

Nov. 25, 1969

W. D. BOHANNON, JR., ET AL

3,479,720

AUTOMATIC WIRE WRAPPING APPARATUS

Filed Sept. 1, 1967

8 Sheets-Sheet 1

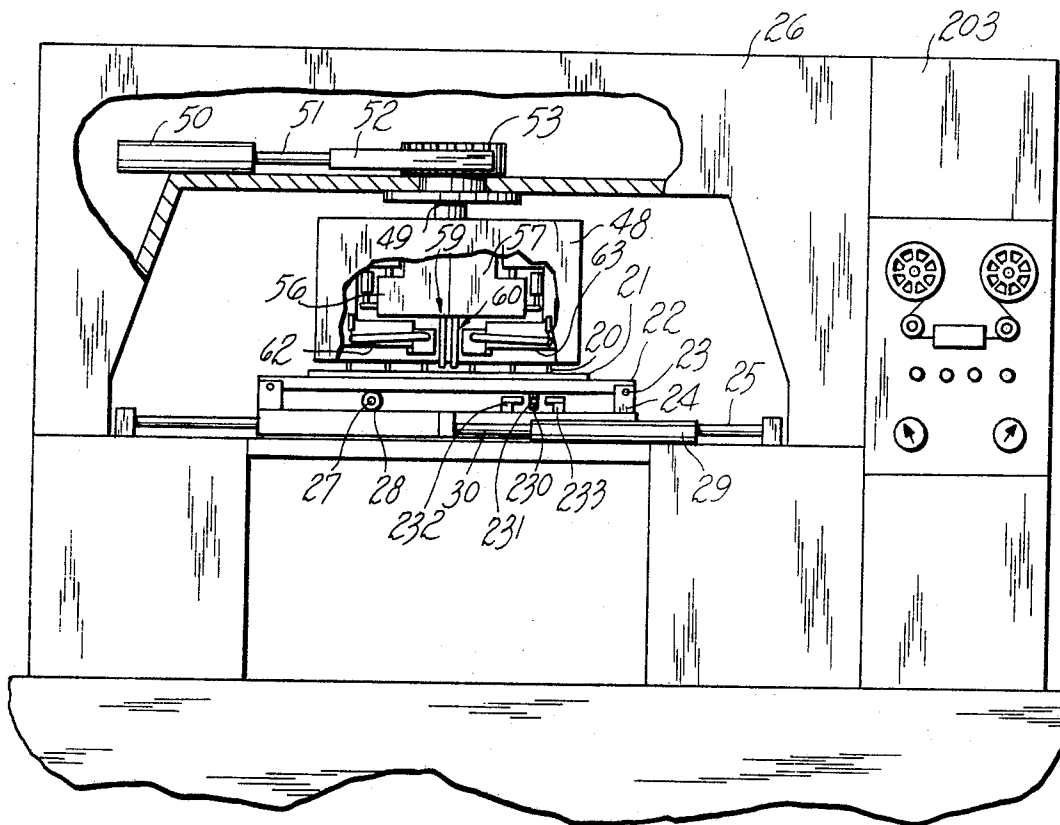


FIG-1

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8 Sheets-Sheet 2

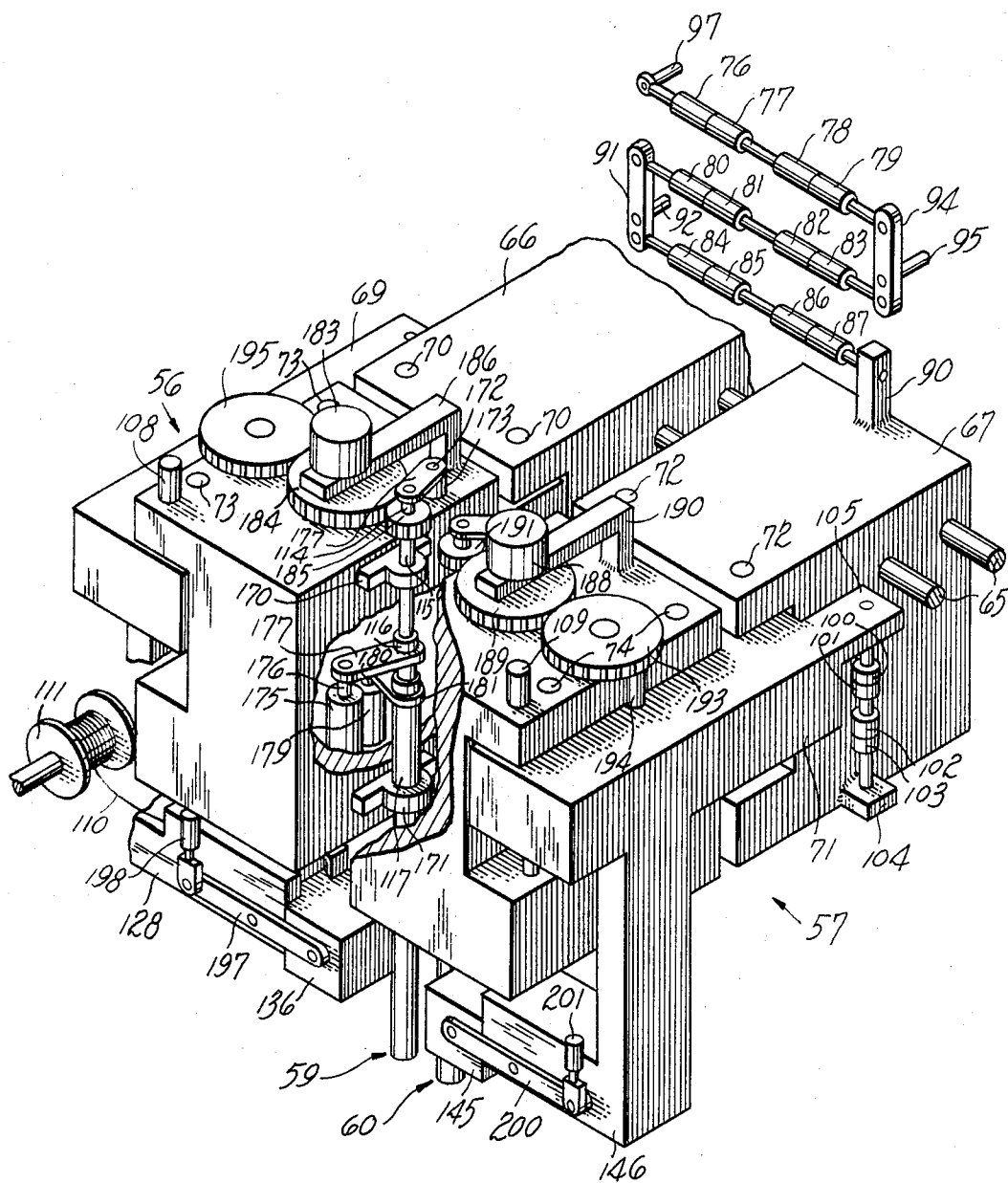


FIG-2

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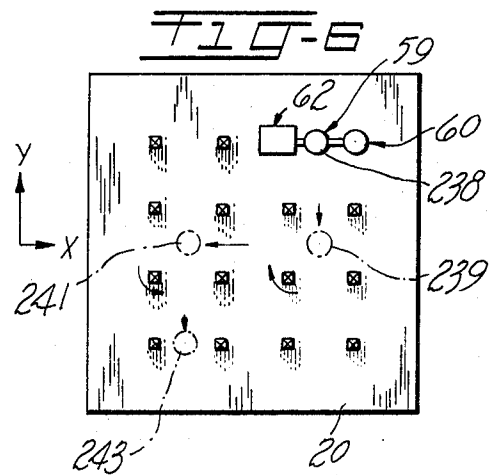
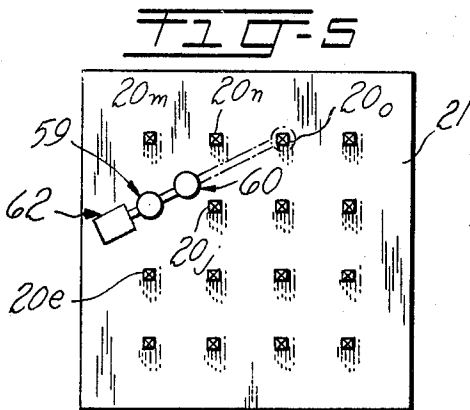
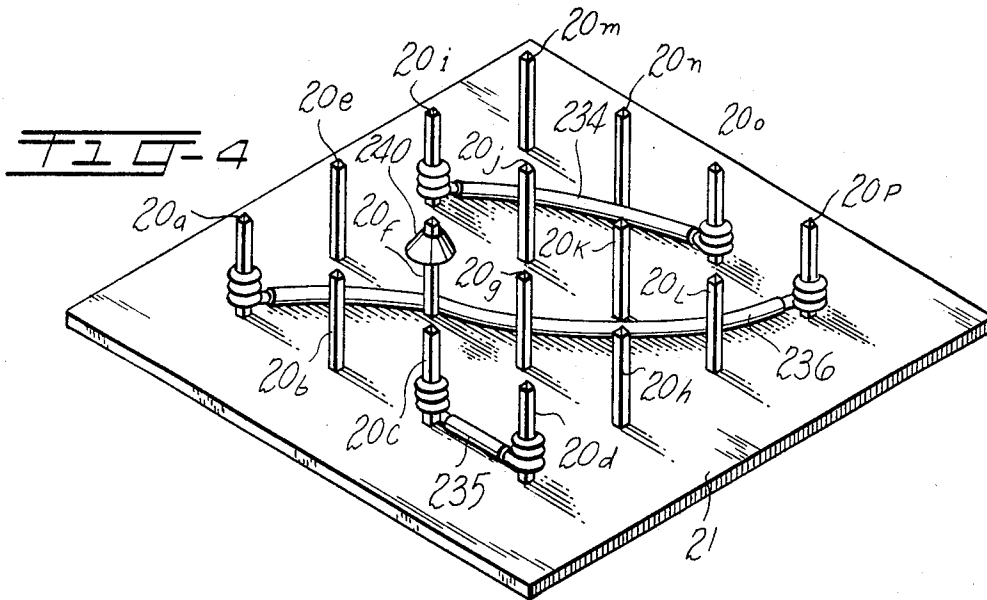
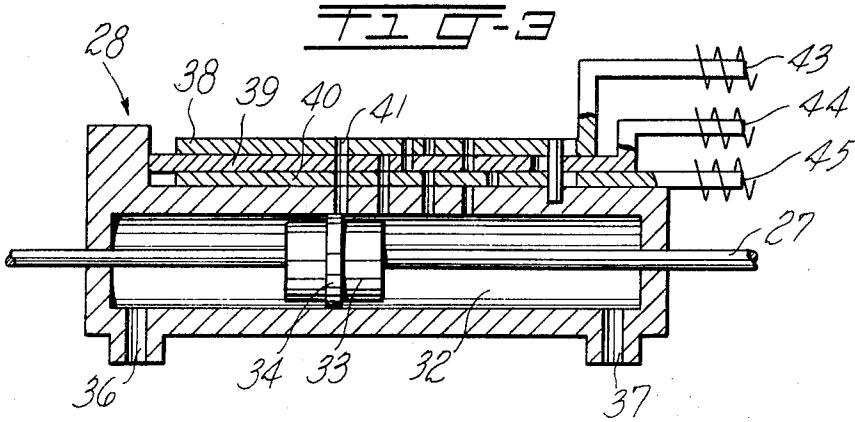
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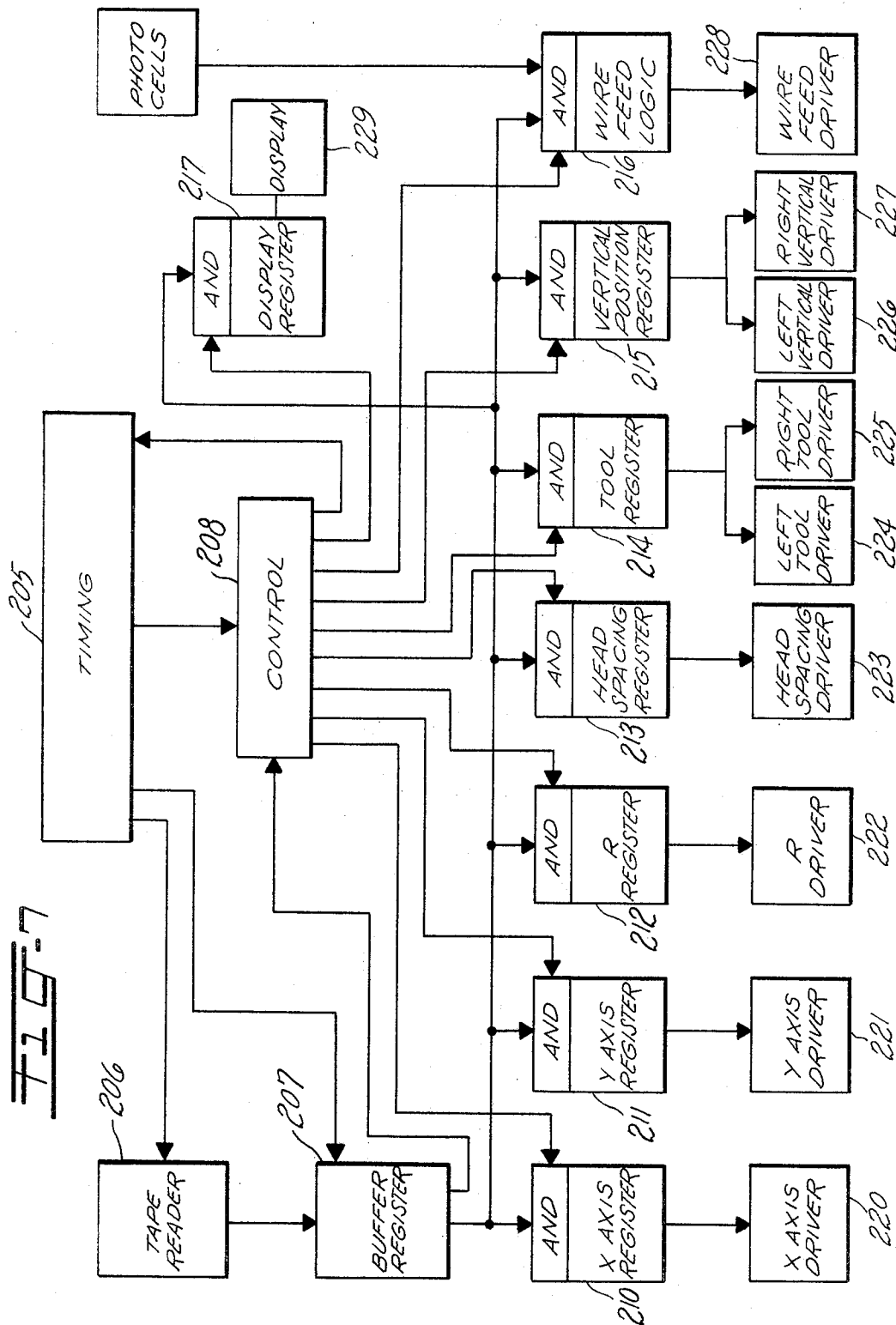
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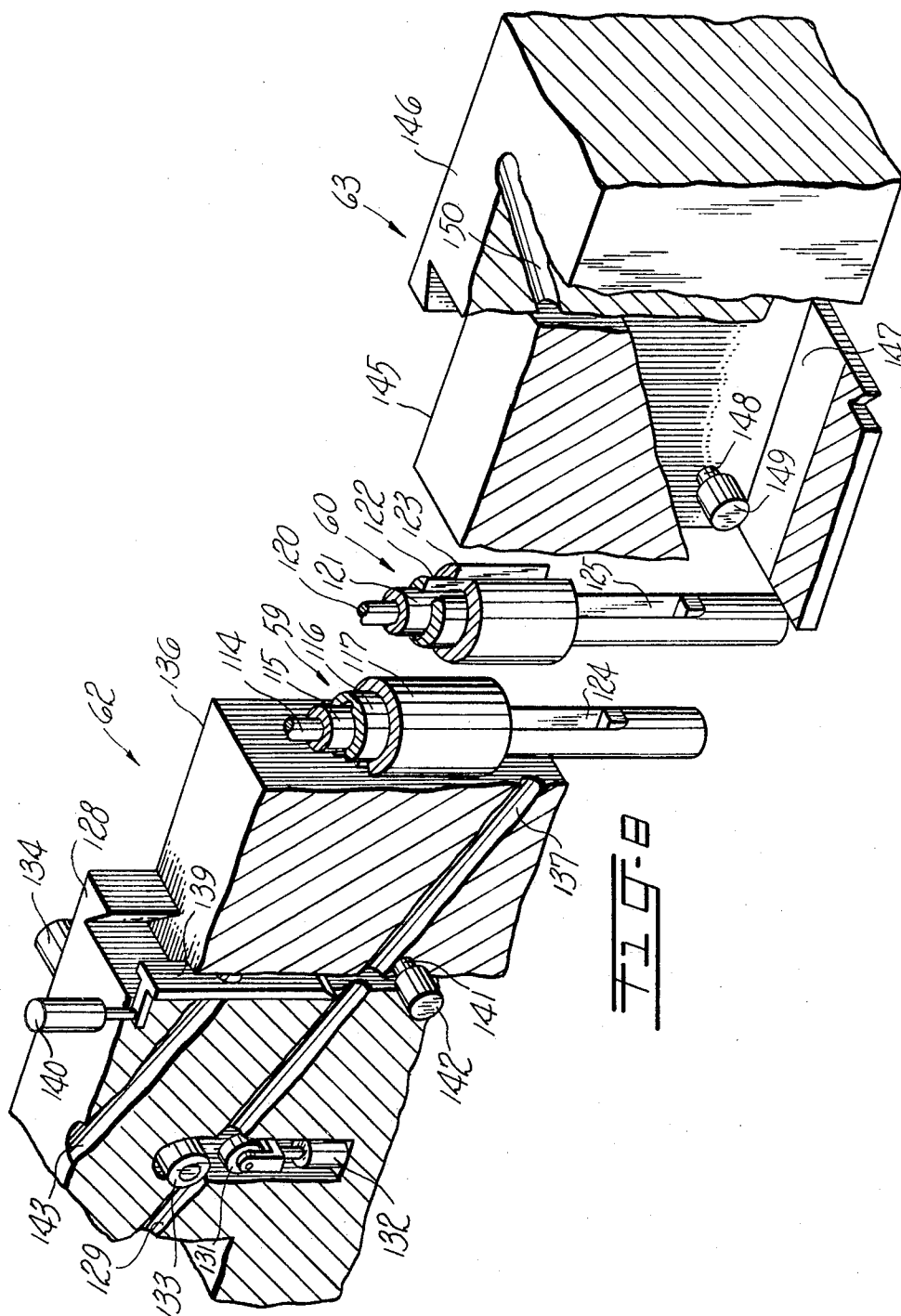
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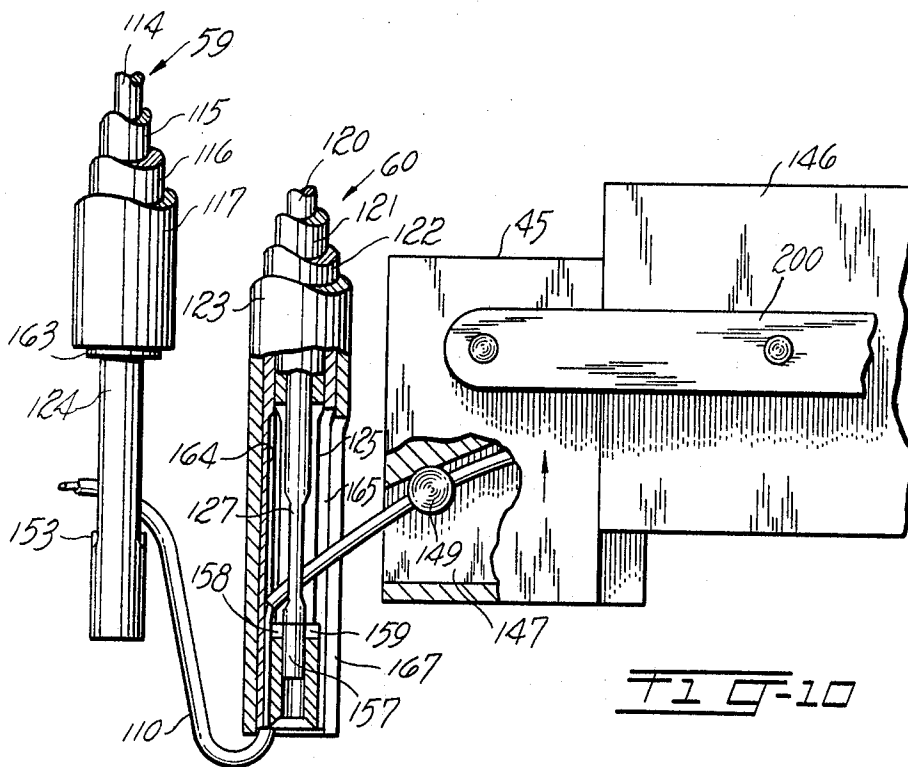
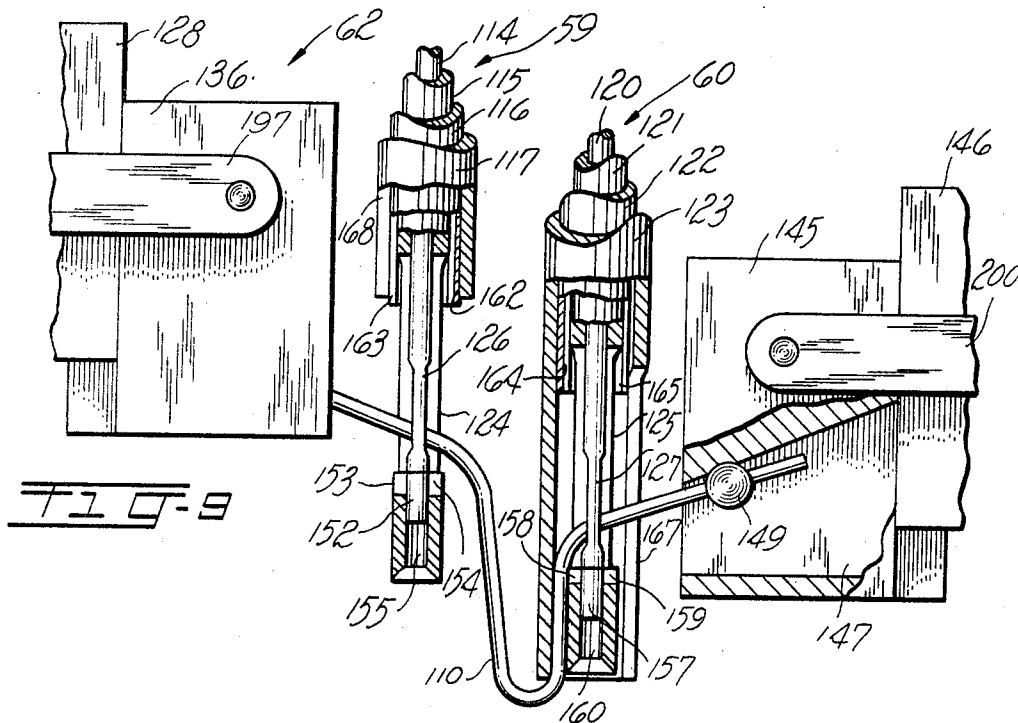
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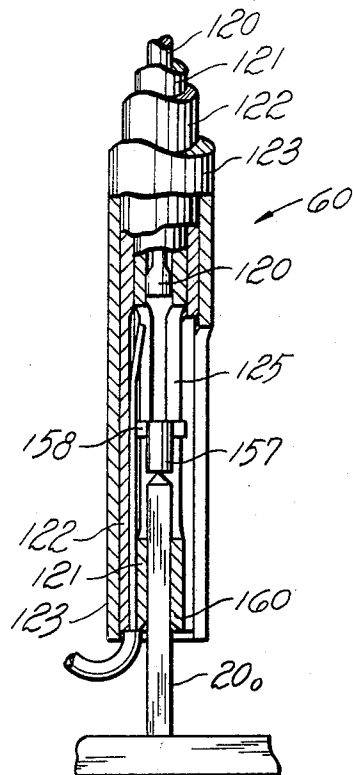
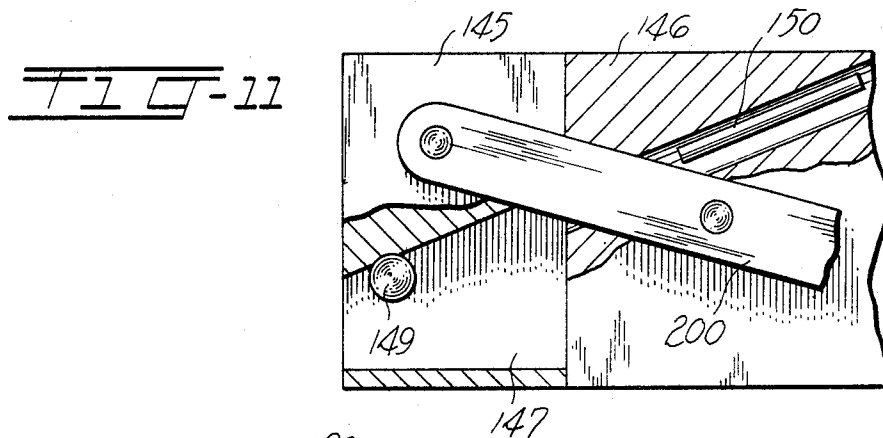
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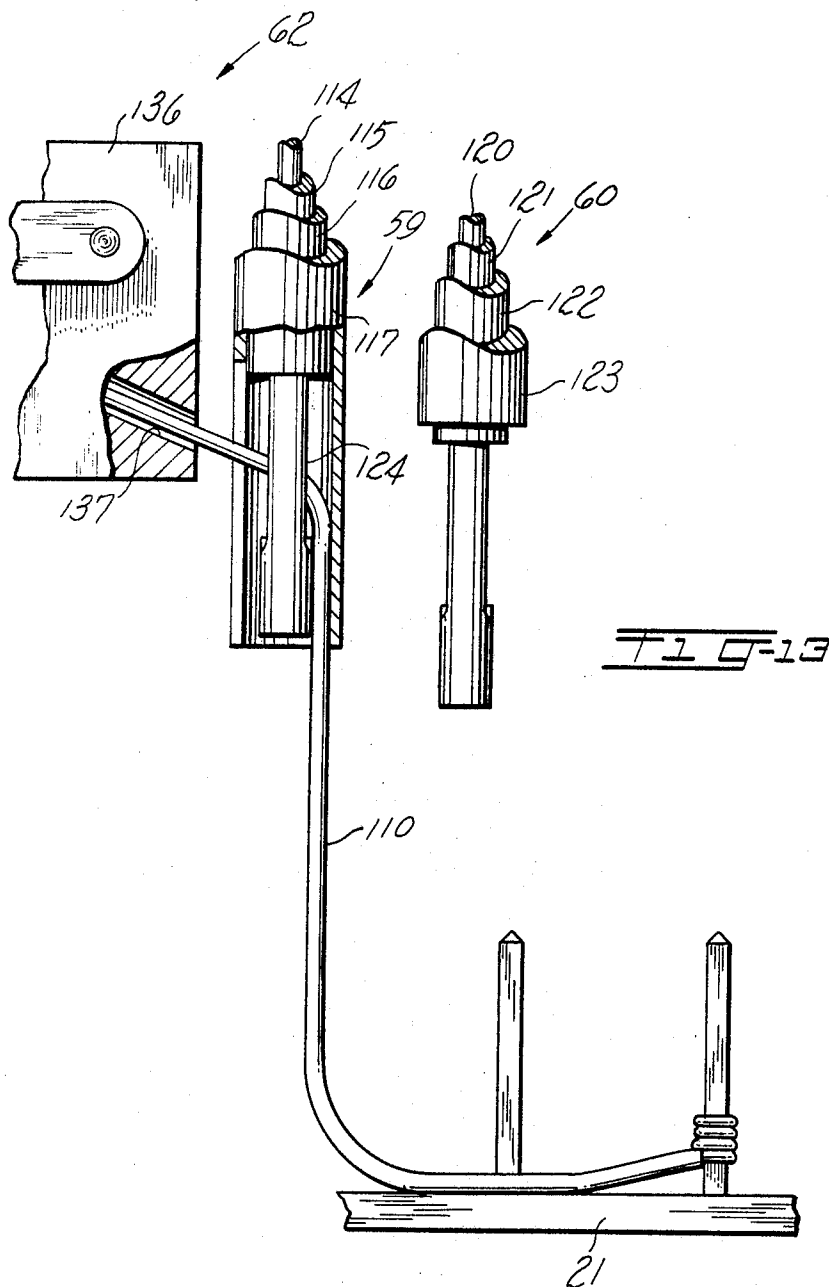
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AUTOMATIC WIRE WRAPPING APPARATUS
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U.S. Cl. 29—203

3 Claims

ABSTRACT OF THE DISCLOSURE

An automatic wire wrapping apparatus wraps the ends of a section of wire on respective first and second terminals on a terminal board in a selected one of two modes of operation. The first mode of operation is to simultaneously wrap the ends of the wire on the respective first and second terminals. The second mode of operation is to sequentially wrap a first end of the wire on the first terminal, lay the wire in a predetermined path on the terminal board from the first to the second terminal, and wrap the second end of the wire on the second terminal. During the laying of wire, the wire is fed toward the terminal board to lay the wire directly on the terminal board.

GOVERNMENT CONTRACT

The invention herein claimed was made in the course of, or under contract with the United States Army.

BACKGROUND OF THE INVENTION

Field of the invention

In the manufacture of complex electronic equipment, such as computers, switching systems, etc., electrical connections are made between terminals on terminal boards or chassis by automatic apparatus which wraps the ends of a length of wire on respective terminals. In order to avoid inductive coupling between wires, the wires must sometimes be laid in complex patterns to provide maximum spacing between certain wires. Also, the automatic apparatus must operate quickly in order to make a large number of electrical connections within a short period of time.

Description of the prior art

In the prior art, there are many numerically controlled apparatus which automatically wrap the ends of lengths of wires on terminals. Basically, there are two types of wire wrapping apparatus in the prior art. The first type of prior art wire wrapping apparatus utilizes a single wire wrapping assembly to sequentially wrap a first end of a length of wire to a first terminal, lay the wire in a pattern on the terminal board from the first terminal to a second terminal and wrap the second end of the length of wire onto the second terminal. This first type of apparatus is capable of laying the wire in almost any pattern on the terminal board but the sequential operation is time consuming with fewer than the desirable number of electrical connections being made within a given period of time.

The second type of prior art wire wrapping apparatus simultaneously wraps both ends of a length of wire to respective terminals. This second type of apparatus is faster in operation than the first type but is limited in the pattern in which the wire may be laid on the terminal board. One or more dressing fingers are required to lay the wire in even a simple L-shaped pattern. As the complexity of the pattern increases, more and more dressing fingers are required with a resultant increase in the complexity of the wire wrapping apparatus.

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Prior art apparatus were incapable of utilizing the advantages of both types of apparatus.

SUMMARY OF THE INVENTION

One feature of the invention contemplates a wire wrapping apparatus having a pair of wire wrapping assemblies which may be selectively operated in one of two modes of operation to wrap the ends of a section of wire on respective terminals on a terminal board. In the first mode of operation, (1) the terminal board is moved in X and Y coordinates with respect to the wrapping assemblies, the wrapping assemblies are rotated with respect to the terminal board, and one wrapping assembly is moved transversely with respect to the other wrapping assembly to position the wire wrapping assemblies over respective terminals, and (2) the wrapping assemblies are operated to simultaneously wrap the ends of a section of wire on the terminals. In the second mode of operation, (1) the terminal board is moved in X and Y coordinates with respect to the wrapping assemblies to position a first wire wrapping assembly over a first terminal, (2) a first wrapping assembly is operated to wrap a first end of the wire on the first terminal, (3) the terminal board is moved in X and Y coordinates with respect to the wrapping assemblies to lay the section of wire in a predetermined pattern from the first terminal to a second terminal, and (4) the second wrapping assembly is operated to wrap the second end of the section of wire on the second terminal.

Another feature of the invention contemplates the feeding of the section of wire through one of the wrapping assemblies toward the board to lay the wire directly on the terminal board during the second mode of operation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front elevation drawing, partly in cross-section of an apparatus for wrapping the ends of a length of wire on respective terminals.

FIG. 2 is an isometric drawing showing two wire wrapping assemblies which are mounted in the apparatus of FIG. 1.

FIG. 3 is a cross-section drawing of a fluid operated cylinder and piston shown in FIG. 1 which may be indexed to selected positions.

FIG. 4 is an isometric drawing of a terminal board showing different wire connections which may be made by the apparatus of FIG. 1.

FIGS. 5 and 6 are plan drawings of the terminal board in FIG. 4 and showing in dashed lines the movement of the two wrapping tools of the apparatus of FIGS. 1 and 2 relative to the terminal board for two different modes of operation.

FIG. 7 is a diagram of a control circuit for operating the apparatus shown in FIG. 1.

FIG. 8 is an isometric drawing, partly in cross-section, showing the details of the wire wrapping tools and wire feeding and stripping mechanism of the apparatus in FIG. 1.

FIGS. 9-13 are elevation drawings, partly in cross-section, showing the sequence of operation of the wrapping tools and the wire feeding and stripping mechanism of FIGS. 1 and 8.

Referring to FIG. 1, there is shown an automatic wire wrapping apparatus for making electrical connections between respective terminals 20 on a terminal board 21. The terminal board 21 is placed on a table 22 which is slidably mounted on rods 23 for movement in a first horizontal direction which may be designated Y coordinate direction. The rods 23 are mounted upon a frame 24 which is slidably mounted upon rods 25 for movement in a second horizontal direction which is perpendicular to the first horizontal direction. The second horizontal di-

rection may be designated X coordinate direction. The rods 25 are mounted on a support 26 of the wire wrapping apparatus.

A hydraulic cylinder 28 having a piston rod 27 which may be indexed to selected positions, is mounted on the frame 24 with the piston rod connected to the table 22 for moving the table 22 in the Y direction. A similar hydraulic cylinder 29 having a piston rod 30 is mounted on the support 26 with the piston rod 30 connected to the frame 24 for moving the terminal board 21 in the X direction.

Referring to FIG. 3, there is shown a cross-section of the cylinder 28. The cylinder 28 has a cylindrical cavity 32 in which a piston 33, connected to the piston rod 27, is slidably mounted. The piston 33 has a narrow seal 34 mounted thereon for engagement with the cylindrical wall of the cavity 32. Fluid having equal pressure is admitted to end ports 36 and 37 of the cavity 32. Three slidable valve members 38, 39 and 40 have holes formed therethrough for selectively forming passageways communicating with holes extending through the side of the cylinder 28 into the cavity 32. The valve members 38, 39 and 40 are connected to respective solenoids 43, 44 and 45 which may be selectively operated to move the valve members to left or right positions.

When the valve members 38 and 40 are in their right positions and the valve member 39 is in its left position, as viewed in FIG. 3, a passageway 41 is formed through the valve members 38, 39 and 40 and the wall of the cylinder 28 to form an exhaust port for fluid from the cavity 32. If the seal 34 on the piston 33 is to the left of the passageway 41, fluid escaping through the passageway 41 reduces the pressure within the right side of the cavity 32 to cause the piston 33 to move to the right until the seal 34 has covered the passageway 41 and the movement of the piston is stopped by equalization of the pressure on both sides of the piston. Thus, it is seen that by selectively energizing the solenoids 43, 44 and 45, it is possible to position the piston 33 in a number of positions.

Referring back to FIG. 1, a housing 48 is attached to a shaft 49 which is rotatably mounted in the support 26 above the table 22. A hydraulic cylinder 50 has a piston rod 51 attached to a rack 52 which meshes with a pinion 53 mounted on the shaft 49 for rotating the housing 48 with respect to a terminal board 20 placed on the table 22. The cylinder 50 is preferably similar in structure to that of the cylinders 28 and 29 to selectively rotate the housing 48 to a predetermined angular position with respect to the table 22.

The housing 48 contains a pair of wire wrapping assemblies 56 and 57 having respective wire wrapping tools 59 and 60 mounted thereon. The tool 59 is located along the axis of rotation of the housing 48. Wire feeding and stripping assemblies 62 and 63 are mounted on the wrapping assemblies 56 and 57 adjacent to the tools 59 and 60 for feeding wire into the tools.

Referring to FIG. 2, there is shown a detailed view of the wire wrapping assemblies 56 and 57. Rods 65, mounted in the housing 48 between a projection 66 and a wall of the housing, slidably support a block 67 for movement in a horizontal direction. A movable member 69 is slidably mounted on vertical rods 70 mounted on the projection 66 of the housing 48. Similarly, a movable member 71 is slidably mounted on vertical rods 72 mounted on the block 67. The wire wrapping assembly 56 has a pair of vertical rods 73 which are slidable within holes formed in the member 69. Similarly, the wrapping assembly 57 has a pair of vertical rods 74 which are slidable within holes formed through the member 71.

A plurality of serially connected fluid cylinders 76-87 are selectively operable to move the block 67 on the rods 65, and thus position the wire wrapping assembly 57 in a predetermined horizontal position with respect to the wrapping assembly 56. The cylinders 84-87 are serially connected between a projection 90 of the block 67 and

one end of a link 91, which is pivotally mounted on a rod 92 attached to the housing 48. The cylinders 84-87 may have different lengths of travel. For example, air cylinder 84 may be extended 0.1 inch, the air cylinder 85, 0.2 inch, the air cylinder 86, 0.4 inch, and the air cylinder 87, 0.8 inch. Thus, the air cylinders 84-87 may be selectively energized to position the wrapping assembly 57 from 0.1 inch to 1.5 inches from an initial position with respect to the projection 66 in 0.1 inch increments. The cylinders 80-83 are serially connected between a second end of the link 91 and a first end of a link 94 pivotally mounted on a rod 95 connected to the housing 48; and similarly, the cylinders 76-79 are serially connected between a rod 97 mounted on the housing 48 and a second end of the link 94 for selectively moving the block 67. The cylinders 80-83 and cylinders 76-79 have different lengths of travel in the same manner as the cylinders 84-87 have different lengths of travel. The links 94 and 91 provide a 10-1 reduction in the movement of the cylinders 80-83 and a 100-1 reduction in movement of the cylinders 76-79. The lengths of travel of the respective cylinders 76-87 may be chosen to provide for highly selective and accurate horizontal movement of the wrapping assembly 57 with respect to the assembly 56.

Four serially connected cylinders 100-103 are connected between a projection 104 of the block 67 and a projection 105 of the member 71 for moving the member 71 to a selected vertical position with respect to the block 67. A similar arrangement of cylinders (not shown) is connected between the member 69 and the projection 66 for selectively moving the member 69 to a predetermined vertical position with respect to the projection 66.

An air cylinder 108 is mounted in the wrapping assembly 56 and has a piston rod (not shown) which abuts against the top of the member 69. Air is admitted to the cylinder 108 to reduce the downward force applied by the tool 59 as it wraps wire on a terminal 20. A similar cylinder 109 is mounted in the wrapping assembly 57 for reducing the force of the tool 60 when it wraps wire on a terminal 20.

Referring to FIG. 8, the tools 59 and 60 and the wire feeding and stripping assemblies 62 and 63 are shown. The tool 59 has a shaft 114, a spindle 115, an inner sleeve 116 and an outer sleeve 117, all concentrically mounted and vertically slidable with respect to each other. Similarly, the tool 60 has a shaft 120, a spindle 121, an inner sleeve 122 and an outer sleeve 123 which are concentrically mounted and vertically slidable with respect to each other. The shaft 114, the spindle 115, and the inner sleeve 116, have mating longitudinal grooves and ribs such that the shaft 114, spindle 115, and inner sleeve 116 must rotate as a unit. The shaft 120, the spindle 121, and the inner sleeve 122 are similarly mated together. Transverse slots 124 and 125 are formed through the respective spindles 115 and 121 for receiving and encompassing the end of a wire fed therethrough.

The assembly 62 includes a wire feeding mechanism 128 mounted on the member 69 and has a passageway 129 through which the wire 110 is fed. A capstan wheel 131, just below the passageway 129, is vertically movable by an air cylinder 132 against a wheel 133 which is rotated by a reversing motor 134. When the wheel 133 is rotated and the capstan 131 forces the wire 110 in the passageway 129 against the wheel 133, the wire 110 is moved through the passageway 129.

A vertically slidable stripping member 136 is mounted on the mechanism 128 and has a passageway 137 which may be aligned with the passageway 129 for directing the wire 110 fed by the motor 134 through the slots 124 and 125 of the tools 59 and 60. The passageways 129 and 137 are formed at an acute angle with respect to the table 22 so that the wire will be fed toward the terminal board 21 from the wire feeding and stripping assembly 62.

A cutter 139 is slidably movable by an air cylinder 140

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between the mechanism 128 and the member 136 for cooperating with the opening of the passageway 129 to sever the wire 110. An air cylinder 142 is mounted in the member 136 and has a piston rod 141 for gripping the insulation on the severed end of wire as the member 136 is moved upward to strip the insulation from the severed end. A vacuum duct 143 is provided in the mechanism 128 for removing the stripped insulation from the passageway 137 when the member 136 is in its raised position.

The assembly 63 has a vertically slidable stripping member 145 mounted on an extension 146 of the member 71. The member 145 has an opening 147 for receiving the end of the wire 110 after it is inserted through the slots 124 and 125. An air cylinder 149 is mounted in the member 145 and has a piston rod 148 for gripping the insulation on the inserted end of the wire 110 as the member 145 is moved upward to strip the insulation from the end of the wire 110. A vacuum duct 150 is provided in the extension 146 for removing the stripped insulation from the opening 147.

Referring to FIG. 2, a lever 197, pivotally mounted on the mechanism 128, is connected to a fluid cylinder 198 mounted on the mechanism 128 for moving the stripping member 136 vertically with respect to the mechanism 128. Similarly, a lever 200, which is pivotally mounted on the extension 146, is connected to an air cylinder 201 mounted on the projection 146 for moving the stripping member 145 vertically with respect to the extension 146.

As shown in FIG. 9, the spindle 115 has a longitudinal recess 155 extending from the end of the spindle to the slot 124 in the spindle for receiving the end of a terminal. Preferably, the recess 155 is beveled at its opening in the end of the spindle 115 for improving the capturability of a terminal being received therein. A similar longitudinal recess 160 extends from the end of the spindle 121 to the slot 125 in the spindle 121 for receiving a terminal 20.

A cylindrical element 152 having two winged portions 153 and 154 is slidably mounted within the lower portion of the slot 124 and the recess 155 in the spindle 115 for cooperating with the inner sleeve 116 to sever the insulation on the wire 110 and hold the stripped end of wire against the side of the inner sleeve 116 to prevent the engagement of the end of a wire 110 against a terminal received in the recess 155 and slot 124. Similarly, a cylindrical element 157, having winged portions 158 and 159, is slidably within the recess 160 and the slot 125 for cooperating with the inner sleeve 122 to sever the insulation on the end of the wire 110 and hold the stripped end of wire 110 away from a terminal 20 received in the recess 160 and slot 125.

The inner sleeve 116 has a longitudinal groove 162 which extends from the end of the sleeve upwardly. The edge of the groove 162 on the end of the inner sleeve 116 cooperates with the winged portion 154 of the element 152 for severing and partially stripping the insulation on the end of a length of wire 110 which has been severed by the cutter 139 (FIG. 8). The stripped or bare end of wire is captured within the longitudinal groove 162 such that when the shaft 114, spindle 115, and inner sleeve 116 are rotated, the bared end of wire is wrapped around a terminal received in the recess. Slot 163 is formed in the inner sleeve 116 opposite to the groove 162 such that when the inner sleeve 116 is lowered to the end of the spindle 115, the end of the wire is received in the slot 163. Referring to FIG. 10, a longitudinal groove 164 is formed in the inner sleeve 122 similar to the groove 162 of the sleeve 116 for cooperating with the wing 159 of the element 157 for severing the insulation on the inserted end of the wire 110 and partially stripping the insulation from the inserted end of the wire 110. A slot 165 is formed in the inner sleeve 122 opposite to the groove 164 similar to the slot 163 in the sleeve 116, for

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receiving the end of the wire 110 when the sleeve 122 is lowered over the spindle 121.

As shown in FIG. 9, the outer sleeve 123 has a slot 167 aligned adjacent to the opening 147 for receiving the end of the wire when the outer sleeve 123 is lowered. The cooperation of the sleeve 123 and the spindle 121 bends the wire upward in the opening 147 against the upper wall of the opening 147 in position to be gripped by the piston rod of the air cylinder 149. The wire 110 is captured longitudinally between the spindle 121 and the sleeve 123 in position to be stripped by the inner sleeve 122. The outer sleeve 123 does not rotate with the shaft 120, the spindle 121, and the inner sleeve 122. Also, as shown in FIG. 12, the outer sleeve extends slightly below the inner sleeve 122 and spindle 121 to hold the wire 110, extending from the end of the tool 60, away from the rotating sleeve 122 and spindle 121 to prevent the rotating sleeve 122 from snagging the wire 110. Referring back to FIG. 9, the outer sleeve 117 contains a similar slot 168 for allowing free movement of the severed end of wire 110 when the outer sleeve 117 is lowered to capture the wire 110 between the sleeve 117 and spindle 115. With the sleeve 117 lowered, wire may be fed as the table 22 and terminal board 21 (FIG. 1) are moved to lay wire in a pattern on the terminal board 21 as shown in FIG. 13. The wire is fed directly toward the terminal board 21 to lay the wire upon the board 21.

Referring to FIG. 9, the shaft 114 has a transverse slot 126 and the shaft 120 has a transverse slot 127. The slots 126 and 127 are aligned with the slots 124 and 125 of the spindles 115 and 121 to receive the wire 110 when the shafts 114 and 120 are in their positions shown in FIG. 9. When the shaft 120 is raised as shown in FIG. 12, the stripped end of wire is placed or laid completely within the slot 125 of the spindle 121.

Referring to FIG. 2, the inner sleeve 116, the spindle 115, and the shaft 114, are rotatably mounted on the wrapping assembly 56 by a bracket 170. The outer sleeve 117 is slidably mounted in a bracket 171. An air cylinder 173 is mounted on the assembly 56 and has a piston rod 172 connected to an arm 177 rotatably connected to the shaft 114 for vertically moving the shaft 114 within the spindle 115. Similarly, an air cylinder 175 has a piston rod 176 connected to an arm 177 which is rotatably connected to the inner sleeve 116 for vertically moving the sleeve 116 with respect to the spindle 115. An air cylinder 179 has a piston rod 180 connected to an arm 181 which is connected to the outer sleeve 117 for vertically moving the outer sleeve 117 with respect to the inner sleeve 115. A similar arrangement of air cylinders and arms (not shown) is provided in the wrapping assembly 57 for vertically moving the shaft 120, the inner sleeve 122, and the outer sleeve 123, with respect to the spindle 121.

The spindle 115, shaft 114, and inner sleeve 116 are rotated by a 270° rotation hydraulic motor 183 which rotates a gear 184 meshing with a pinion 185 mounted on the spindle 115. The motor 183 and gear 184 are mounted on a bracket 186 extending from the assembly 56. Similarly, a motor 188 and gear 189 are mounted on a bracket 190 for rotating a pinion 191 mounted on the spindle 121 to simultaneously rotate the shaft 120, spindle 121, and inner sleeve 122 of the tool 60.

A gear 193 is rotatably mounted on the assembly 57 to mesh with the gear 189. The gear 193 has a lower cam surface which engages a projection 194 of the member 71 to raise the assembly 57 as the end of a wire is wrapped on a terminal by the tool 60. Similarly, a cam gear 195 is rotatably mounted on the assembly 56 and meshes with the gear 184 for engaging a projection (not shown) of the member 69 to raise the assembly 56 as the end of a wire is wrapped on a terminal by the tool 59.

Referring to FIG. 7, there is shown a numerical control circuit which is mounted in a console 203 shown in FIG. 1 for controlling the operation of the wire wrap-

ping apparatus. A timing circuit 205 operates a tape reader 206 to read information into a buffer register 207. An output of the buffer register 207 is applied to a control circuit 208 for operating the control circuit 208 in accordance with the information transferred from the tape reader. Other outputs of the buffer register 207 are applied to AND gates in an X axis register 210, a Y axis register 211, an R register 212, a head spacing register 213, a tool register 214, a vertical position register 215, and a wire feed register and logic 216, and a display register 217. In accordance with the information stored in the buffer register 207, the control circuit 208, in response to a signal from the timing circuit 205, selectively operates the AND gates of the registers 210-217. The registers 210-216 operate respective driver circuits 220-228 which operate appropriate solenoids and valves (not shown) to control the operation of the apparatus shown in FIG. 1. The display register 217 operates a display circuit 229 which indicates the operation of the wiring apparatus. The timing circuit 205 may be controlled by signals from the tape reader 206 through the buffer register 207 and control circuit 208.

Referring to FIG. 1, there is shown a strip 230 mounted beneath the table 22 which has a plurality of holes 231 horizontally spaced throughout its length. A light source 232 is mounted on the frame 24 on one side of the strip and a photocell 233 is mounted on the frame 24 on the other side of the strip. As the table 22 is moved in a Y direction with respect to the frame 24, the holes pass in front of the light source 232 to excite the photocell 233. A similar strip (not shown) is mounted on the frame 24 in the X direction and a similar light source (not shown) and photocell (not shown) are mounted on the support 26 for sensing movement of the frame 24 in the Y direction. Referring to FIG. 7, the outputs of the photocells are applied to the wire feed logic 216 to control the wire feed driver 228 when the information from the buffer register 207 has set up the logic 216 to allow such control.

As shown in FIG. 4, a cone-shaped plastic retainer 240 is force fit upon a terminal 20f. Other retainers may be mounted on other terminals. After the wiring of the board 21 is completed, the retainer 240 is slipped on the terminal against the wires on the board to prevent the wires from moving away from the board during handling or use of the board 21.

OPERATION

Referring to FIG. 4, there is shown the terminal board 21 having terminals 20a-20p mounted thereon. The apparatus shown in FIG. 1 may be used to selectively connect various terminals of the terminal board 21 in two modes of operation. For example, the automatic wiring apparatus may simultaneously wrap the ends of a length of wire 234 about terminals 20i and 20o, or the automatic wiring apparatus may first wrap one end of a length of wire 236 about terminal 20p and lay the wire in a zig-zag pattern through the remaining terminals to the terminal 20a where the other end of the wire 236 is wrapped on the terminal 20a. It is noted that the path the wire 236 is laid in from the terminal 20p to 20a, may be selected to provide maximum spacing from two wires 234 and 235. When a wire connection may be formed in a straight line between terminals, for example, the wire 235 between terminals 20c and 20d, and the wire 236 between terminals 20i and 20o, the connection is more quickly made by simultaneously wrapping the ends of the section of wire around the respective terminals rather than using the time consuming process of routing the wire through the terminals.

FIG. 5 shows the position and movement of the tools 59 and 60 in simultaneously wrapping the ends of the wire 236 onto the terminals 20i and 20o. Initially, the tape reader 206, buffer register 207, control circuit 208, and timing circuit 205 feed information to the registers 214 and 215 to operate the driver circuits 224-227 to

position the shafts 114 and 120 (FIGS. 8-12), the spindles 115 and 121, the inner sleeves 116 and 122, the outer sleeves 117 and 123, the stripping mechanisms 136 and 145 in the position shown in FIG. 8. Next, the tape reader 206, the buffer register 207, and control circuit 208 feed information to the X axis register 210, Y axis register 211, and R axis register 212. The X axis driver circuit 220 and the X axis driver circuit 221 cause the actuation of the indexing cylinders 28 and 29 (FIG. 1) to move the table 22 and position the terminal 20i directly beneath the tool 59. The R driver circuit 222 causes the actuation of the indexing cylinder 50 to rotate the head 48 and position the tool 60 in a direct line with the terminal 20o as shown in FIG. 5. Information fed to wire feed logic and register 216 operates the feed driver circuit 226 to actuate the air cylinder 132 (FIG. 8) and the motor 134 to feed wire through the passageways 129 and 137, and the slots 124 and 125 of the spindles 115 and 121, the slots 126 and 127 of the shafts 114 and 120 (FIG. 9), into the opening 147 of the stripping mechanism 145.

Information from the tape reader 206 is then fed to the tool register 214, to actuate the air cylinder 179 and lower the outer sleeve 123 as shown in FIG. 9, to bend the inserted end of the wire 110 against the upper wall of the opening 147 adjacent to the air cylinder 149. The capstan wheel 131 is released to allow additional wire to be pulled from the wire feeding stripping assembly 62 as the sleeve 123 is lowered. The air cylinder 148 is then actuated to grip the insulation on the end of the wire. Next, the inner sleeve 122 is lowered as shown in FIG. 10 to sever and partially strip the insulation on the end of the wire 110. The insulation on the end of the wire is pulled off by upward movement of the stripping member 145 and the stripped insulation is removed by the vacuum duct 150 as shown in FIG. 11. The bared end of wire is then positioned completely with the slot 125 of the spindle 121 by upward movement of the shaft 120. The shaft 120 is shown in its raised position in FIG. 12.

In the next step, information is fed to the head spacing register 213, whereupon the cylinders 76-87 (FIG. 2) are selectively actuated to position the tool 60 directly over the terminal 20o. As the cylinders 76-87 are operated, wire is pulled through the slot 124 of the spindle 115 (FIG. 9) and the slot 126 of the shaft 114 from the wire feeding and stripping assembly 62 wherein the capstan wheel 131 has been released.

After the bit 60 is positioned over the terminal 20o, the cylinder 140 (FIG. 8) is operated to move the cutter 139 to sever the wire between the passageways 129 and 137. Next, the outer sleeve 117, the inner sleeve 116, the stripping mechanism 136, and the shaft 114 are operated to sever and strip the insulation from the severed end of the wire and position the stripped end completely within the slot 124 of the spindle 115.

Information is then fed to the vertical position register 215 which excites the drivers 226 and 227 to selectively actuate the air cylinders 100-103 and the air cylinders (not shown) connected between the member 69 and assembly 56 to lower the wrapping assemblies 56 and 57, whereupon the terminals 20i and 20o are received within the respective recesses 155 and 160 of the spindles 115 and 121. As the terminal 20o is received in the recess 160, it engages the cylindrical element 157 and causes the member 157 to move upward within the slot 125 as shown in FIG. 11. The wing 158 of the element 157 holds the bare end of the wire against the wall of the inner sleeve to prevent the bare end of the wire from engaging the terminal 20o and being bent as the shaft 120, spindle 121 and sleeve 122, are rotated. The cylindrical element 152 (FIG. 9) of the tool 59 is moved upward within the slot 124 by the terminal 20i in the same manner as the element 157 of the bit 60.

The shaft 114, the spindle 115 and the inner sleeve 116 of the tool 59 and the shaft 120, the spindle 121, and the inner sleeve 122 of the tool 60 are now rotated by

the motors 183 and 188 (FIG. 2) and the gears 184 and 189 to wrap the stripped ends of the wire on the respective terminals 20i and 20o and form a wired connection 234 (FIG. 4). The camming gears 193 and 195 (FIG. 2) are also rotated to raise the wrapping assemblies as the tools 59 and 60 rotate to form tightly wound helical wraps on the terminals 20i and 20o. The wrapping assemblies 56 and 57 are raised and the tools 59 and 60 returned to their initial positions ready to receive a wire to complete a cycle of operation.

In making the wire connection 236 (FIG. 4) between the terminals 20a and 20p, the shafts 114 and 120, the spindles 115 and 121, the inner sleeves 116 and 122, the outer sleeves 117 and 123, and the stripping members 136-145, are in their initial positions as shown in FIG. 8. The indexing cylinders 28 and 29 move the table 22 (FIG. 1) and terminal board 21 to position terminal 20p directly beneath the tool 60 as shown in FIG. 6.

The end of a wire 110 is fed through the slots 124 and 125 of the spindles 115 and 121 and the slots 126 and 127 of the shafts 114 and 120 into the opening 147 of the stripping mechanism 145. The outer sleeve 123, the inner sleeve 122, the stripping member 145, and the shaft 120 are then operated to strip the insulation from the end of the wire and place the stripped end entirely within the slot 125 of the spindle 121.

Next, information is fed to the vertical position register 215 (FIG. 7) which actuates to lower only the tool 60 over the terminal 20p whereupon the terminal 20p is received within the recess 160 of the spindle 121. During the lowering of the tool 60, the capstan wheel 131 is released to allow additional wire to be pulled from the wire feeding and stripping assembly 62. The tool 60 is now rotated to wrap the stripped end of the wire 110 on the terminal 20p. The tool 60 is then raised to its initial position from the terminal board.

In the next step, the sleeve 117 is lowered over the spindle 124 as shown in FIG. 13. The terminal board 21 on the table 22 is moved in the Y direction beneath the tool 59 to position the tool 59, as shown at 239 in FIG. 6, with respect to the terminal board 21. As the table 22 moves in the Y direction, pulses from the photocell 233 pass through the logic circuit 216 to actuate the wire feed driver 226 and cause the feeding of wire through the passageways 129 and 137, the slot 124 of the spindle 115, and the slot 126 of the shaft 114 and between the sleeve 117 and spindle 124 toward the terminal board 21. The wire 110 naturally bends against the terminal board to lay between the terminals 20. The table 22 is then moved in the X direction beneath the housing 48 to position the tool 59 as shown at 241 in FIG. 6 with respect to the terminal board 21. Again, wire is fed through the tool 59 to lay on the terminal board 21 between the terminals. Movement of the table 22 in the Y direction while wire is fed through tool 59 lays wire from point 241 to point 243 adjacent to terminal 20a as shown at 243 in FIG. 6. Subsequently, the table 22 is moved in the X direction to position the bit 59 directly over the terminal 20a.

The wire feed motor may now be reversed to take up slack in the wire laid from the terminal 20p. Next, the wire cutter 139, inner sleeve 116, stripping mechanism 136, and shaft 114 are operated to sever and strip the insulation from the severed end of wire and place the stripped end of wire completely within the slot 124 of the spindle 115. The tool 59 is then lowered over the terminal 20a and rotated to wrap the stripped end of wire on the terminal 20a to form the wire connection 236. Raising the tool 59 from the terminal 20a completes the cycle of operation for making the wire connection 236 (FIG. 4).

The wire connection 236 may be laid in any selected pattern on the terminal board 21. By moving the terminal board 21 simultaneously in the X and Y directions, it is

possible to lay the connections 236 along a diagonal to the X and Y directions.

In feeding the wire through the tool 59 when the connection 236 (FIG. 6) is made, the wire may be fed through the slot 124 (FIG. 9) in the spindle 115 and the slot 126 in the shaft 114 without the sleeve 117 being lowered. The wire is then fed at an angle toward the terminal board as the board is moved under the tool 59. At the points 238, 239 and 241 (FIG. 6), it is necessary to rotate the housing 48 such that the wire is always fed in the direction that the terminal board is moved.

It is to be understood that the above-described embodiment is simply illustrative of the invention and that many other embodiments may be devised without departing from the scope and spirit of the invention.

What is claimed is:

1. An automatic wire wrapping apparatus for connecting terminals of a terminal board comprising:

a table for supporting the terminal board;

a housing;

means for moving the table along two transverse axes with respect to the housing;

means for rotating the housing with respect to the table;

first and second wire wrapping tools mounted in the housing, each tool having (1) an axis substantially perpendicular to the table, (2) means for receiving a terminal, and (3) means for receiving an end of a section of wire such that when the tool is rotated about its axis the end of the section of wire is wrapped on the terminal;

means for transversely moving the second tool relative to the first tool;

means for axially moving the first and second tools toward and away from the table to receive terminals in the tools;

means for rotating the tools about their axes; and control means for selectively operating the table moving means, the housing rotating means, the second tool transversely moving means, the first and second tool axially moving means, and the tool rotating means in first and second modes of operation;

said first mode of operation being to simultaneously wrap the ends of the section of wire on respective first and second terminals; and

said second mode of operation being to sequentially (1) wrap a first end of the section of wire on the first terminal, (2) lay the section of wire in a predetermined path on the terminal board from the first to the second terminal, and (3) wrap the second end of the section of wire on the second terminal.

2. An automatic wire wrapping apparatus for connecting terminals of a terminal board, comprising:

a support;

a table mounted on the support for movement along two transverse axes;

a housing mounted on the support for rotation with respect to the table;

means for feeding a first end of a section of wire at an angle toward the table;

first and second elongated wrapping tools mounted in the housing such that the first tool is between the wire feeding means and the second tool; each of said tools being rotatable about an axis substantially perpendicular to the table and movable along its axis toward and away from the table; and each of said tools having (1) means thereon for receiving a terminal, (2) a slot formed transversely through the tool for receiving an end of a section of wire, and (3) means for encompassing the end of the section of wire such that rotation of the tool wraps the end of the section of wire on the terminal; and

means for sequentially (1) aligning the transverse slots of the tools in the path of the first end of the sec-

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tion of wire being fed from the wire feeding means, (2) axially moving the second tool and rotating the second tool to wrap the first end of the section of wire on a first terminal, (3) moving the table such that the section of wire from the wire feeding means passes through the slot in the first tool and is laid in a pattern on the terminal board from the first terminal to a second terminal, and (4) axially moving the first tool and rotating the first tool to wrap the second end of the section of wire on the second terminal.

3. An automatic wire wrapping apparatus for connecting terminals of a terminal board comprising:

a table for supporting the terminal board;

a housing;

means for moving the table along two transverse axes with respect to the housing;

means for rotating the housing with respect to the table;

means mounted in the housing for feeding a first end of a section of wire at an angle toward the table;

first and second elongated wrapping tools mounted in the housing such that the first tool is between the wire feeding means and the second tool; each of said tools being rotatable about an axis substantially perpendicular to the table and movable along its axis toward and away from the table; and each of said tools having (1) means thereon for receiving a terminal, (2) a slot formed transversely through the tool for receiving an end of a section of wire, and (3) means for encompassing the end of the section of wire such that rotation of the tool wraps the end of the section of wire on the terminal;

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means for transversely moving the second tool relative to the first tool;

means for axially moving the first and second tools toward and away from the table to receive terminals in the tools;

means for rotating the tools about their axes; and

control means for selectively operating the table moving means, the housing rotating means, the second tool transversely moving means, the first and second tool axially moving means, and the tool rotating means in first and second modes of operation;

said first mode of operation being to simultaneously wrap the ends of the section of wire on respective first and second terminals; and

said second mode of operation being to sequentially (1) wrap a first end of the section of wire on the first terminal, (2) lay the section of wire in a predetermined path on the terminal board from the first to the second terminal, and (3) wrap the second end of the section of wire on the second terminal.

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