nut 114 to mobile module 34 and gear motor 112 permits positioning of mobile module 34 resting on rollers 35 at a desired distance from stationary module 32. Gear motor 112 is controlled from control panel 56, Fig. 2, so that the operator can adjust the length of platform 38 to accommodate various size coils. The vertical position of cradle platform 38 is also adjustable and is accomplished by means of vertical slide 114 which is raised and lowered by jacks 116 driven through shaft 118 by gear motor 120 which is also operated from control panel 56, Fig. 2.

Backstop cylinder 52 is driven rotationally by shaft 122 powered by drive belt 123. Drive belt 123 is contained by pulley 124 which itself is driven from three-axis gear box 126. Gear box 126 also drives pulley 128 containing drive belt 130 which rotationally drives retention cylinder 54. Clutches 125a and 125b provide a safety release in case of a jam-up of either retention cylinder 54 or backstop cylinder 52 under control of programmable controller 58. A pneumatic actuator (not shown), such as a 627-3-ITW-CBV by Mack Corporation, engages or disengages the clutches. When the clutches are engaged they allow rotation of the retention and backstop cylinders and when disengaged the clutches stop rotation of these cylinders. Horizontal pneumatic cylinder 132 horizontally positions retention cylinder housing 106 and retention cylinder 54 into the appropriate locations during the operating cycle, while vertical pneumatic cylinder 134 located within the retention cylinder housing 106 lifts and retracts retention cylinder 54 during the operating cycle. Throughout this disclosure various descriptions of mechanical activating means are illustratively described as pneumatic; that is, activated by compressed air. However, this is not a limitation of the present invention as they could be operated with hydraulic instead of pneumatic force or, as still another alternative, with electric actuators or with electric actuators for some functions, pneumatic for others, and hydraulic for still others.

The left end view of system 30, Fig. 9, depicts pivot post 136 around which pivot shell 138 pivots. Pivot shell 138 is interconnected with retention cylinder housing 106 by pivot arms 139 which when forced by the extension or retraction of horizontal pneumatic cylinder 132 move cylinder retention 54 towards and away from backstop cylinder 52.

When, for example, proximity switch 96, Fig. 3, is closed indicating that innermost loop of core ribbon 40a has passed the switch and indicating that retention cylinder 54 must be extended above ribbon support platform 44 and pressed against backstop cylinder 52, programmable controller 58, Fig. 2, emits successive signals to two solenoid operated air valves 140 and 142 causing them to release compressed air to, respectively, vertical pneumatic cylinder 134, Fig. 8, located within retention cylinder housing 106 and horizontal pneumatic cylinder 132 over lines 141 and 143. The piston rod of vertical pneumatic cylinder 134 is attached to retention cylinder 54 forcing its up and down movement depending on the selection of the inlet port on the vertical pneumatic cylinder 134, and at this part of the cycle it forces its upward movement. Similarly, the piston of horizontal pneumatic cylinder 132 is attached to arms 139 which are affixed to retention cylinder housing 106 forcing its rotation about an arc centered on pivot post 136 which is enveloped by pivot shell 138 which itself is an integral part of retention cylinder housing 106. The successive extension of the piston rod of vertical pneumatic cylinder 134 and the retraction of the piston rod of horizontal pneumatic cylinder 132 forces retention cylinder 54 above the surface of ribbon support plate 44 and into a position pressed against backstop cylinder 52, thereby holding the core bundle 104 between the two cylinders 52 and 54 except for the bundle's innermost loop 40a.

Also visible in this figure is drive belt 144 driven by shaft 122 for driving ribbon feed belts 76a-d, Fig. 3, and retention paddles 64 which are mounted on supports 145.

The right end of system 30 is shown in Fig. 10. Retention cylinder 50 and backstop cylinder 48 are operated in the same manner as retention cylinder 54 and backstop cylinder 52, described above, and their like components have the same reference numbers but are labeled with a prime. Within stationary module 32 motive power is transferred from motor 150 via gear box 152 and shaft 154 to three-axis gear box 126' which drives gear box 126 by shaft 155, Fig. 8.

The manner in which the retention cylinders are driven within the retention cylinder housings is shown, with regard to retention cylinder 54, in Figs. 11A and B. Drive belt 130 driven by pulley 128 passes into and out of retention cylinder housing 106 through openings 160 and 161 and wraps around and engages drive cylinder 162. Drive cylinder 162 is linked to retention cylinder 54 by means of link keys 163-166 which impart rotational momentum to retention cylinder 54 without impeding its vertical movement. The vertical movement of retention cylinder 54 is effected by the vertical movement of piston 168 of pneumatic cylinder 134 suspended on cylinder bracket 170. Piston 168 is linked to retention cylinder by link plate 172.

An alternative retention cylinder 180, Figs. 12A and B, for use in conjunction with, for example, backstop cylinder 52 is split horizontally into two halves 182 and 184 which are attached to linear actuators, such as pneumatic cylinders 186 and 188, respectively. Linear actuators 186 and 188 are connected to air compressors 190 and 192 through solenoid operated valves 194 and 196 which under control of programmable controller 58, Fig. 2, are capable of quickly separating retention cylinder halves 182 and 184 as shown in Fig. 12B to allow the release of innermost loop of coil 40a. The horizontal split of cylinder 180 enables the quick withdrawal by cylinder half 184 below ribbon support plate 44 while the other half 182 rises above it high enough to allow innermost loop of ribbon 40a to pass. To effect movement of cylinder half 182 actuator 186 is interconnected to its associated air compressor 190, through two ports 197 and 198 which when compressed air is provided therethrough causes the piston's extension and retraction, respectively. Ports 199 and 200 interconnecting air compressor 192 to actuator 188 perform the same function.

Cylinder halves 182 and 184 are also moved horizontally toward and away from backstop cylinder 52 by any suitable means.

Keeping core ribbon 40 which has already been wound onto coil set 12 from unraveling is typically ensured by the repeated tightening of the loops on coil set 12 to a predetermined tension as coil set 12 successively slides to the right and to the left in response to a pull on the ribbon 40 a predetermined distance resulting from the action of the rotating retention cylinders. Unraveling can also be prevented by an alternate means involving no back and forth sliding of coil set 12. This alternative relies on a clamp mechanism 220, Figs. 13A and B, affixed to cradle platform 38 proximate core bobbin 20. Of course, an identical mechanism would be affixed to the other side of cradle platform 38 for clamping coil 40 wound to the other end of coil set 12 proximate core bobbin 22. Clamp mechanism 220 includes pneumatic rotary actuator 222 for rotatably driving clamp arm 224 through shaft 226 and clamp hub 228. Also included is spring 230 positioned around shaft 226 as shown in Fig. 13B.

Figs. 14A-D schematically portray the two step clamping process: Figs. 14A and 14B illustrate the first step in the sequence depicting a side view and a plan view, respectively; Figs. 14C and 14D illustrate the second step in the sequence depicting a side view and a plan view, respectively. With clamp arm 224, Fig. 14A, at rest, cam follower 232 is positioned in the well of cam 234, Fig. 14B. In response to a signal from programmable controller 58, Fig. 2, the rotary pneumatic actuator 222 turns shaft 226 clockwise until the tip 235 of clamp arm 224 presses against core ribbon 40, Figs. 14C and D, already deposited on core bobbin 20, thereby holding in place all loops of core ribbon 40. As tip 235, which is typically made of a high-friction elastomeric material, of clamp 224 meets resistance from core ribbon 40 it compresses. Shaft 226 continues to turn, causing cam follower 232 to change position relative to cam 234 and in so doing axially moves hub 228 into which cam surface 234 has been milled and clamp arm 224 which is an integral part of hub 228. The axial movement of hub 228 is accompanied by a lateral movement of tip 235 of clamp arm 224. The surface of tip 235 grips core ribbon 40 thereby further tightening the loops of core ribbon already laid down to ensure that they are positioned to a predetermined tension onto coil set 12. This core ribbon tightening process is carried out on the opposite side of coil set 12 proximate core ribbon 22 to ensure repetitive tightening of core ribbon 40 as it is formed into a core.

The steps of operation of apparatus 30 are depicted in flow chart 300, Fig. 15. The first step in the process involves loading the appropriate amount of core ribbon at step 302 for the size core which is being stacked on the one or more coils involved. At step 304 the end of the innermost loop of core ribbon is affixed to one of the two bobbins associated with the one or more coils. At step 306 the core ribbon loops are rotated in the clockwise direction and at step 308 when the innermost loop trips the first proximity switch as it is drawn toward the coil(s), a signal is sent to cause the first retention cylinder to be extended from its initial retracted position to its extended position pressed against its associated backstop cylinder thereby holding the remaining loops of core ribbon between the two cylinders except for the innermost loop which has been drawn towards the one or more coils. As the core ribbon loops continue to be rotated in the clockwise direction the remaining loops of ribbon pull on the innermost loop which forces the coil (s) to move and cause a first microswitch to trip. With the tripping of the first microswitch the second retention cylinder is retracted at step 310. This allows the innermost loop of core ribbon to be released and drawn toward the coil(s). After that innermost loop of core ribbon passes over a second proximity switch that switch is tripped and at step 312 causes the extension of the second retention cylinder such that it is pressed against its backstop cylinder to hold the remaining loops except for the innermost loop which has been released. At step 314 the first retention cylinder is retracted after the second microswitch is tripped due to the tightening of the innermost loop on the coil(s) causing movement of the coil(s). At step 316 it is determined, as described below with regard to Figs.16A and B, if there are more than 1½ loops remaining in the loop bundle. If there are not, at step 318 the winding process is terminated, the remaining loops are wound manually, and the end of the core ribbon is welded to the penultimate loop. If there are more than 1½ loops remaining at step 316 the system loops back to step 308 and the winding process continues.

Two sets of sensors, typically optical, 320 and 322, Figs. 16A and 16B, include LEDs 324 and 326 (Banner SE 6IE), and optical receivers 328 and 330 (Banner SE 6IR), respectively. When bundle 104 consists of multiple loops of core ribbon 40, as shown in Fig. 16A, light from both LEDs 324 and 326 is blocked so that it is not detected by either optical sensor 328 or 330. Near the end of the stacking/winding process when only approximately 1½ loops of core ribbon 40 remain to be stacked/wound, bundle 104 on one side of the machine, for example, proximate retention cylinder 54, is reduced to a single layer 332 while on the opposite side, proximate retention cylinder 50, bundle 104 is still comprised of two layers. As the stacking/winding process continues, single layer 332 of core ribbon 40 is pulled toward coil set 12 and eventually allows light from LED 324 to be received by optical sensor 328. When optical sensor 328 receives the light from LED 324 a signal is sent to programmable controller 58 which then causes the stacking/winding process to be halted.

Although the form has been described as a prewound inductive coil and the element as a core of transformer, this is not a limitation of the invention. Form 350, Fig. 17, is a previously wound magnetic core, having layers 352 seen in cross-section. Layers 354 and loading coil 356 include electrically conductive material, such as copper or aluminum foil, which will be wound about form 350 to form an inductive coil. The foil may be coated with a varnish or other insulating material providing electrical separation between the layers of the element once they are wound in a final coil about core form 350. Alternatively, the element may be formed from number of adjacent, parallel wires held together by adhesive material to form a ribbon.

Although specific features of this invention are shown in some drawings and not others, this is for convenience only as each feature may be combined with any or all of the other features in accordance with the invention.

Claims

1. A winding apparatus for winding a length of element onto a form, comprising:

a first retention cylinder which in a first position retains a first end of the length of element against a first backstop cylinder;

a second retention cylinder which in a first position retains a second end of the length of element against a second backstop cylinder;

means for driving said retention and backstop cylinders to rotate the length of element in a first direction through the form; and

means for alternately, successively moving one of said first and second retention cylinders to its second, retracted position to release the innermost loop of element to cause it to be wound onto the form as the length of element rotates.

2. A winding apparatus according to claim 1 in which the element is a core ribbon.

3. A winding apparatus according to claim 1 in which the form includes at least one magnetic device coil.

4. A winding apparatus according to claim 1 in which said first retention cylinder and first backstop cylinder are affixed to one of a stationary module and a movable module and said second retention cylinder and second backstop cylinder are affixed to the other of said stationary module and movable module.

5. A winding apparatus according to claim 1 in which said means for driving includes means for driving said retention and backstop cylinders to rotate the element in a second direction, opposite said first direction, through the form to load the length of element to subsequently be wound onto the form.

6. A winding apparatus according to claim 1 further including means for winding said innermost loop of element onto the form to a predetermined tension.

7. A winding apparatus according to claim 1 further including means for returning said moved retention cylinder to its first position after said innermost loop of element is released to retain the remaining loops of element.

8. A winding apparatus according to claim 1 further including restraining means for imparting a force on said innermost loop of element to hold it against the remaining loops of the length of element until the tension on said innermost loop exceeds said force when said restraining means releases said innermost loop.

9. A winding apparatus for winding a length of core ribbon onto one or more magnetic device coils, comprising:

a first retention cylinder which in a first position retains a first end of the length of core ribbon against a first backstop cylinder;

a second retention cylinder which in a first position retains a second end of the length of core ribbon against a second backstop cylinder;

means for driving said retention and backstop cylinders to rotate the length of core ribbon through the magnetic device coils;

means for alternately, successively moving one of said first and second retention cylinders to its second, retracted position to release the innermost loop of core ribbon to cause it to be wound onto the magnetic device coils as the length of core ribbon rotates;

means for returning said moved retention cylinder to its first position after said innermost loop of core ribbon is released to retain the remaining loops of core ribbon;

means for winding said innermost loop of core ribbon onto the magnetic device coils to a predetermined tension; and

said means for alternately, successively moving includes means, responsive to said means for winding, for initiating the movement of the next retention cylinder to its second, retracted position after the innermost loop of core ribbon is wound onto the magnetic device coils to said predetermined tension.

10. A winding apparatus according to claim 9 in which the magnetic device coils are mounted on a movable platform and in which said means for winding includes switch means which activate said means for initiating when the magnetic device coils are laterally moved to a predetermined distance by the force of said innermost loop of core ribbon being wound onto the magnetic device coils to said predetermined tension.

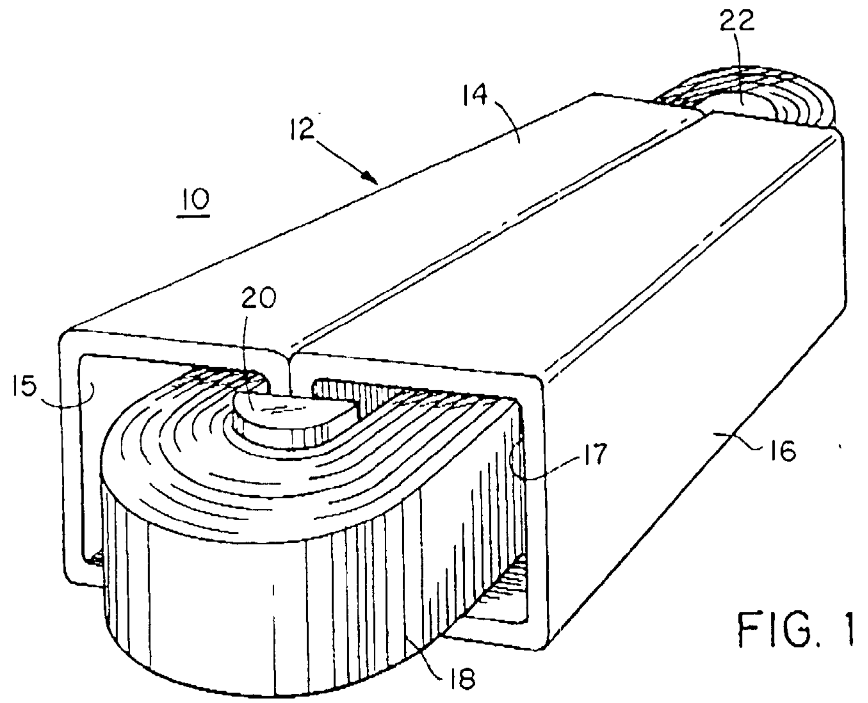
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FIG. 1

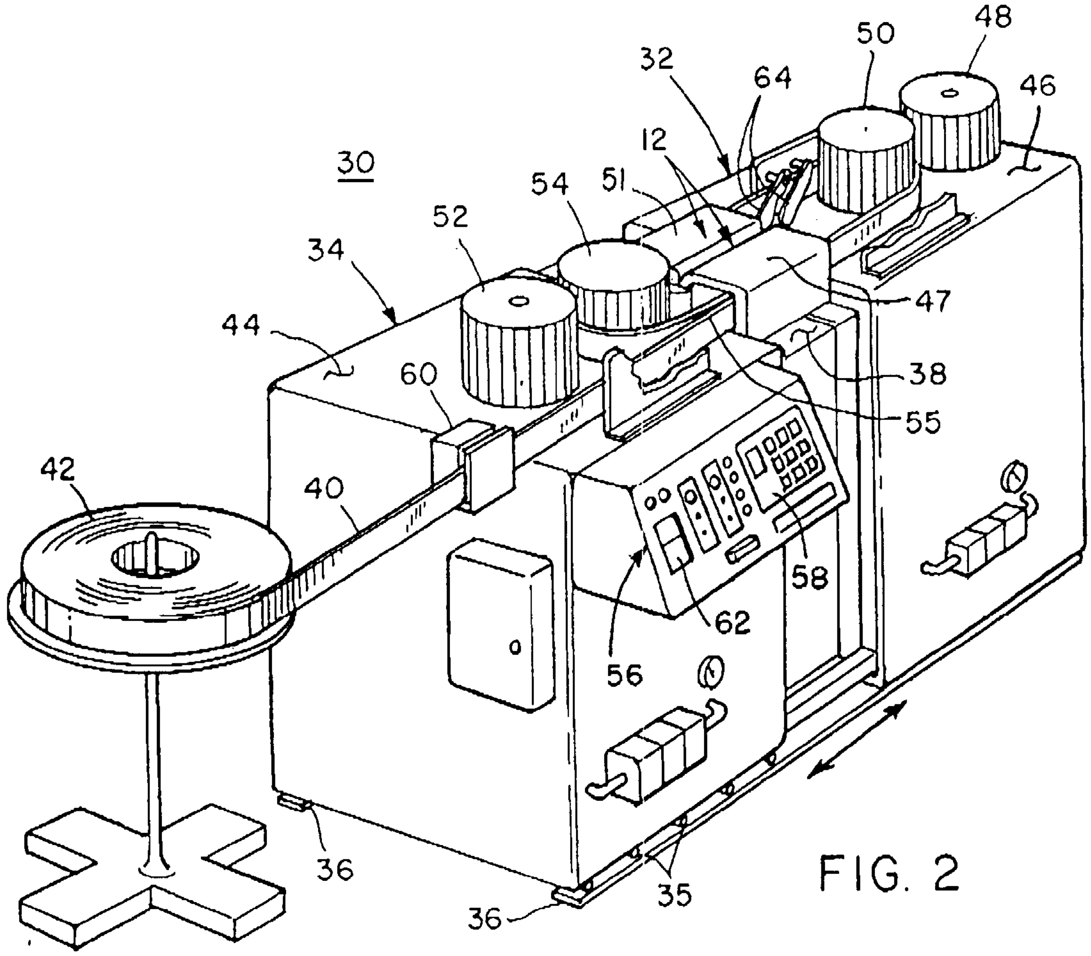
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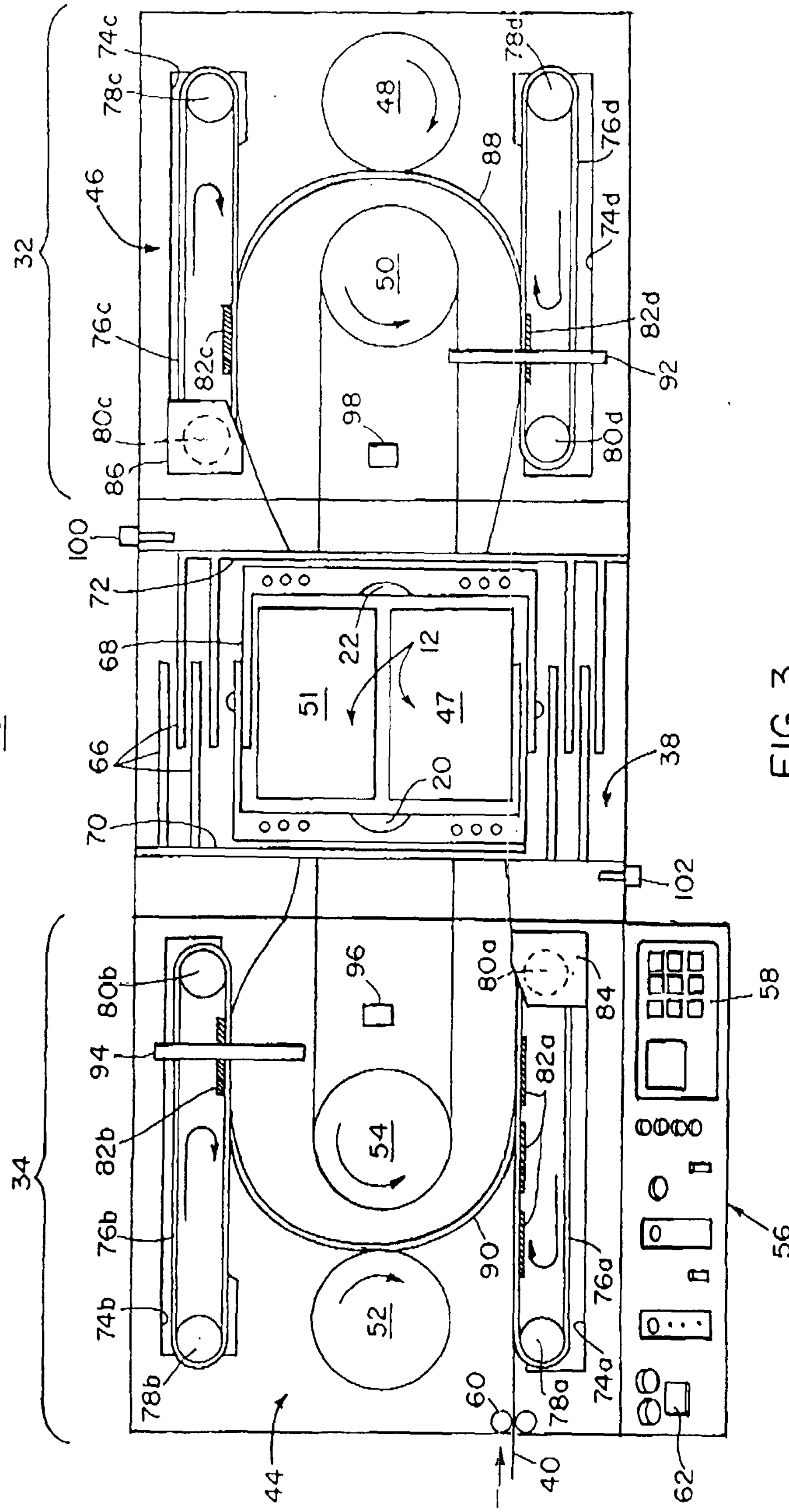
FIG. 2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78d
80a
80b
80c
80d
82a
82b
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82d
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98
100
102
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22

FIG. 3

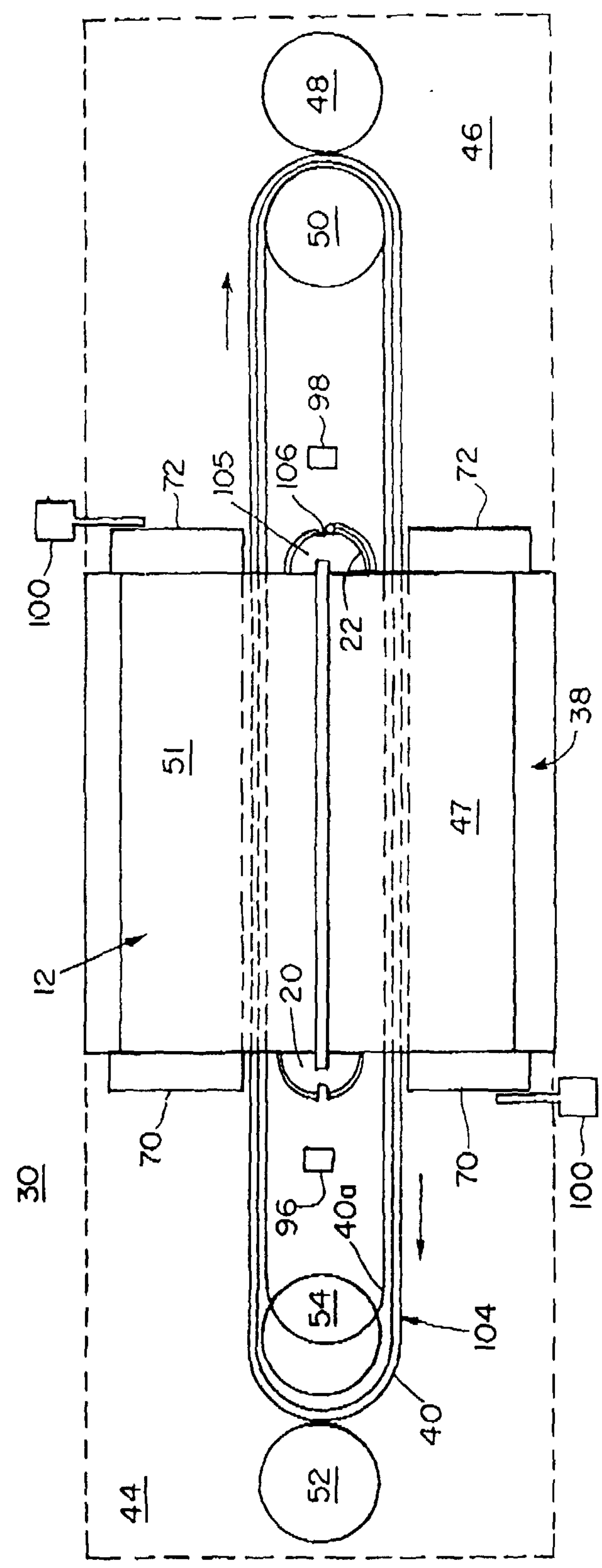


FIG. 4

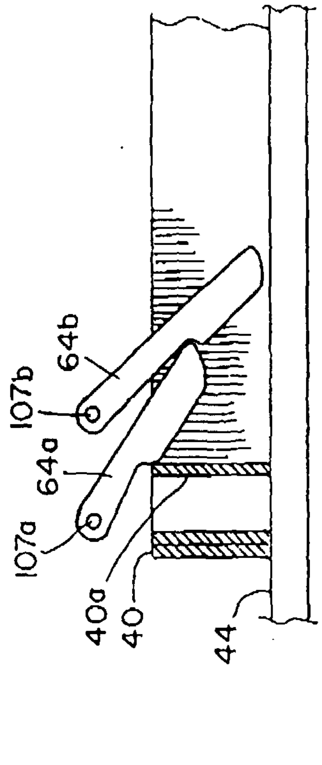


FIG. 7A

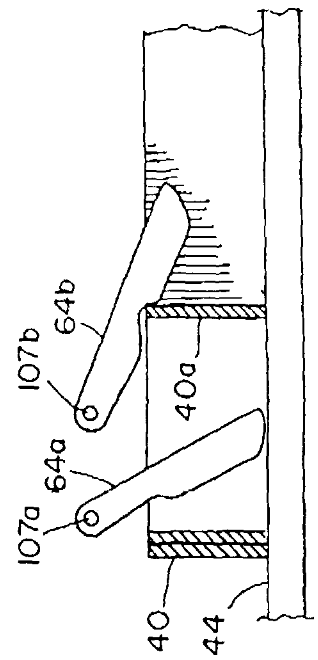


FIG. 7B

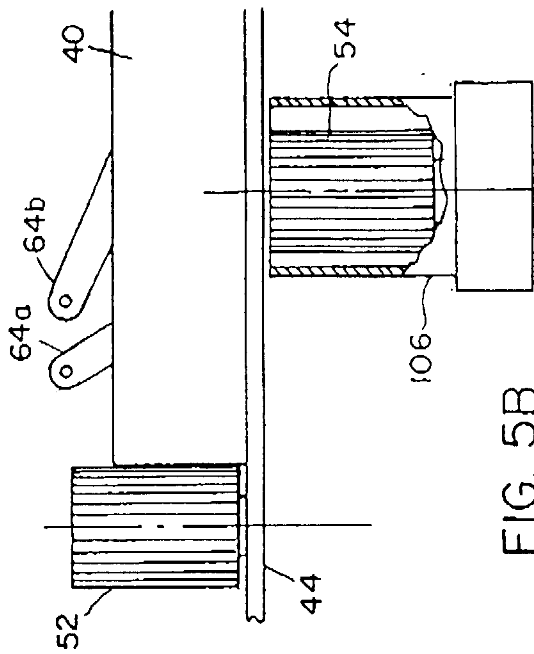


FIG. 5B

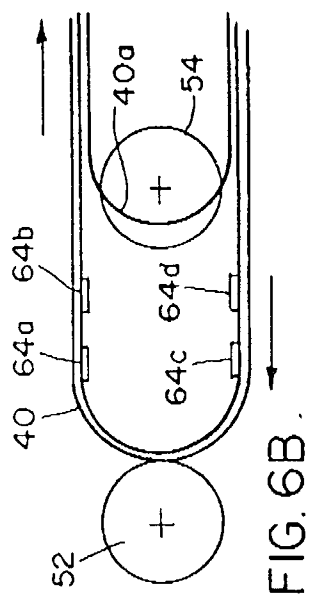


FIG. 6B

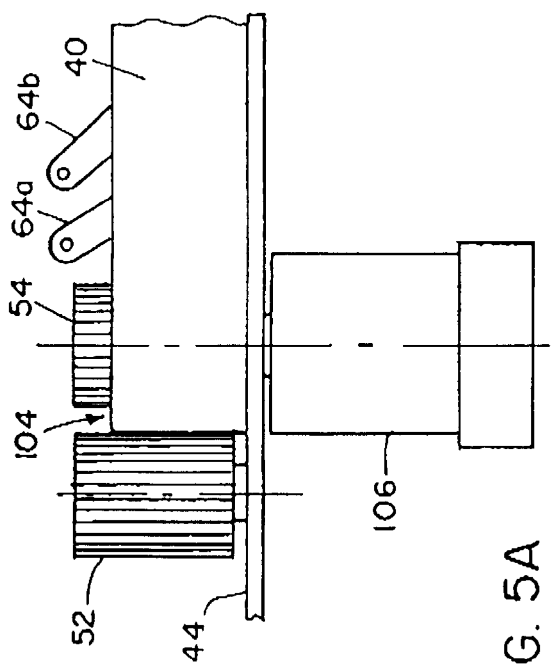


FIG. 5A

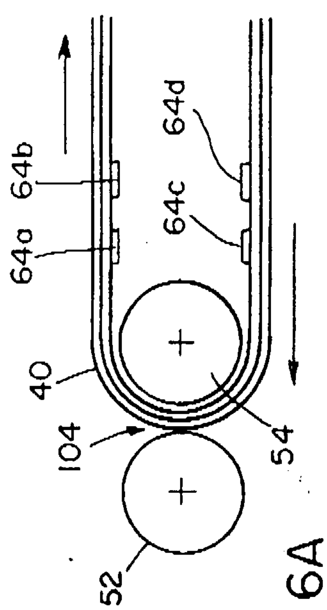
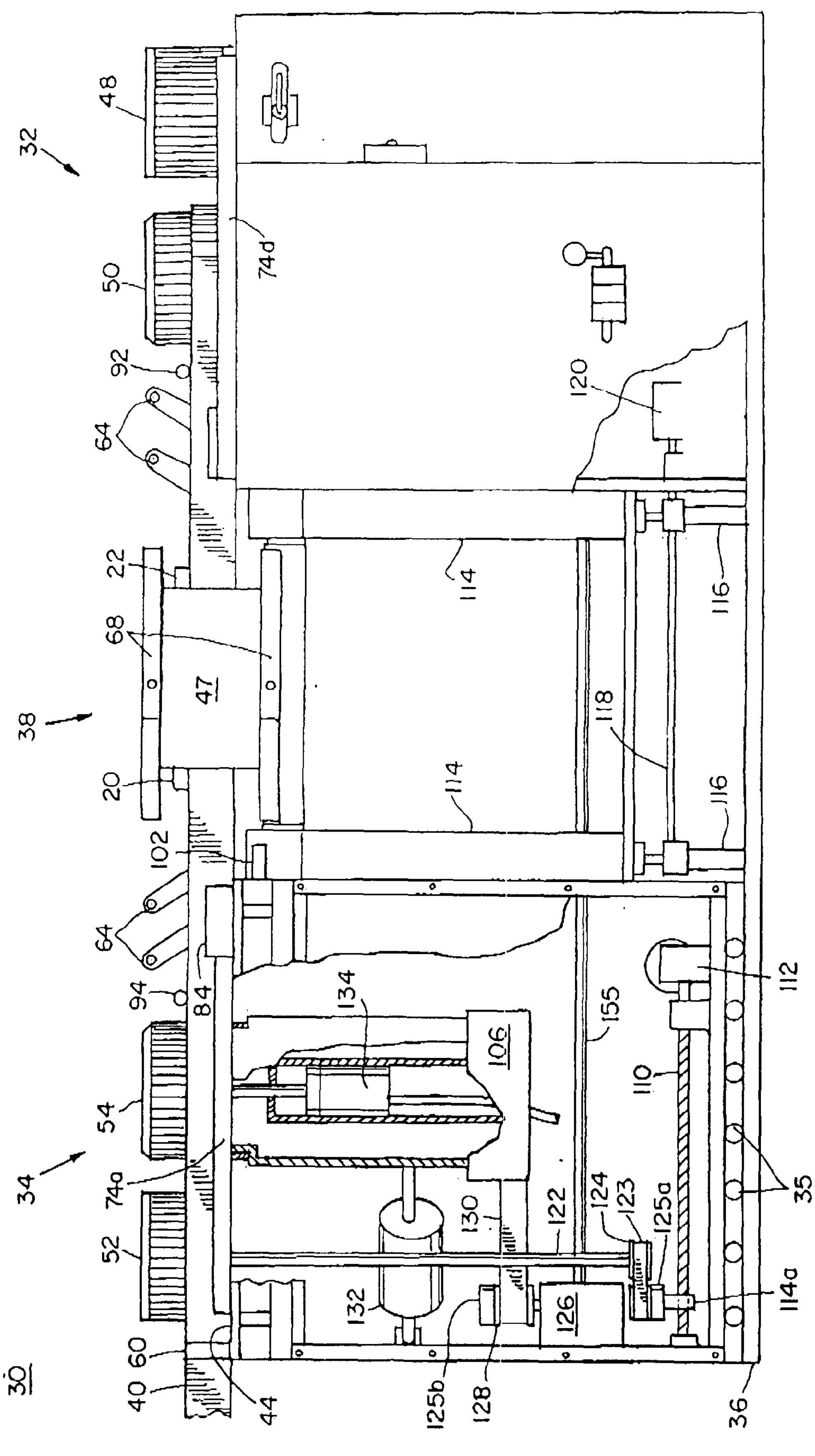


FIG. 6A



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74a
74d
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106
110
112
114
114a
116
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122
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124
125a
125b
126
128
130
132
134
155
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22

FIG. 8

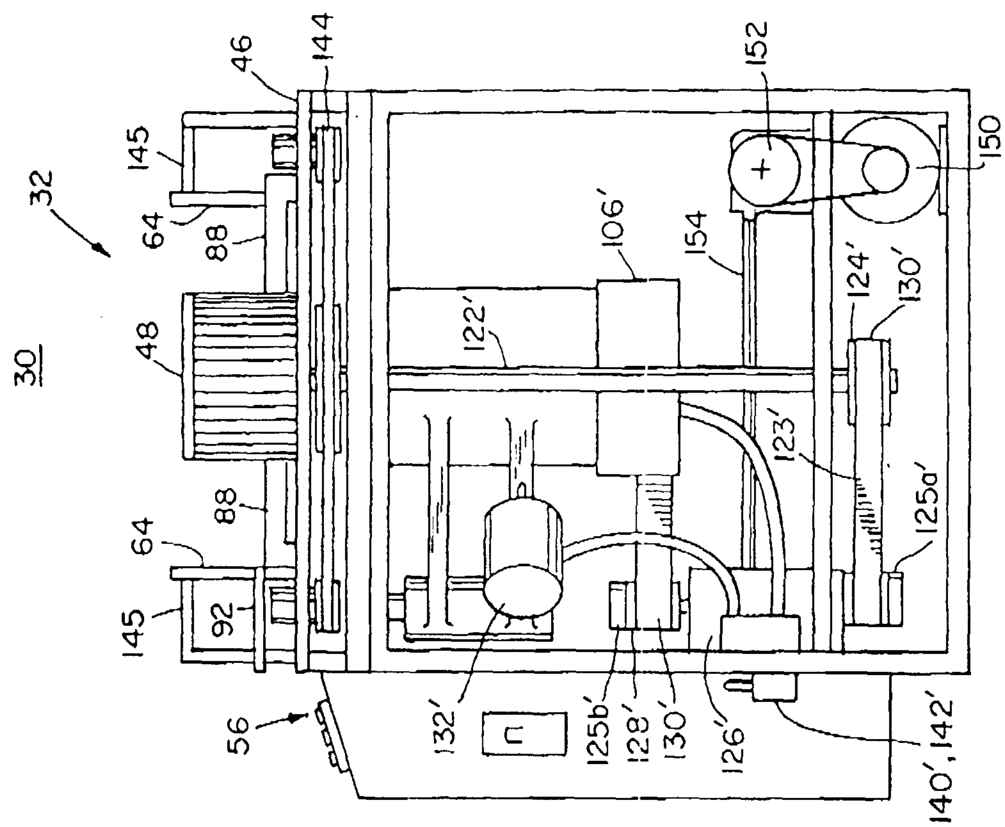
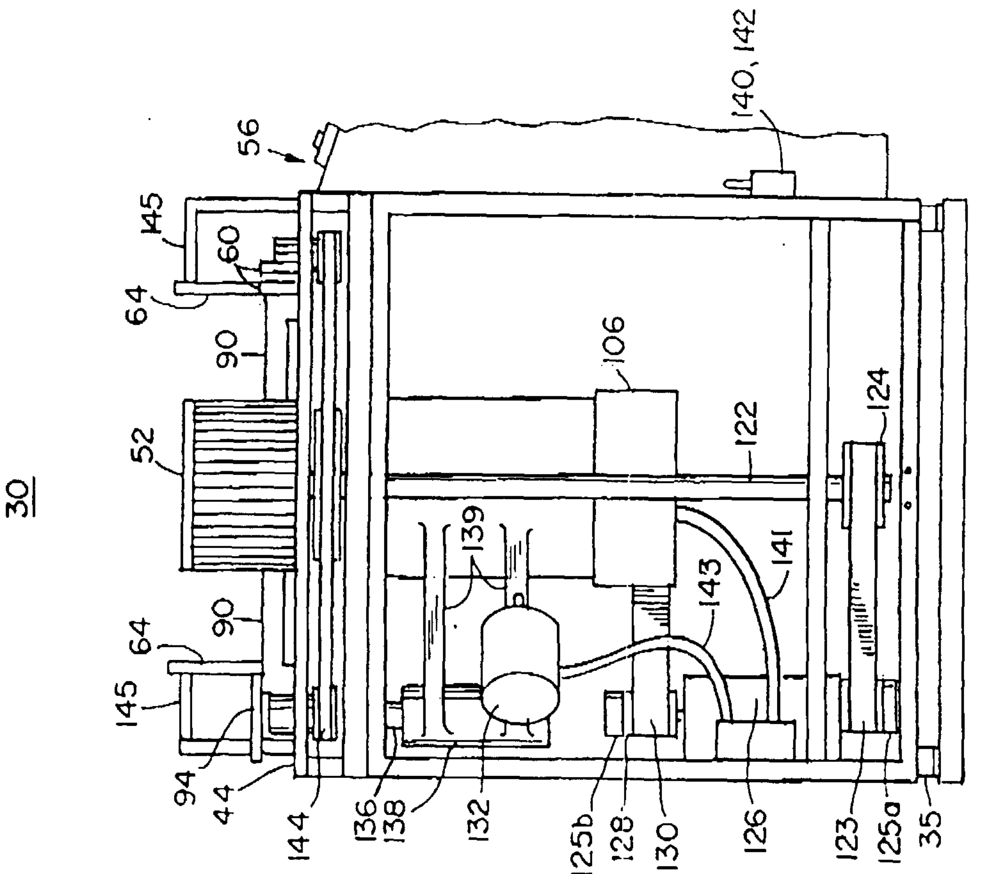

30
32
145
64
88
48
46
144
152
150
106'
154
122'
124'
130'
123'
125a'
92
132'
125b'
128'
130'
126'
140',142'
56

FIG. 10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52
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90
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141
94
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144
136
138
132
125b
128
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123
125a
35
140,142
56

FIG. 9

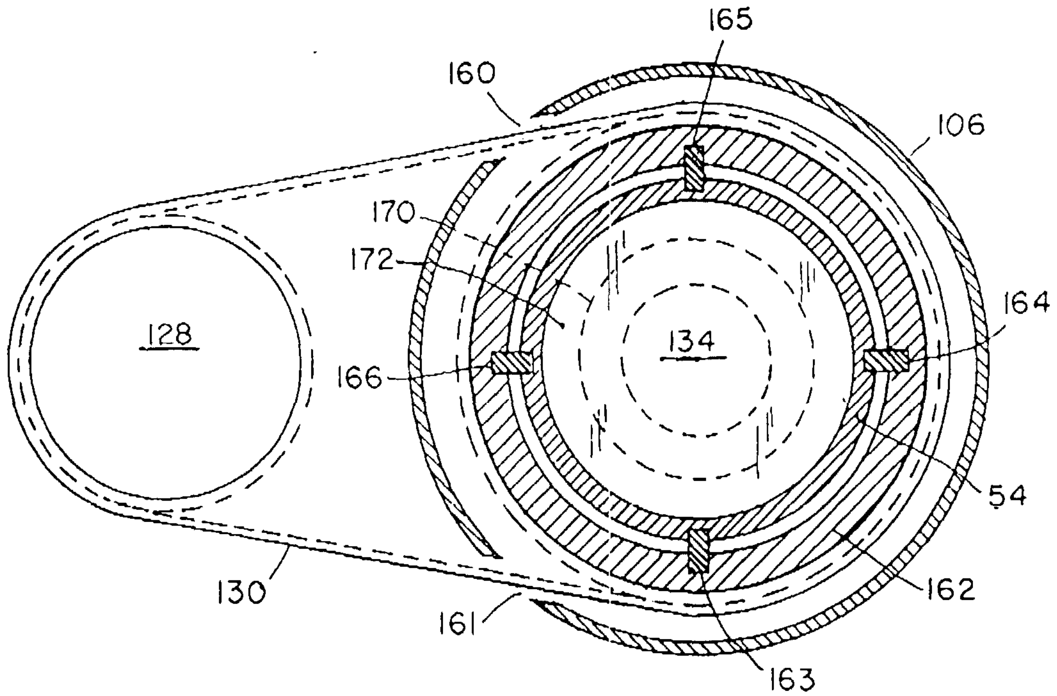

FIG. 11A

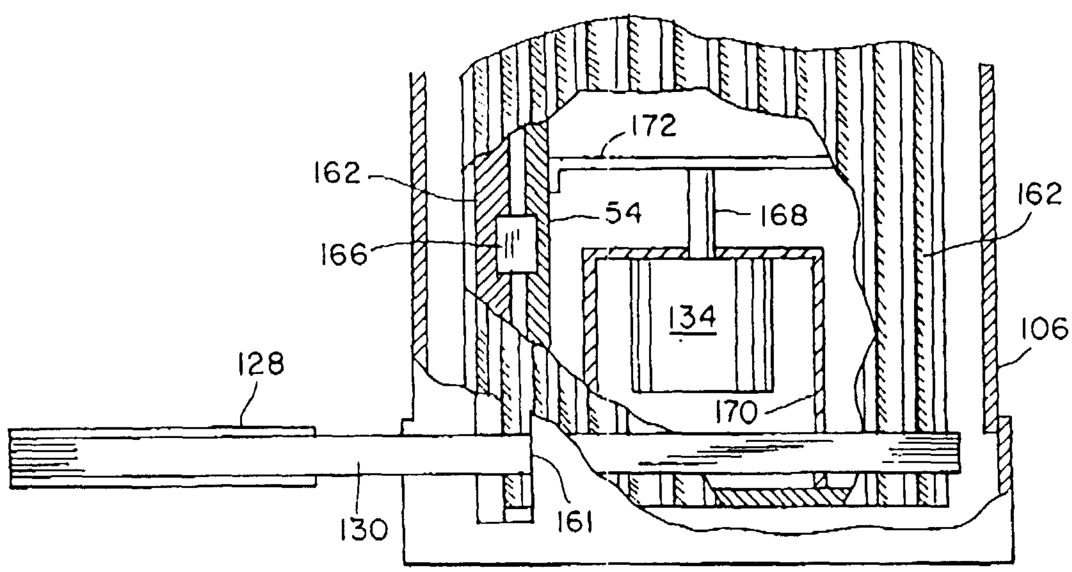

FIG. 11B

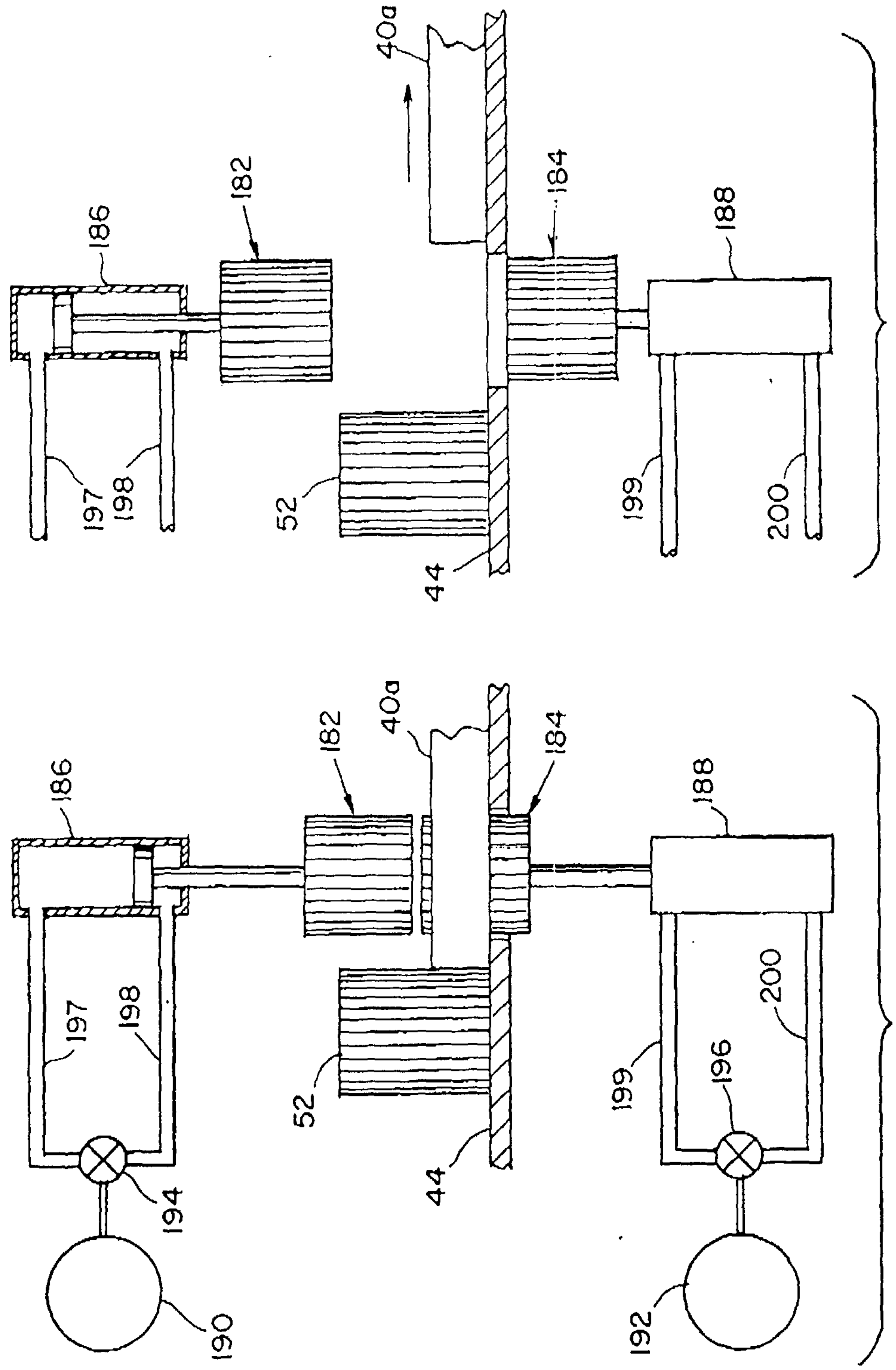

FIG. 12A

FIG. 12B

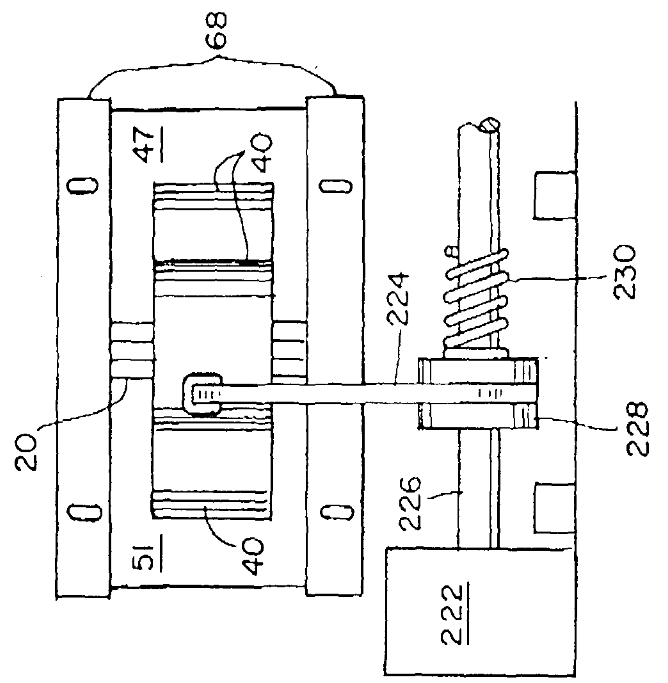

FIG. 13B

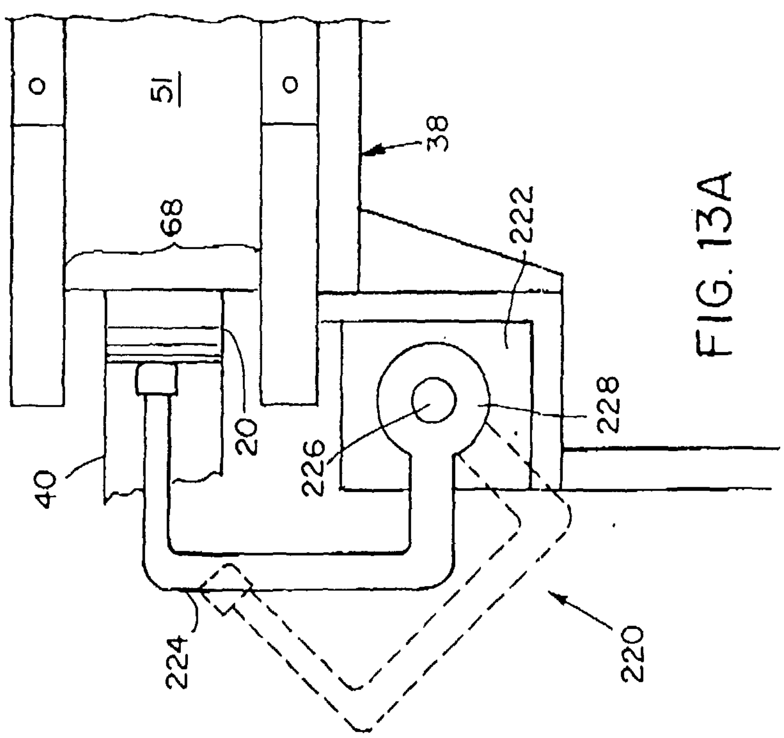

FIG. 13A

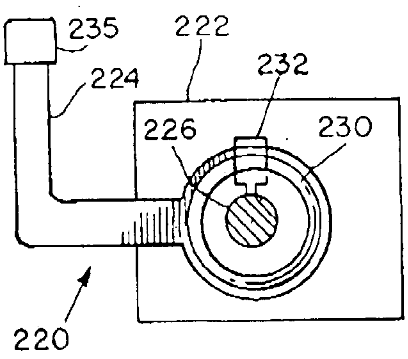

FIG. 14A

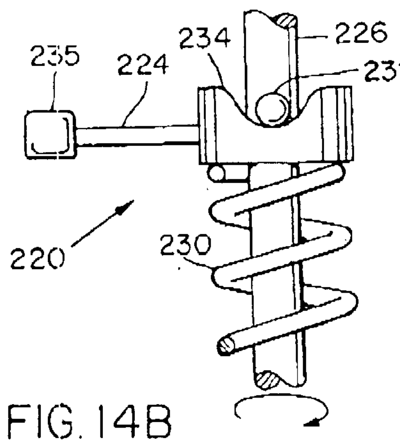

FIG.14B

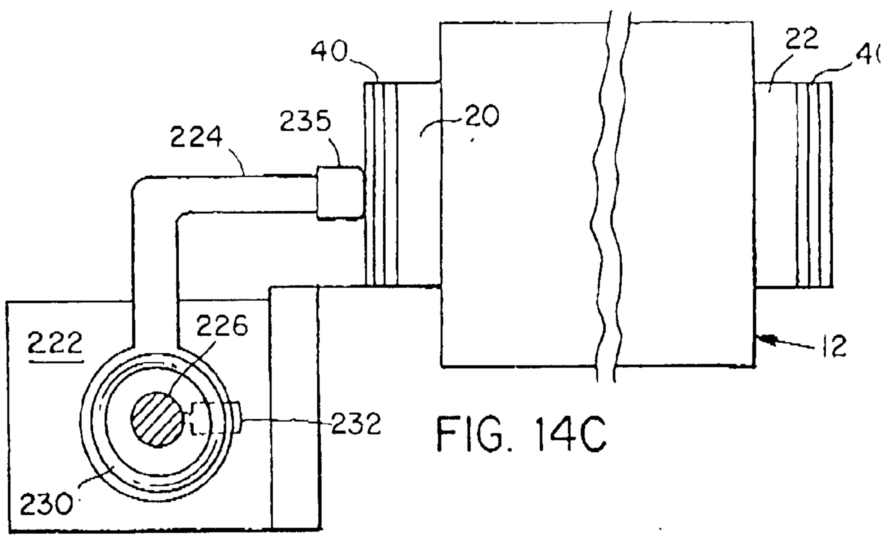

FIG. 14C

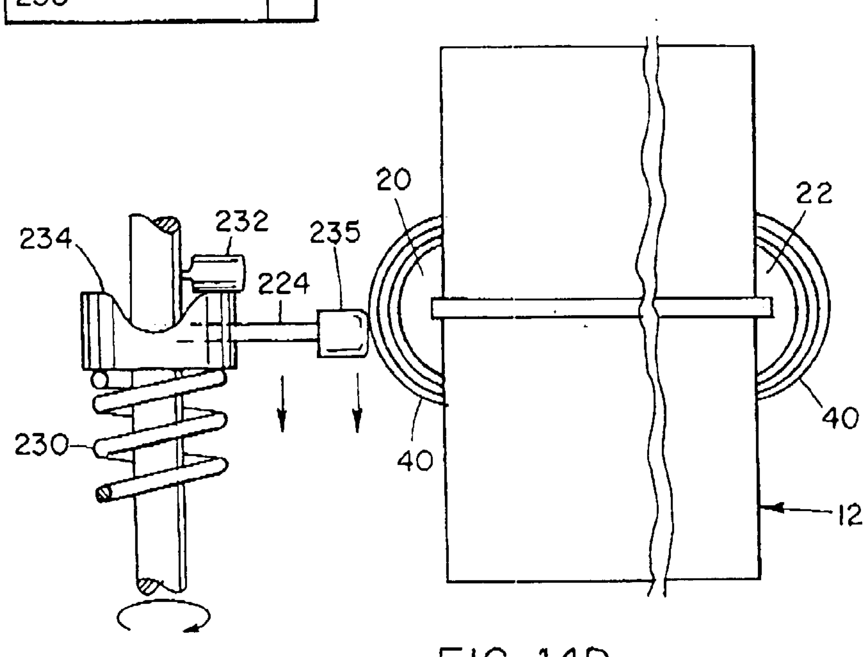

FIG. 14D

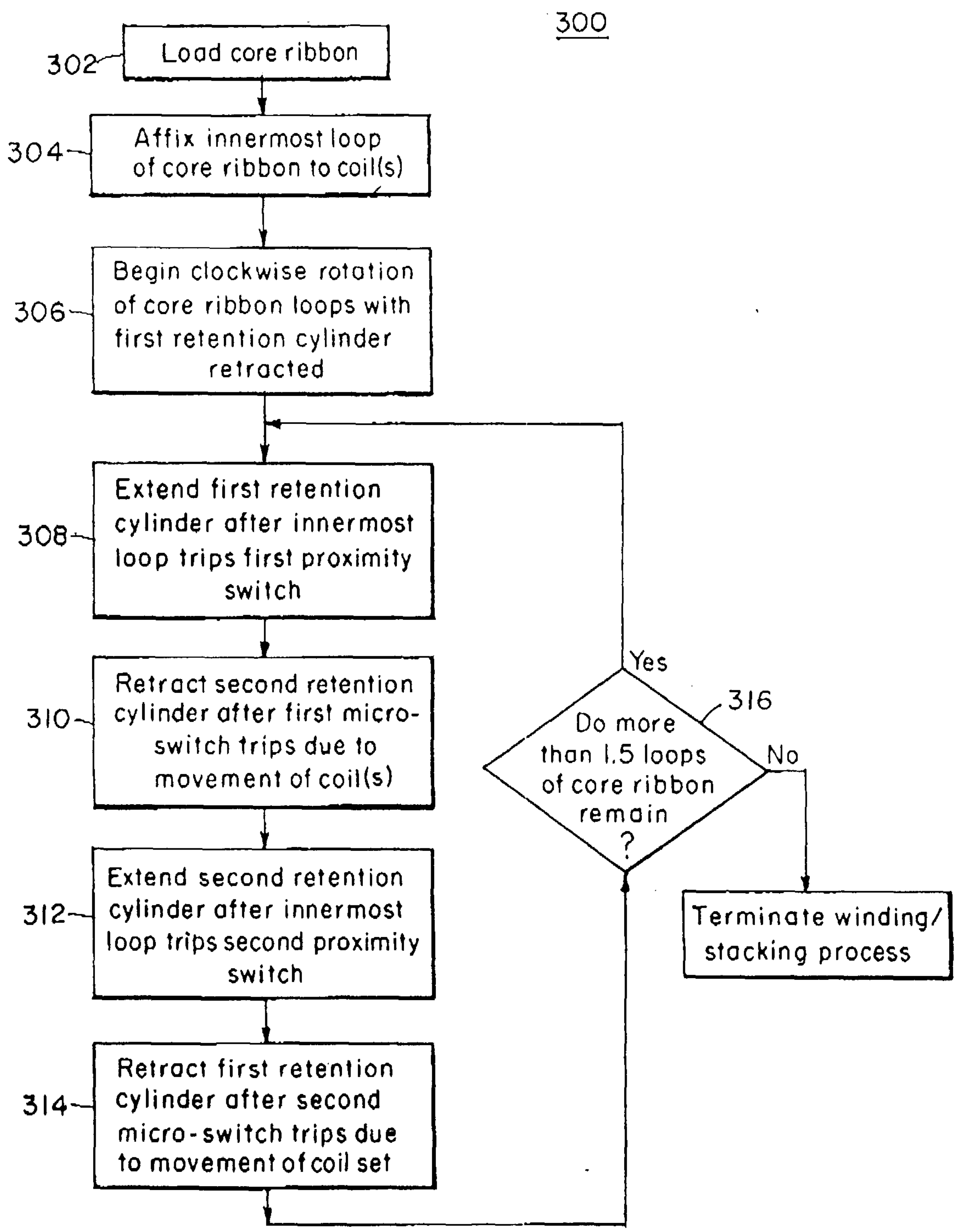
300
302
Load core ribbon
304
Affix innermost loop of core ribbon to coil(s)
306
Begin clockwise rotation of core ribbon loops with first retention cylinder retracted
308
Extend first retention cylinder after innermost loop trips first proximity switch
310
Retract second retention cylinder after first micro-switch trips due to movement of coil(s)
312
Extend second retention cylinder after innermost loop trips second proximity switch
314
Retract first retention cylinder after second micro-switch trips due to movement of coil set
316
Do more than 1.5 loops of core ribbon remain ?
Yes
No
Terminate winding/ stacking process

FIG. 15

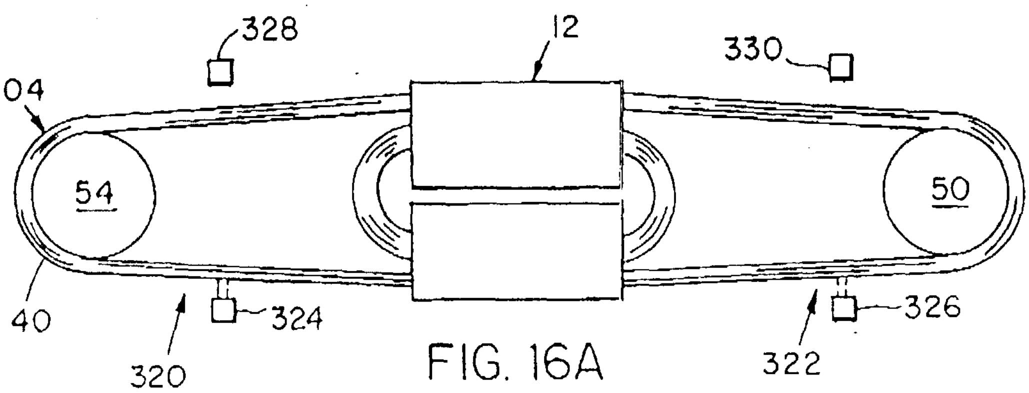

FIG. 16A

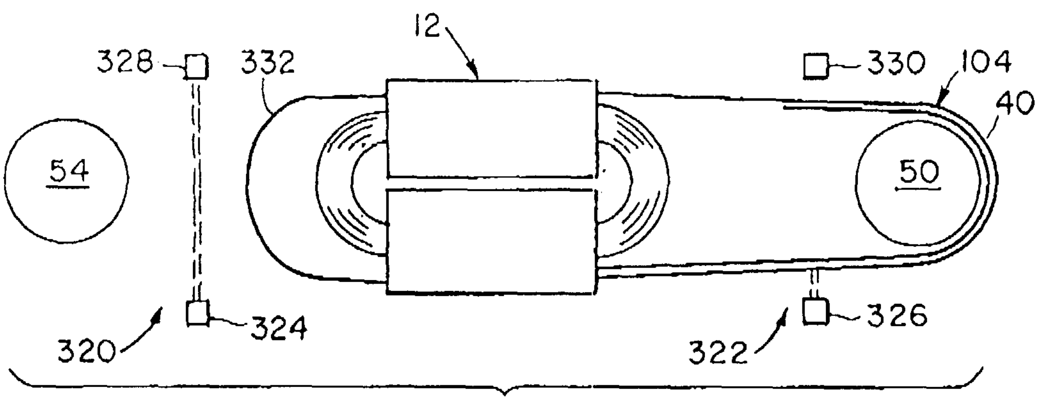

FIG. 16B

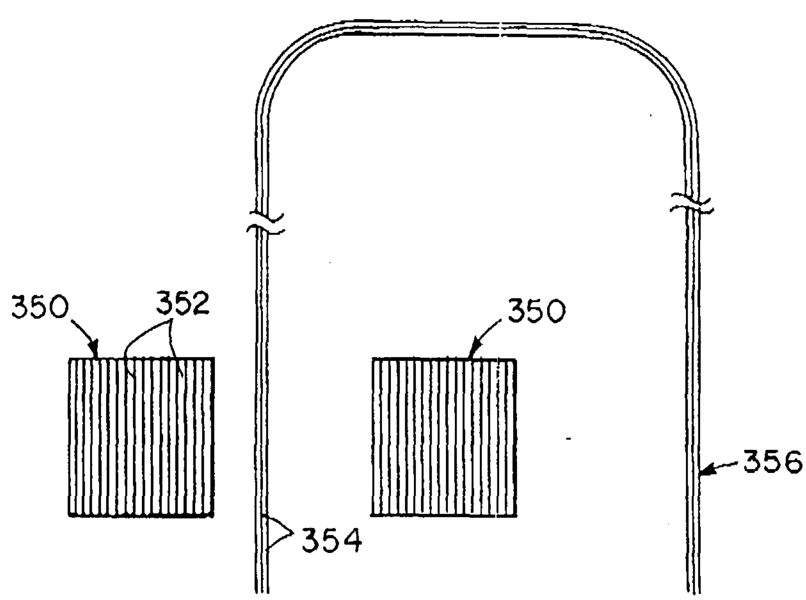

FIG. 17