United States Patent [19]

Tarbox et al.

[11] **3,885,161**

[45] **May 20, 1975**

[54] STRAND DETECTION ARRANGEMENT

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Related U.S. Application Data

[62] Division of Ser. No. 103,233, Dec. 31, 1970, Pat. No. 3,699,630.

[52] **U.S. Cl.** **250/571**; 250/559; 250/560; 356/159

[51] **Int. Cl.** **G01b 7/12**

[58] **Field of Search** .... 356/199, 200, 238, 159, 356/199; 250/219 S, 559, 571, 560

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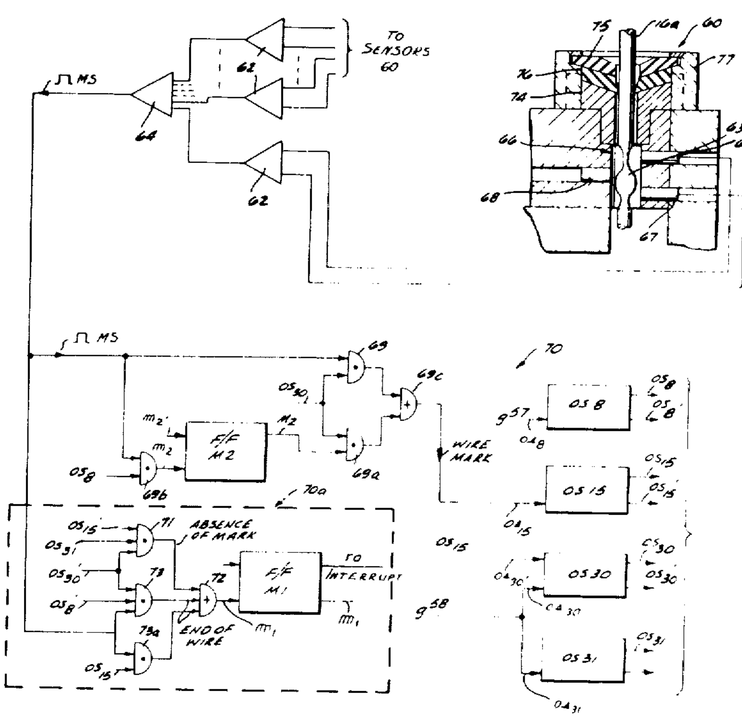
Attorney, Agent, or Firm—Richard J. Rengel; W. H. MacAllister

[57] ABSTRACT

A wire-dispensing system provides for ordered dispensing and forming of wires along predetermined paths to produce cables and including automating the production of cable harnesses. A wire-dispensing head is controlled to selectively dispense wires from a group of supply spools, laying the wire along predetermined paths according to the desired harness pattern configuration, cutting the wires to conform to the individual path lengths, and securing the wires at respective termination sites. The wire-dispensing head includes feed tubes selectively actuated to secure the wires at the termination sites wherein movements of the dispensing head are controlled to accurately move the selected feed tubes along the paths determined by the harness pattern configuration. The desired length of an individual precoded wire is determined by optically sensing the configuration of a wire mark which controls wire payout by a rotatable capstan, while feed rate of the tension of the wires is regulated by the same capstan at a low level capable of accurately locating the wires along the wire layout paths of the cable harness wherein the tension is requested so as not to exceed the level of wire retention at the termination sites. The termination sites include openings having resilient retaining means comprising a slit pattern in neoprene at each opening for receiving the end portion of a feed tube and retaining wires on withdrawal of the feed tube.

11 Claims, 8 Drawing Figures



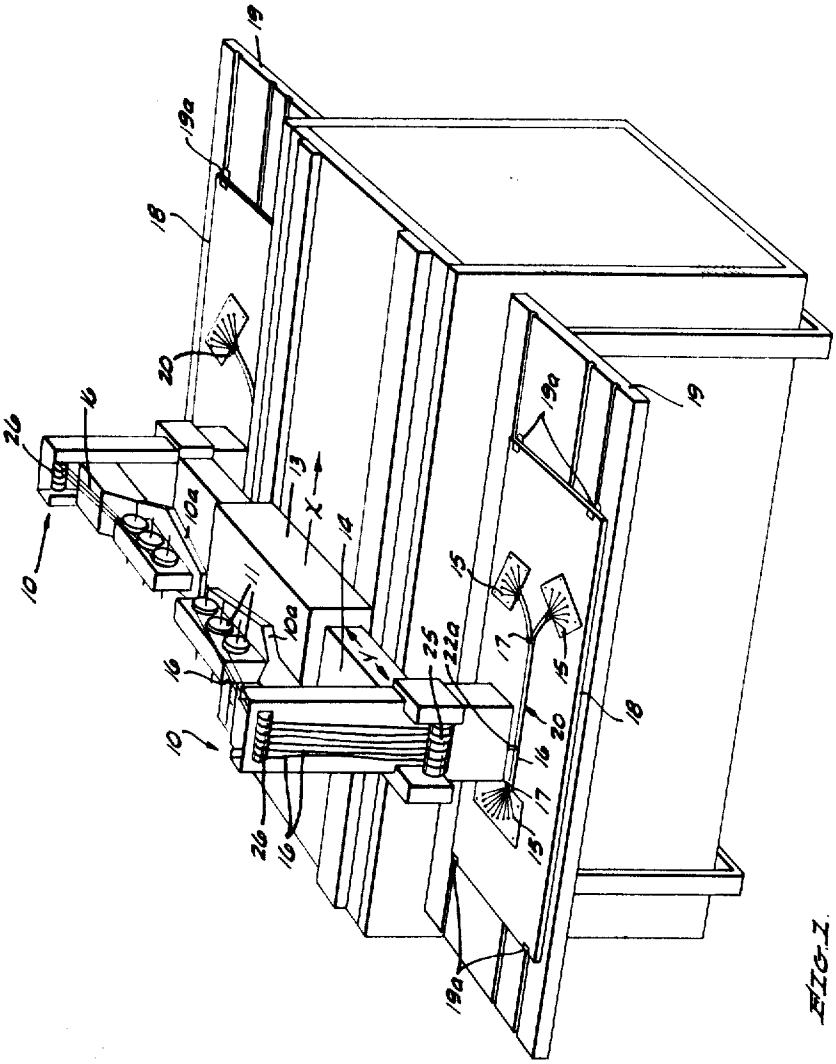
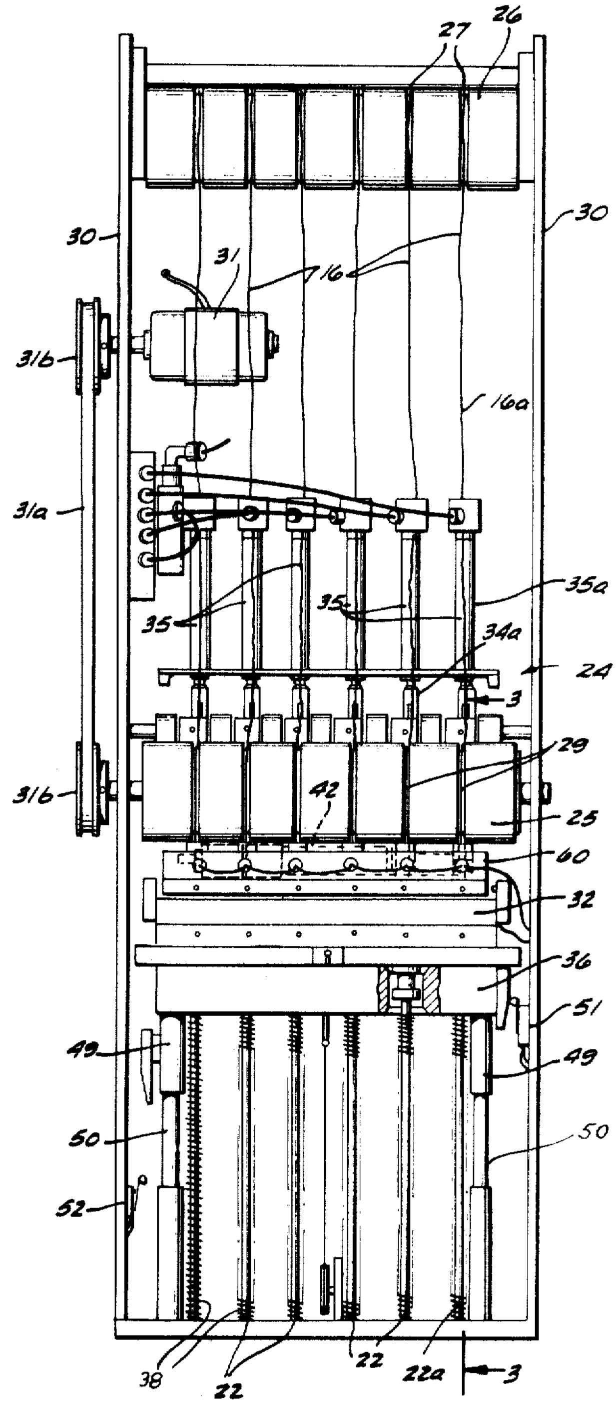


FIG. 1

FIG. 2.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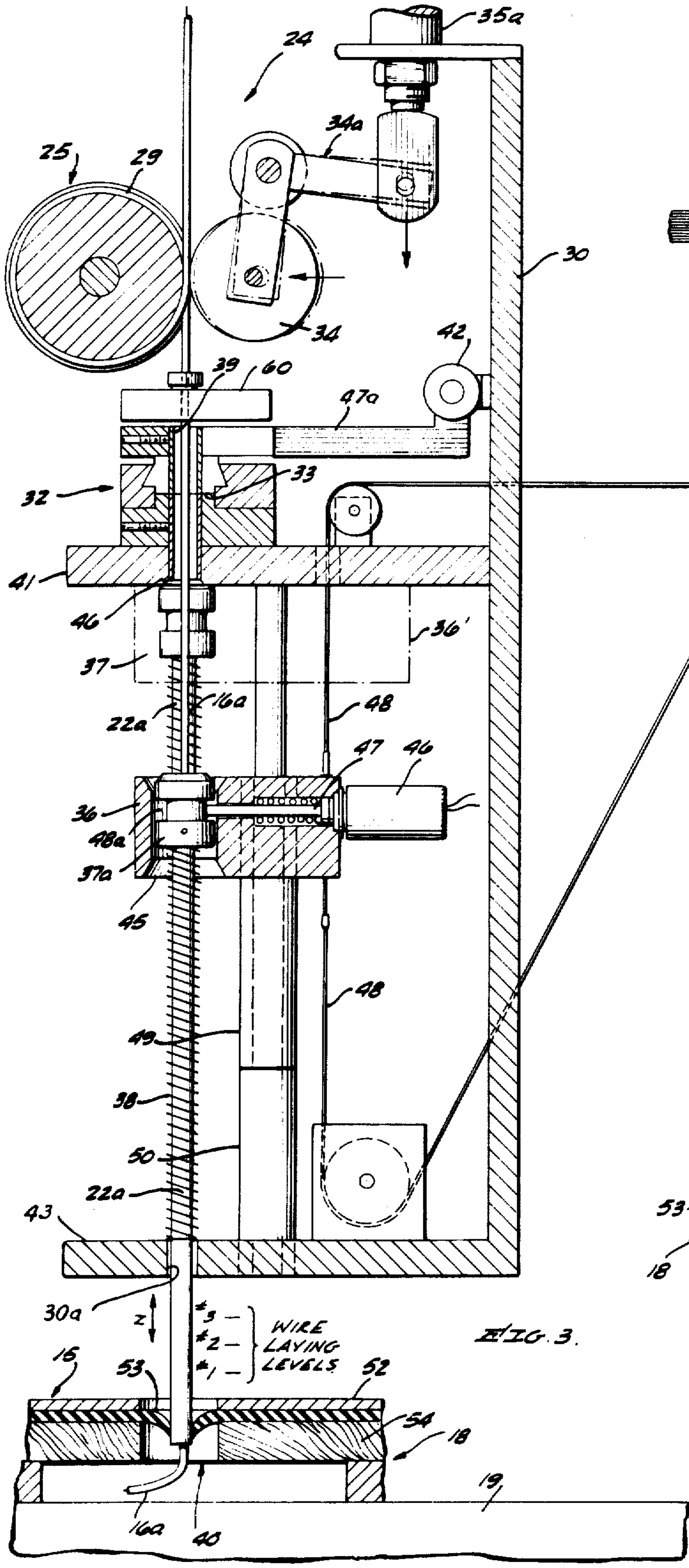


FIG. 3.

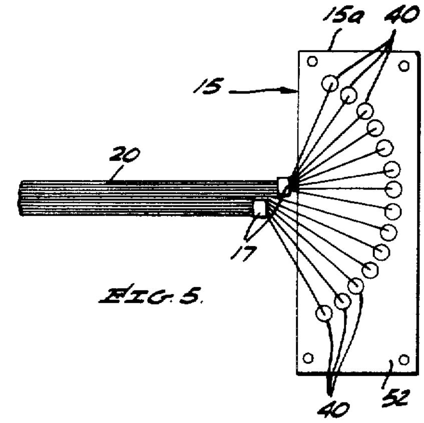
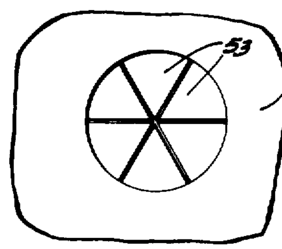


FIG. 5.

FIG. 4a.



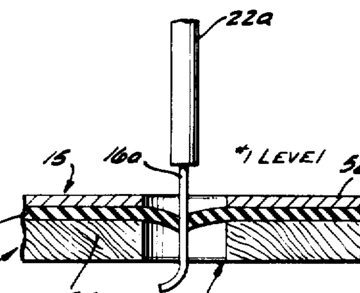
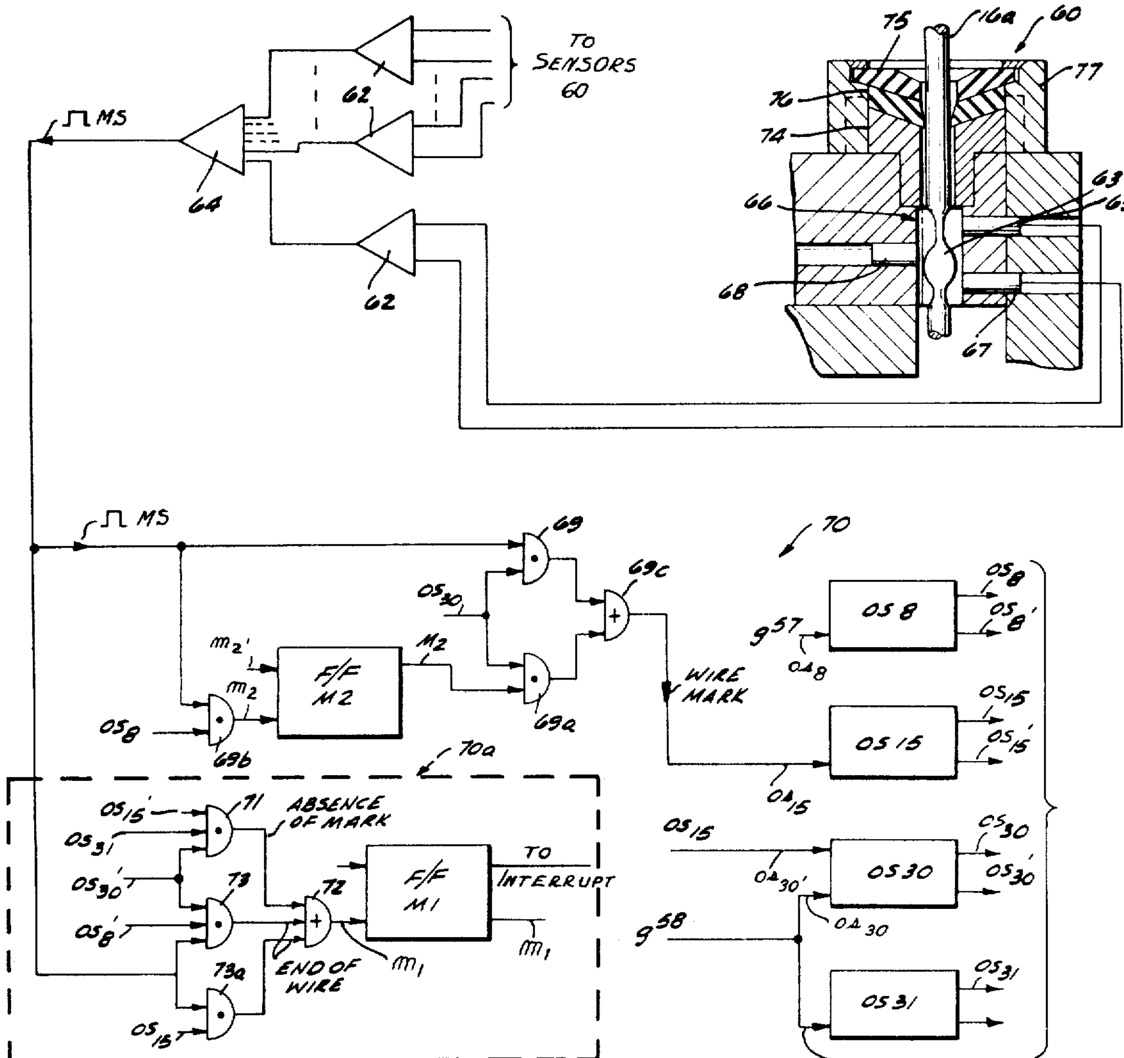


FIG. 4.


TO SENSORS 60
MS
62
64
75
16a
60
77
76
74
66
63
65
68
67
69
69c
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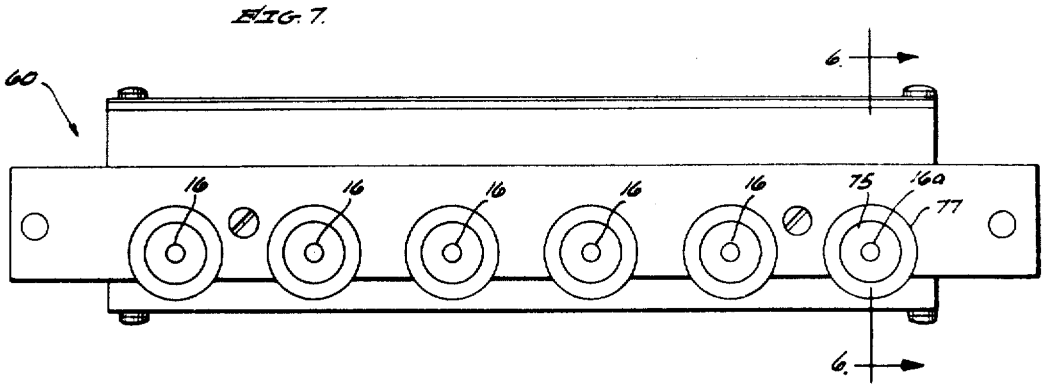
OS 8
OS 15
OS 30
OS 31
F/F M2
F/F M1
WIRE MARK
ABSENCE OF MARK
END OF WIRE
TO INTERRUPT
69a
69b
70a
71
72
73
73a
g57
g58

FIG. 6

FIG. 7.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STRAND DETECTION ARRANGEMENT

CROSS REFERENCE

This application is a division of Ser. No. 103,223 filed Dec. 31, 1970, now U.S. Pat. No. 3,699,630, granted Oct. 24, 1972.

BACKGROUND OF THE INVENTION

Automatic assembly of electronic equipment has progressed substantially with technology advancements in microelectronics including integrated circuit systems. Several types of automatic wiring machines have been developed and are in extensive use to provide circuit interconnections between circuits, e.g., printed circuit boards mounted on circuit panel boards. These interconnections are made between rows of terminal pins projecting from one side of the panel board to provide power and signal distribution to circuits mounted on the other side of the panel board. Because of the greater efficiency and accuracy of these machines over other methods of making extensive wire interconnections required for complex electronic equipment, these wiring machines provide a substantial advantage in production of electronic equipment.

Despite the successful operation and use of these automatic wire machines in wiring of circuit panel boards, many other types of circuit interconnections are being made manually. One of these latter types of interconnection commonly in use in electrical or electronic equipment is the cable harness which provides power and signal distribution internally between circuit board panels of subassemblies and between individual units including distant units of electronic or electrical equipment.

Automatic assembly of these latter types of interconnections has not progressed due to the many difficult problems encountered in providing a system arrangement or machine which is versatile, i.e., a machine capable of accommodating diverse requirements of the electrical and electronic industry without the complexity of foregoing wire wrapping machines. In this field, there is little standardization in wire use including color coding, multiple wire colors and gauges which has resulted in difficult problems of wire manipulation, and particularly in those instances where long cables are required for interconnection of distant terminals. Further, a machine for automatic assembly of cable harnesses, for example, must also provide a high degree of realibility in providing the proper interconnections to multiple terminal sites.

Accordingly, the present invention is directed to a system providing ordered dispensing of wire along predetermined paths to produce cables interconnecting a plurality of terminal sites according to a stored program including data for locating the wire between terminal sites.

SUMMARY OF THE INVENTION

The system arrangement provides, in response to a digital stored program including data for termination points and the paths therebetween, for selectively dispensing of individual wires by wire-dispensing heads movably disposed on the carriage of a controlled positioning device disposed above respective cable harness forms, each harness form including a plurality of termination sites having openings for retaining terminal portions of individual wires laid along predetermined paths between designated sites to form the cable harness. The common paths for individual wires form the branches and main trunks, and the branches lead to termination sites where the individual wires are separated and retained. Selection of individual wires is provided by system control of wire payout and feed tubes threaded from a precoded wire supply wherein the length of individual ones of the wires is designated by marks which are detected prior to securing the lead-ends of the wires at the beginning of respective wire paths to form a cable harness having each wire coded and located according to the code identification. In dispensing an individual wire of a harness in a wire-dispensing cycle of the system, the wire is removably secured in a selected one of a plurality of wire retention positions of a termination site and the tension on the wire during movement along a predetermined path to another termination site is regulated by a capstan drive in order to accurately place the length of wire along the path while not exceeding the retention capability at the initial termination site.

In a cycle of operation, one of a plurality of wires supplied to each dispensing head is paid-out by the capstan into a corresponding feed tube aligned with the wire feed position on the capstan. The feed tube is lowered to secure the lead-end of the wire at the termination site, then raised to the proper wire laying level whereupon the dispensing head is moved along the layout path to the desired termination site for securing the other end of the wire. The tension of wire is regulated during layout by the capstan operating in a feed mode and the wire is cut upon approaching the termination site whereby the end of the wire is drawn from the feed tube to be secured at the latter site.

The cable harness pattern of the preferred embodiment comprises a form board disposed on a work table of the machine and this board includes wire retainers and termination sites located at the end of branches of the cable harness, each site comprises a plurality of openings for receiving the end of a feed tube and a resilient layer having slit pattern coaxially disposed in the respective openings. The slit pattern provides for passing the end of a feed tube while retaining the wire projecting therefrom upon feed tube withdrawal. After the wires of cable harness have been dispensed, the cable harness can be removed from the board for assembly of other cable harnesses. Preferably, any additional processing of the cable harness desired is performed prior to removal from the board. For example, when the wire retainers are fixed to the board and are not removed with the cable harness formed, the wires are tied or otherwise secured to maintain the desired configuration required for use, including branch separation and orientation in two or more axes on individual configurations desired.

Individual wires are precoded to identify each wire and the length thereof. Accordingly, mark sensors provide for detection of the beginning of each wire length by the physical configuration of a wire-mark. The absence of a wire-mark, or the exhausting of a supply of wire selected to be dispensed, is also detected to interrupt wire-dispensing operations for the selected wire.

While the system of the present invention, as described herein, is directed to wire-dispensing, strand material including fibers, fiber optical strands and tubing, other corresponding elongated materials which are capable of being dispensed between points by the system are intended to be included in the present invention. Further, the term "cable harness," as used herein, refers to strand material dispensed to form interconnections between termination sites in which common paths between these sites form branches of the cable harness.

Accordingly, it is an object of the present invention to provide a system for ordered dispensing of wire or other strand material and the like, having the foregoing features and advantages.

Another object of the invention is the provision of an improved system for automatic dispensing of strand material and the like to form a desired cable harness configuration of individual strands.

A further object of the present invention is to provide a system arrangement for dispensing strand material about strand retainers, according to a stored program which controls the dispensing operations to dispense the strand material about the retainers, in order to locate the strand material in the desired cable harness configuration.

Another object is to provide a cable harness or the like by dispensing a length of strand material in a pattern which is determined, in combination, by the path of strand dispensing and retainers on a forming board providing for layout and removal of the strand material.

A further object of the invention is to provide a feed arrangement for regulating the tension of strand material being dispensed.

Still another object is to provide a system arrangement for facilitating the securing of strands at termination sites during automatic strand dispensing.

Another object is the provision of strand-dispensing arrangement providing for selection, payout and regulated feed of any strand of a group being selectively dispensed.

Other objects and features of the invention will become apparent to those skilled in the art as the disclosure is made in the following detailed description of the preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view showing the wire dispensing system arrangement of the preferred embodiment of the invention for ordered dispensing of wires to form wire harnesses;

FIG. 2 is a front view of one of the wire dispensing heads shown in the system of FIG. 1, having covers removed to show the structural arrangement thereof and partly broken away to show a typical feed tube assembly;

FIG. 3 is a sectional view of the dispensing head shown in FIG. 2 taken along a sectional line 3—3 and showing a selected one of the feed tubes lowered into position for securing a wire at a termination site;

FIG. 4 is an enlarged detailed view of a section of a termination block of the site shown in FIG. 3 for showing certain details in the securing of a wire at the termination site;

FIG. 4*a* is a detailed view of the preferred radial pattern for securing the end of the wire in the termination block shown in FIGS. 3 and 4;

FIG. 5 is a top view of the termination block;

FIG. 6 is a schematic diagram for the wire-mark sensors of the wire guide-sensor assembly including a sectional view of a typical sensor and the logical circuit diagram therefor;

FIG. 7 is a top view of the wire guide-sensor assembly including six (6) wire-mark sensors for individual wires for each wire dispensing head.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, FIG. 1 shows the system of the preferred embodiment of the invention comprising a dual arrangement of wire dispensing heads **10** mounted on opposite ends of a head positioning carriage **13** including a boom **14** which is made operative to move the heads **10** to automatically dispense individual wires **16** along separate paths of a wire harness pattern defined by wire retainers **17** and wire termination sites **15** on wire harness form boards **18.**

Positioning and movement of the wire dispensing heads **10** relative to the form boards **18** are provided by a numerically programmed control system to produce incremental positioning of the heads **10** in accordance with a discrete signal program, for example, or other numerical or computer controlled systems providing for controlled movements from point to point or along continuous paths. In this connection, illustrative reference is made for the first-mentioned system described in U.S. Pat. Nos. 3,252,147 and 3,262,105. A positioning control system found in machine tool control is described wherein movable platens or tables, spindles, and workpiece are positioned in one or several axes in accordance with programs defined by a numerical code in individually programmed blocks of a product tape or by other suitable information input.

As shown in FIG. 1 by arrows X and Y, operational movements of heads **10** parallel to the form boards **18** provides concurrent and selective dispensing of wires **16** by heads **10** along individually programmed wire paths between termination sites **15** which pass about projecting arms of retainers **17** to produce a wire harness **20,** for example. The wire harness form boards **18** are mounted on work tables **19** by suitably positioned fixtures or clamps **19*a*** which provide for positioning individual boards uniformly on tables **19** for ordered wire dispensing operations. In addition to providing for control of movement of the heads **10** over the form boards **18,** the preferred numerically controlled system controls certain auxiliary and preparatory functions for internal operations of heads **10** including wire selection, pay-out and feed intervals of selected wires, wire cutting, and operating levels of feed tubes **22** in a manner described more fully hereinafter.

Considering now the details of construction of the wire-dispensing heads **10,** a wire supply is shown in FIG. 1 to comprise groups of precoded spools **11** disposed above platforms **10*a*** for respective ones of wire-dispensing heads **10.** Wires **16** are selectively supplied from spools **11** to corresponding capstans **25** and then to feed tubes **22,** for example, feed tube **22*a*.** As provided for each of the dispensing heads **10,** wires **16** from the respective group of spools **11** are guided to the feed tubes **22** by peripheral channels in guide rollers **26** and in the capstans **25.** The capstan drive assemblies of the respective heads **10** provide individual operating modes, including a positive payout mode in which the capstans selectively pay out one or more of the wires **16** into corresponding feed tube **22*a*,** and a regulated feed mode in which the capstan assembly regulates the tension of the selected wires **16** being dispensed along individual wire paths of harnesses **20.**

DETAILED DESCRIPTION OF A TYPICAL WIRE DISPENSING HEAD

Referring now to FIGS. 2 and 3 for a more detailed description of the structure of a typical one of the wire dispensing heads 10, FIG. 2 is a front view which shows the internal construction with the feed tubes 22 in their retracted position prior to wire dispensing operations, and FIG. 3 shows the wire dispensing head 10 in payout operating mode securing a selected wire 16*a* at a selected location at a wire group termination site 15 at the beginning of a layout "run". A frame 30 supports cooperating members of the wire dispensing head 10 to guide the wires 16 laterally from the supply spools 11 to respective channels 27 of the guide roller 26, and vertically to respective channels 29 of the capstan 25 to be fed through respective wire mark sensors 60 and guide tubes 39 of a cutter bar assembly 32. The ends of the wires 16 in guide tubes 39 are thus disposed to be fed into feed tubes 22 which are coaxially disposed along the axes of respective guide tubes 39. In the preferred embodiment therefore, provision is made in each head 10 for guiding seix wires 16 from the supply spools 11 to the capstan 25, maintaining uniform separation of the wires 16 by guiding the wires 16 in annular channels 27 of the guide roller 26. The spools 11 on respective spindles are constructed to provide drag during pay-out and wire feed intervals. Each of the wires 16 is wrapped one or more times around the capstan 25 in respective channels 29 to provide pay-out of the wires 16 and regulate the feed rate thereof. For example, any selected wire 16*a* is paid-out by actuation of a corresponding pinch roller 34 and frictional engagement of the wire 16*a* with the rotating capstan 25 as shown more clearly in FIG. 3. Subsequently, the driving force transmitted to the wire 16*a*, during regulated feed while laying of the wire along paths of the wire harness 20 is determined by the degree of frictional engagement of the wire 16*a* and the annular surface formed by the bottom of the channel 29 for translation of the rotary motion of a capstan 25 to linear movement of the wire 16*a* through the feed tube 22*a* to regulate the tension during layout of the selected wire 16*a*. In actual operation of the preferred embodiment, by way of example, the feed tension of wire 16*a* is regulated to a constant low level of the two (2) pounds for 14–16 gauge insulated wire. By regulation of feed tension, i.e., frictional engagement without pressure of an engaged pinch roller 34, wires 16 in the harness 20 will be maintained taut during wire feed from feed tubes 22 to assure that the wires will precisely follow along the layout paths to produce the programmed wire harness. Concurrently, the tension of the wires during feeding is regulated by the capstan drive to prevent excessive tension and possible damage thereto as they are passed out of tapered openings at the lower ends of the feed tubes 22 to be disposed about retainers 17 on the form board 18. Further, the regulation of wire tension to a low level assures retention by gripholes 40 in individual positions at the wire termination sites 15 of the wire harness form board 18 (FIG. 3).

In FIG. 2, the capstan drive assembly 24 is shown to comprise a continuously rotating capstan 25 driven by a motor 31 via a belt drive including a belt 31*a* and pulleys 31*b* which couple the drive shaft of the motor 31 to the drive shaft of the capstan 25. The motor 31 drives the capstan 25 continuously at a speed corresponding to the desired rate of pay-out of the selected wire 16*a*. As shown more clearly in FIG. 3, the selected wire 16*a* is driven down by the capstan 25 into feed tube 22*a*, e.g., during a payout interval. In the preferred embodiment of the control arrangement, which is described in detail in the description in FIG. 3, the selected wire 16*a* is paid out in sections before and after lowering of the selected feed tube 22*a*. In general, the length of wire paid out must project out of the feed tube 22*a* for securing an end portion thereof in the slit pattern of the selected griphole 40 at the wire termination site 15, as shown in FIG. 3.

At the beginning of pay-out interval, the end of selected wire 16*a* is moved from its position at shearing edge 33 of the cutter bar assembly 32 through the lower section of guide tube 34 and into the selected guide tube 22*a*. After the feed tube 22*a* is lowered to plunge into griphole 40, an additional length of wire 16*a* is paid out to provide an exposed end position which is retained by the layer 53 as the tube 22*a* is withdrawn from the griphole 40 as will be explained in detail later.

The pay-out interval occurs at the beginning of each wire dispensing cycle in the process of forming a wire harness 20, and is followed by a wire feed interval in which the capstan 25 maintains a constant feed tension on the selected wire 16*a* during traversal of the harness layout pattern. During the pay-out interval, a positive drive is applied to the wire 16*a* as a result of engagement and pressure applied by pinch roller 34 as shown in FIG. 3. An individually actuated pinch roller 34 is provided for each of the six (6) wires 16, and only the pinch roller 34 corresponding to the selected wire 16*a*, for example, is energized to engage wire 16*a* by entering the corresponding groove in the capstan 25. As the pinch roller 34 engages wire 16*a*, it forces the selected wire 16*a* into frictional engagement with the bottom of the groove of the constantly rotating capstan 25 to payout wire 16*a*.

In the pay-out interval, the selected wire 16*a* must be paid out past the cutter assembly 32 and into the corresponding feed tube 22*a* to provide a length of wire projecting from the end of the selected feed tube 22*a* which is retained by the griphole 40. Accordingly, at the beginning of each dispensing cycle, the pinch roller 34 shown in FIG. 3, which corresponds to the selected wire 16*a*, is moved laterally by actuation of the corresponding linkage 34*a* coupled to a pneumatic actuator 35*a*. As shown in FIG. 2, six (6) pneumatic actuators 35 are individually connected to a regulated air supply and electromagnetically actuated to selectively control the supply of air to individual ones of the actuators 35 for corresponding pinch rollers 34.

The cutter bar assembly 32, shown in FIGS. 2 and 3, is disposed below the capstan assembly 24 and consists of a stationary lower section secured to a laterally projection 41 of the frame 30; and a slidable upper section disposed on the lower section to form a wire cutting edge 33. A cutter actuating solenoid 42 is mounted on the opposing wall of frame 30. The armature of solenoid 42 is connected to the movable upper section of the wire cutter assembly 32 by an arm 47*a*. The solenoid is energized to produce relative movement of the upper section to cut the wire 16*a*, for example, at a predetermined point approximately 10 inches from the end of the layout run which is at a predetermined one of termination sites 15 for the selected wire 16*a*.

Each of the feed tubes **22** is slidably disposed for vertical movement to different plunging and operating levels for inserting a respective one of the wires **16** in gripholes **40** and for operational layout movements over the wire harness form board **18** at different operating levels, e.g., wire laying levels No. 1, No. 2 and No. 3, as shown in FIG. **3**. Selective vertical movement and positioning of feed tubes **22** at these levels is provided by an actuator bar **36**. Tube guides **30***a* formed in the lower section **43** of the frame **30** guide the lower sections of feed tubes **22** which are biased upwardly by helical springs **38** having lower sections seating on the lower section **43** of frame **30**. Springs **38** bias respective feed tubes **22** into respective seats **46** formed in an opposing lower surface of upper frame section **41**. Annular end sections **37** of feed tubes **22** are secured to the upper ends of the tubing and sections **37** are formed to pass through respective tapered openings **45** in the actuator bar **36** to pass all but selected feed tubes **22**. As shown in FIG. **3**, the selected feed tube **22***a* is positioned in griphole **40** of one of the termination sites **15** by energization of the corresponding one of the solenoids **46** which positions the end of plunger **47** in an annular channel **48***a* in the end section **37** of feed tubes **22***a*. As a result, when the actuator bar **36** is lowered, only one selected feed tube **22***a*, for example, is lowered to plunge the end thereof into griphole **40**.

Thus, a selected one of the feed tubes **22***a* is lowered along with the actuator bar **36** in the bar's movement from the upper position, indicated by dashed line **36**', to the lower position as shown in FIG. **3**. In a wire layout cycle, the feed tube selection is made prior to lowering actuator bar **16**. Accordingly, only the selected feed tube **22***a* is lowered and the remaining feed tubes **22** remain seated in their respective seats **46** by the bias of the helical springs **38**.

As noted, the selected feed tube **22***a* is positioned by actuator bar **36** to locate the mouth thereof at any one of several operating levels during X–Y movements, indicated as wire laying levels No. 1, No. 2, No. 3 in FIG. 3 and also a lower-most position in which the mouth of the feed tube **22***a* is located in griphole **40** for securing the selected wire **16***a* at the desired termination site **15**. Positioning of the actuator bar **36** to a desired level is controlled by pneumatically actuated positioners or other suitable positioning devices (not shown) coupled to cables **48**. In a preferred arrangement the positioners for actuator bar **36** comprise a primary pneumatically operated positioner (not shown) which when actuated applies tension to the lower cable **48** to move the actuator bar **36** down from the top position **36**' to plunge the selected feed tube **22***a* into griphole **40**. Additional positioners are subsequently energized to return the primary positioner in increments to position the selected feed tube **22***a* to the desired operating level and at the end of the cycle to return the feed tube **22***a* actuator bar **36** to the initial position **36**'. As evident from the showing, the position of feed tube and actuator bar **36** corresponds to the location of the primary positioner.

In FIGS. 2 and 3, actuator bar **36** is shown secured to guide tubes **49** for limited vertical travel on guide posts **50**. As shown in FIG. 3, the downward travel of the actuator is limited by engagement of guide tubes **49** with shoulders on the guide posts **50**. Cam operated switches **51** and **52** (FIG. 2) disposed on either side of the actuator bar **36** are operated by respective cam surfaces to provide an indication of the extreme positions

of the actuator bar **36**. these positions are the return position as shown in FIG. **2** and the plunged position in which the mouth of the selected feed tube **22***a* in positioned in the griphole **40** as shown in FIG. **3**. Switches **51, 52** provide signals for the logic circuits for determining the location of the feed tubes prior to layout travel, for example. In this instance, switch **52** being operated, the logic signal would inhibit travel in the layout run because the feed tube has not been raised.

TERMINATION SITES

Referring to FIGS. **4** and **4***a* for a more detailed description of the termination sites **15** and gripholes **40**, a plurality of gripholes **40** are located at each of the wire termination sites **15** of the wire harness form board **18**. As described in connection with FIG. **1**, the wire harness form board **18** includes a plurality of wire termination blocks **15***a* located at respective termination sites **15**, a typical one of these blocks is shown in FIG. **5**.

A wire termination block **15***a* comprises a metal plate **52** which is secured to a baseboard **54** to firmly and uniformly seat the entire area of a layer **53** of resilient material, such as neoprene, against the opposing area of baseboard **54**. A uniform array of openings is provided in the plate **52** for gripholes **40** including a slit pattern formed in the resilient layer **53** and located coaxially over openings in the baseboard **54** as shown in FIGS. **4** and **4***a*. In the preferred embodiment as shown, the wire termination block is spaced from the work table **19**, as indicated in FIG. **3**, to accommodate the length of wire **16***a* which is paid out through the mouth of the feed tube **22***a* after insertion thereof into the griphole **40**.

An important feature of the present invention is the provision of the wire termination sites **15** having gripholes **40**, each of which is capable of receiving the end of a feed tube and retaining the end of the wire **16***a* upon withdrawal of the feed tube and against the force of tension applied to the wire during the layout between sites **15**. In the feed time period regulation of feed to maintain constant low wire tension is provided by frictional engagement of the wire **16***a* and the capstan **25** due to the tension exerted on the wire **16***a* during head movement in the layout of wire **16***a* in the harness pattern. Various parameters such as size and diameter of the wires **16**, type of insulating material on the wire and composition of the material of the resilient layer **52** determine the level of holding force of the griphole **40**. In general, the diameter of the wires, including the insulation, varies from 0.1 to 0.3 inches and the coefficient of friction between a neoprene layer **53** and the insulating plastic of a wires **16** should be adequate to retain the wires in the gripholes **40** when the feed tension is regulated to approximately two pounds or in the range of approximately one to three pounds, for example. The preferred slit pattern in the layer **53** is shown in FIG. **4***a* and provides for deflection of the radial sections thereof during plunging of the end of feed tubes **22** therein, and return of these sections during withdrawal of the end of feed tubes **22** to engage the plastic insulation of the wires **16**. The radial sections of layer **53** retain the end of the wires against the force of the tension applied to the wires **16** during feed and layout thereof in the harness pattern.

In the preferred embodiment, gripholes **40** were provided for insertion of a 0.125 inch diameter insulated wire (16-gauge) for example, by a feed tube **22***a*. Feed tubes **22** have an outside diameter of 0.250 inch and an internal diameter of 0.187 inch wherein the mouths of the feed tubes are tapered internally and externally to accomodate frictional engagement with the wires and layer **53.** In order to accommodate the plunging of the end of the feed tube into the gripholes, and provide for retaining the wires **16** upon withdrawal of the feed tubes **22,** the griphole openings are made substantially larger than the feed tubes **22***a* relying upon the thickness and the shoe of the neoprene layer **53** to retain the wires **16** in the gripholes **40** by the radial sections of the slit patterns in the respective gripholes.

Accordingly, for feed tubes having a 0.250 inch outside diameter, ½ inch diameter openings are provided in an aluminum plate **52** and baseboard **54**, and the slit pattern is located coaxially with respective concentric openings in the plate **52** and baseboard **54.** The diameter of the cut in the slit pattern can vary from the size of the openings to a lesser diameter of approximately 75 percent of the opening, and in a particular structural embodiment, the cuts of the slit patterns extended substantially across the openings of the respective gripholes **40.** The thickness and the hardness of the neoprene layer **53,** as well as the extent of the slit diameter, determine in part the gripping force produced on the wires **16.** The limitation on the retaining force provided by the gripholes to the wires **16** is primarily due to the need for insertion of the feed tubes **22** into the gripholes without damaging or bending the feed tubes, and preferably to facilitate ease of insertion and removal thereof while providing sufficient frictional force on the wires **16.**

The preferred slit pattern of gripholes **40** is shown in FIG. 4*a* which consists of six (6) radial sections formed by three cross cuts passing through the center of the gripholes **40.** Other suitable gripholes **40** have been formed by an H grid pattern, for example, in the neoprene layer **53** in which the cross bar of the H projects across the center of the griphole opening. The H pattern can be modified to provide a grid pattern H-H having additional cuts normal to the cross bar to facilitate passage of the end of feed tube **22***a* allowing for deflection of the individual sections of the grid pattern according to the location and diameter of the feed tube projecting into particular sections.

In general, the thickness of the neoprene layer **53** varied from ⅛ to ¼ inch in thickness having a shore hardness of **40.** A resilient layer **53** formed of neoprene of ⅛ inch thickness and having a shore hardness of **40** was preferred to provide for ease in insertion and withdrawal of the feed tubes **22** while providing more than adequate retaining force on wires **16.** In the testing of the griphole construction, it was found that with larger diameters of wire **16,** having the same insulation material, the larger the holding force for the same griphole construction. Also, it was found that with increasing thickness of a resilient layer **53** of neoprene, and the higher hardness or shore, the greater is the holding force, while the shape of the slit or grid pattern did not produce any significant change on the wire holding force value which varied from two to four pounds for smaller range of wire sizes, i.e., 0.125 inch or less in diameter.

Further it was found that a force of four pounds is required to plunge the end of feed tube **22***a* into griphole **40,** in a manner as shown in FIG. **3,** in which the layer had a ¼ inch thickness and a shore hardness of **40.** At a shore hardness of **70,** the force increased from four pounds to within the range of six to eight pounds with a radial slit pattern diameter of ⅜ inch in a ½ inch opening having a pattern as shown in FIG. 4*a*.

Further, it should be noted that the retaining force of the griphole **40** on the wire **16***a* does not vary with direction in which the wire is being fed, i.e., a pull exerted coaxially with the griphole or in a direction normal thereto, such as produced in movements of withdrawal of the feed tube **22** from a griphole or during travel parallel to the surface of the board **18.** Thus, the retention by the resilient material of layer **53** is directly related to the elasticity of the material and the coefficient of friction between the material of layer **53** and insulating plastic of the wire **16***a*. Preferably, the gripholes **40** are formed by an opening of minimum diameter suitable to accommodate the outside diameter of feed tubes **22** and tolerances required for positioning of the feed tubes coaxially with the opening. Assuming these latter conditions are satisfied, the maximum feed tension on a selected wire **16***a* while retaining the wire in the griphole **40** is independent of the amount of wire passed through the griphole, i.e., only sufficient wire must be passed through the pattern in layer **53** to provide engagement of the wire **16***a* with the engaging edges or surfaces of the material in the layer **53** in the pattern.

In an alternate arrangement of the present invention, the wire dispensing head **10** pays-out a length of wire out of the feed tube before plunging the end of any selected feed tube **22***a* into the griphole, and as a result, a loop of wire is retained by the pattern in the griphole **40** with the end of the wire **16***a* remaining above the form board **18.** Thus, if it is desired to provide for ends of wires **16** remaining above the board, pay-out of wire **16** past the end of the feed tube **22***a* precedes plunging of the end of the feed tube **22***a* into the griphole **40.** It should be noted that a loop of wire **16** is formed at the end of each run of wire **16** of the wire harness formed by either arrangement of the system of the present invention as described and illustrated by the preferred embodiment. Avoidance of loops or wire **16** at the end of layout runs is readily provided by more precisely cutting the wires **16** or providing for deeper penetration of the gripholes **40** at the end of each run to pull the end of the wires through the gripholes **40,** or both. No need presently exists for elimination of wire loops at gripholes **40** and accordingly, the preferred embodiment actually constructed produced wire loops at gripholes located at the end of layout paths of the harness pattern.

WIRE MARK SENSORS

Referring to FIGS. **6** and **7** for a detailed description of the wire detecting arrangement of the system of the present invention, each wire dispensing head **10** includes wiremark sensors **60** for each of the six (6) wires **16** as shown by the top view of FIG. **7** and by the front view of the head assembly of FIG. **2.** Referring to FIG. **6** for a detailed description of the wire-mark sensors **60,** the wire detection arrangement is indicated in the drawing by the plurality of differential amplifiers **62** coupled to a driver amplifier **64** (including a rectifier to provide a unidirectional output) and a typical one of six wire-mark sensing chambers **66.** The wire-mark sensors **60** perform two functions in the detection of the difference in output of upper and lower photodetectors **65** and **67** which are illuminated by a light source **68** located on the opposite side of the sensing chamber **66.** Each of the wire-mark sensors **60** detects a wire-mark **63** which consists of adjacent flattened areas of the wire **16***a* disposed normal to one another which produces a difference in light intensity at the photodetectors **65** and **67** when the mark passes photodetectors **65, 67.** Also each of the sensors **60** detects the end of a wire passing these photodetectors **65, 67.**

In operation, a difference in output of photodetectors, **65** and **67** in sensing chamber **66,** in response to a wire mark **63** on wire **16***a*, for example, will be detected by differential amplifier **62** having an output connected to the driver **64.** The signal output of amplifier **64,** in response to the difference signal at its input is represented in FIG. **6** by a pulse MS which is coupled to the logical circuitry **70** shown in the lower portion of FIG. **6.** The mark pulse MS is passed by an OR gate **69***c* via AND gate **69** which is enabled by a logical input OS_{30} from timing circuit OS30 which input is present during the mark detection period to trigger a timing circuit OS15 at input os_{15}. Circuits OS8, OS15, OS30 and OS31, i.e., one-shot timing circuits, define the pay-out interval at the beginning of each wire dispensing cycle wherein circuit OS8 is triggered by a signal *g***57** upon selection of a feed tube **22** and prior to plunging thereof to pay-out an 8-inch length of wire **16***a* into feed tube **22,** for example. The length of wire paid out during the period of circuit OS8 is less than the length of feed tube **22** but greater than the maximum downward travel of feed tube **22** to maintain the wire **16***a* threaded in feed tube **22***a*, for example.

After the end of the feed tube **22***a* is inserted into the griphole **40,** as shown in FIG. **3,** timing circuit OS30 is triggered to define a mark sensing interval in which an additional length of wire **16***a* is paid-out. The time period of OS30 provides for a maximum pay-out of 30 inches of wire **16***a*, for example, but circuit OS30 is reset when the wire-mark **63** is sensed and circuit OS15 is triggered to payout a maximum of 15 inches of wire from the time circuit OS15 is triggered. Timing circuit OS15 is triggered by mark pulse MS passed by a gate **69** enabled by the (true) output OS_{30}. During the time period of circuit OS15, the wire **16***a* is paid out to assure that an end portion of sufficient length projects out of the mouth of feed tube **22***a* for gripping by the layer **53** at griphole **40.** To provide for variances in location of wire-mark **63,** i.e., located in the length of wire paid out during the time. period of OS8, a flip-flop M2 is provided to store the mark pulse MS for later triggering of the circuit OS15, i.e., after the OS8 time period. Accordingly, a gate **69***b*, enabled by output OS_8, provides for passing pulse MS for storage by flip-flop M2 which is reset by output OS_{15}. The OR gate **69***c* passes pulse MS or the output of AND gate **69***a* to trigger the timing circuit OS15. The flip-flop circuits M1 and M2 and timing circuits OS8, OS30 and OS31 are triggered by the leading edge of the signal coupled to the set or reset inputs. Thus, upon detection of the mark pulse MS, an output OS_{15} is produced which extends the pay-out interval for a period sufficient to allow fifteen inches, for example, of wire **16***a* to be paid out of the feed tube **22***a* after detection of the wire mark **63.**

In order to detect the absence of a mark pulse MS during the maximum pay-out interval and the end of the wire **16***a*, logic circuit **70***a* is provided to interrupt the wire dispensing operations. In the event that the predetermined pay-out interval is passed for mark sensing, flip-flop M1 is set to provide a true output M_1 which interrupts operation of the wire dispensing head and system.

The maximum time period for wire-mark sensing is determined by timing circuit OS30 and at the end of the sensing period, circuit OS30 times out to produce output OS_{30}'. In the absence of a wire-mark pulse MS, outputs OS_{15}' and OS_{31} gate the output OS_{30}' to trigger flip-flop M1. A timing circuit OS31 provides an overlap in the mark sensing time period for gating output OS_{30}' and is triggered along with circuit OS30 by control signal *g***58** at the beginning of the wire sensing period.

In addition, the gates **73, 73***a* are provided to detect an output from amplifier **64** indicating the end of wire **16***a*, for example, passing through the sensing chamber **66,** i.e., a wire-mark **63** is not expected outside the mark sensing interval defined by output OS_{30} (and OS_8). As indicated previously, timing circuit OS15 defines the pay-out interval after wire-mark **63** is detected and a pulse output from amplifier **64** during this period of OS15 indicates the end of the wire, or a second wire-mark **63** has occurred erroneously. Preferably, the output OS_{15}, in response to a mark pulse MS, is delayed to avoid detection of an extended or double pulse output from amplifiers **63** when a single wire mark passes photodetectors **65** and **67.** Outputs of AND gate **73, 73***a* are passed by OR gate **72** to trigger flip-flop M1 to produce an output M_1 to terminate the wire dispensing operations. Thus, flip-flop M1 is set by outputs of gates **71, 73,** or **73***a* to terminate wire dispensing operations due to the absence of a wire-mark during the sensing period or due to the end of the wire passing through the sensing chamber **63.**

In order to maintain alignment of wire **16***a* in the sensing chamber **63,** a wire guide assembly is shown in FIG. **6** to comprise a flanged guide tube **74** seated in an opening in the top of the enclosure of the sensing chamber **66.** The upper, radial surface of the guide tube **74** is beveled at an angle of 20° relative to the radius for coaxial seating of a diaphragm **76** formed of a resilient material, such as neoprene, to provide resilient, frictional engagement with the wire **16***a*, as it passes through the guide tube **74** and into the wire sensing chamber **66.** A ferrule **75,** formed of nylon, for example, is retained in the position shown by a cap **77** having an annular channel for receiving the periphery of the ferrule **75** to maintain the rubber disphragm **76** deformed between opposing beveled radial surfaces of the guide tube **74** and ferrule **75.** A coaxial passageway is formed in the wire guide by center apertures including a protruding edge of the diaphragm **76** which frictional engages the periphery of wire **16***a* as the wire passes through the wire guide. The aperture of diaphragm **76** is cut at an angle of 30° relative to the axis thereof before deflection and the aperture formed therein has a minimum diameter of approximately 20 percent less than the outer diameter of the wire passing through the guide tube. This wire guide assembly provides for accurately aligning wire **16***a* in the interior of the sensor chamber **66** to position the wire **16***a* precisely along the longitudinal axis of the chamber to be centrally located along this axis which passes between the photodetectors **65, 67** and the light source **69.**

The frictional engagement of the diaphragm **76** with the periphery of the wire **16***a* passing therethrough is slight in the direction of the wire movement into the sensing chamber **66** while inhibiting reverse movement of backlash of the wire **16***a* to provide uniform movement of the wire coaxially through the sensing chamber **66.** As a result, the wire-mark sensor for wire **16***a* is not subjected to lateral movements or deflections of the wire **16***a* along the length of the wire in the chamber which would otherwise tend to produce undesired differences in outputs of the photodetector **65** and **67** due to deflections of the wire **16***a* from the axis of the sensing chamber while passing opposite these detectors.

FIG. 7 is a top view of the six (6) wire-mark sensors **60** for the six (6) wires **16** for the wire dispensing head **10** shown in FIG. **2** and **3**, a typical wire guide assembly having been described and shown in FIG. **6.** In the preferred embodiment of the invention, the wire guide assemblies for sensors **60** are removable and interchangeable to accommodate different ranges in sizes of wires **16** where the diaphragm **76** is approximately 20 percent smaller in diameter than the midrange diameter wire in a particular range. In the present arrangement, two (2) sets of wire guide assemblies were found adequate for accommodating different wire sizes for all wire harnesses in a particular industrial application wherein the most common wire size is 0.125 inch diameter including insulation for No. 16 gauge wire. The preferred shore of the neoprene diaphragm **76** is sixty (60) although neoprene in the range of 40 to 80 shore was found to provide many of the advantages of the invention for wire guiding in the assembly. The thickness of the diaphragm **76** is approximately 0.125 inch, i.e., including the range of thicknesses from 0.10 to 0.156 inches, for example. Another less common wire size in a smaller range of sizes in a No. 26 gauge wire having an outside diameter of 0.025 inch including insulation. In this smaller range of sizes, the diameter of wire was more common in the range of 0.025 to 0.30 inch.

The wires **16** can be either a strand or solid conductors of copper, aluminum or other electrically conductive material capable of being formed in the harness pattern. The insulation most common is a uniform thickness of solid plastic although woven glass threads or other insulating threads forming a woven insulation is suitable. A common insulation which provides the advantage of tolerance to heat is tetrafluoroethylene.

OPERATION

In operation, wire dispensing by the system arrangement of the present invention to form a cable harness, comprising a group of wires formed to a desired layout pattern, is preceded by loading respective heads **10** from spools **11** of preceded wires **16** and threading the wires from these spools to the cutting edge **33** of the cutter bar assembly **32.** Individual wires are passed through channels in the roller guide **26** and the capstan **25** including one or more loops around the capstan by each wire. After the wires **16** have been loaded in the respective heads **10** and the wire harness form boards **18** have been properly positioned on respective tables **19,** as shown in FIG. **1,** the heads **10** are positioned to locate the respective feed tubes **22***a* for the selected wires **16***a* above the first gripholes programmed in the harness layout. Initial positioning of the heads **10** and selected feed tubes **2** is programmed according to the tape or other record provided by the numerical or computer programmed control system. Assuming the tape or other record has been properly loaded into the control for system, the operator need only to press a start button which moves the tape to read the first block of the program. After the heads have been positioned over the first gripholes **40** of the programmed layout the tape is moved to read the next block of the program which includes selection of feed tubes **22***a*, for example, by actuation of the corresponding solenoids **46** as shown in FIG. **3** for one of the heads **10.** Prior to movement of the feed tube **22***a* downwardly into the griphole **40** for the head **10** shown in FIG. **3,** wire **16***a* is paid-out into feed tube **22***a* by energization of pneumatic actuator **35** which positions pinch roller **34** to engage and press wire **16***a* into channel **29** and against the continuously rotating capstan **25.** Actuator **35** retracts the pinch roller **34** after wire **16***a* is paid-out into feed tube **22***a* a sufficient distance to be retained therein when lowered to plunging position, e.g., eight (8) inches, in accordance with the prior description of control by the logic shown in FIG. **6.**

Continuing the description of the operation of only the dispensing head **10** shown in FIGS. **2** and **3**, the actuator bar **36** is then moved downwardly carrying the selected feed tube **22***a* to its lowermost position in which the lower end of this feed tube is positioned in griphole **40**, as shown in FIG. **3.** Wire **16***a* is again paid out until a wire-mark **63**, shown in FIG. **6**, is detected by the corresponding wire-mark sensor **60,** or until the end of the wire-mark sensing time period, as discussed more fully in the discussion of the wire-mark sensor **60** in FIG. **6** supra. Assuming the wire-mark **63** is sensed, wire **16***a* is again paid out for a predetermined time period, corresponding to a length of approximately 15 inches, for example, which assures that the end of the wire **16***a* extends beyond the end of the feed tube **22***a* and into the griphole **40.** The feed tube **22***a* is then withdrawn to any selected one of the wire laying levels, No. 1, No. 2, No. 3, as shown in FIG. **3** for example, by positioning of the actuator bar **36** by cables **48** connected to a primary positioner (not shown).

After the selected feed tube **22***a* has been positioned at the proper one of the operating levels No. 1, No. 2, or No. 3, depending upon the amount of clearance needed to pass over previously laid wires, if any; the wire dispensing head **10** is moved along the desired path towards a termination site **15** laying the selected wire **16** along the programmed path of the wire harness pattern. For example, as shown in FIG. **1**, the movement of the head **10** parallel to the wire harness form board **18** follows a path from a termination site **15** to lay the wire **16***a* via the retainers **17** and then to the wire terminating griphole **40** at one of the termination sites **15** at the other end of the board. Accordingly, wire dispensing head **10** is controlled to be moved at the selected wire length level from point to point or along a contour in order to follow a predetermined path between termination sites **15** (and gripholes **40**) for the selected wire **16***a*.

Also, during the feed interval, the wire dispensing heads **10** are controlled to maintain a fuel tension at a level which does not exceed the retentive force of gripholes **40.** Further, the regulated tension is maintained sufficiently low to insure that no damage occurs as the wires **16***a* passes out of the rounded or tapered mouths of the feed tubes **22***a*. Regulation of feed tension at a constant level is maintained by wire-wraps around the rotating capstans 25 of the respective head 10. If the feed tension exceeds the desired level, the wire-wraps around the capstans become taut engaging the knurled surface in the bottoms of channels 29 of capstans 25 to produce positive feed to assist movement of the wires from the capstans into the feed tubes 22a. It is important to note that the capstans operate in the feed mode when the wires are being positively fed during the fed interval as contrasted with the pay-out interval in which the pinch rollers 34 are moved into actuated position to produce engagement of the selected wires 16a with the respective knurled surfaces of the capstans during the pay-out interval at the beginning of the wire dispensing cycle. Further, the knurled surface is only one form of providing sufficient frictional engagement of the wire 16a with the capstan 25 to provide the positive feed or pay-out of the wire 16a to provide pay-out or regulation of tension at a constant desired level of tension. Other surfaces providing frictional engagement and capable of withstanding a high degree of abrasion or wear over long periods of time under these conditions are suitable.

At the end of each individual wire dispensing cycle of the wire 16a, for example, feed tube 22a is again inserted into a griphole 40 at the "end of the run" termination site 15 to secure the end of the wire 16a in the latter griphole 40 for retaining both the end of the wire and the length of the wire and in the wire harness pattern. After insertion of the wire 16a in the latter griphole 40, the feed tube 22a is retracted by actuator bar 36 to the position shown in FIG. 3 by dashed line 36'. Solenoid 46 is then de-energized to complete the wire dispensing cycle. The wire dispensing head 10 is then moved to the next griphole 40 and the next selected feed tube 22 is positioned in the following programmed griphole 40 to dispense the desired wire 16 in the wire harness layout pattern.

In the light of the above teachings of the preferred embodiment disclosed, various modifications and variations of the present invention are contemplated and will be apparent to those skilled in the art without departing from the spirit and scope of the invention. For example, it is anticipated in accordance with the foregoing description that dual dispensing head 10 are operated concurrently and in parallel to produce two cable harnesses in a single cycle. Alternatively, the program for the individual cable harnesses can be employed to set up form boards 18 by substituting a tool on one end of the boom 14 for a dispensing head and forming openings for gripholes 40 and also for placement of retainers 17 on the board 18. Since the locations of the gripholes 40 is recorded on the programmed tape, boards 18 can be readily set up on the same work tables and control equipment. Further, it is contemplated that the cable harness be formed in three dimensions by providing control of movement in 3 axes or 5 axes, although such need rarely exists due to the flexibility of cables for electronic and electrical equipment. For heavy conductors for high power transmission in interconnections is uncommon and forming in 3 dimensions can usually be accumulated more readily by forming after planar layout. These and other variations of the preferred embodiment of the invention are readily apparent in view of the foregoing disclosure. Further, it is readily apparent that the invention is not limited to dispensing of wire but is equally capable of dispensing strand materials including, but not limited to fibers, fiber optic material, tubing, and other strand materials or variations thereof.

What is claimed is:

1. A strand detection arrangement comprising:
means for detecting the profile of individual portions of a length of strand material to produce corresponding output signals, means for moving said strand and means for comparing said output signals for detecting changes in profile of said strand material in which said strand material includes portions deformed in a predetermined manner marking predetermined sections along the length of the strand.

2. The strand detection arrangement according to claim 1 in which said strand material comprises insulated wire having predetermined sections along the length marked by deformed portions.

3. The strand detection arrangement according to claim 2 in which said deformed portions comprise flattened areas formed for marking predetermined sections along the length of the strand material.

4. The strand detection arrangement according to claim 3 in which a single deformed portion comprises adjacent flattened segments in which the planes of the flattened segments are displaced about the axis of the strand material.

5. A strand material detection arrangement comprising:
means for passing said strand material, said strand material including portions deformed in a predetermined manner marking predetermined sections along the length of the strand;
a triangular detection area for axially passing a length of strand material for scanning the profile thereof, said area being located between oppositely disposed detection elements including a source of light disposed on one side and a plurality of photodetectors disposed opposite thereto in opposing relation thereto to receive light passing around a portion of the strand material passing through the area, a plurality of said photodetectors being disposed along a line parallel to the axis of the portion of strand material in the area;
said plurality of said photodetectors disposed along a line and being spaced to received light around adjacent segments of said portion of strand material in the area;
differential means coupled to said spaced photodetectors to be responsive to detected different levels of received light by said spaced photodetectors to produce an output signal indicating a change in profile of the portion of strand material located in said area.

6. The strand material detection arrangement of claim 5 in which said strand material comprises insulated wire having at least temporary deformable insulating material which is flattened to provide a change in profile.

7. The strand material detection arrangement of claim 5 in which said means for passing includes alignment means including means for restricting the direction of passing the length of strand material through the area.

8. The strand material detection arrangement of claim 7 in which said means for passing includes control means coupled to said differential means and responsive to said output signal for feeding sections of predetermined length.

9. The strand material detection arrangement of claim 8 in which said control means includes timing means for providing timing signals after said output signal and said control means further includes means for interrupting feeding of the strand material in response to an output signal and a timing signal.

10. The strand material detection arrangement of claim 5 in which the spaced photodetectors detect different levels of light upon scanning the end of a length of strand material and control means are provided for disabling said feeding means in response to detection of the end of said strand material.

11. The strand material detection arrangement of claim 5 in which means are provided for indicating a predetermined interval including a change in profile of the strand material and control means responsive to the passing of said predetermined interval without detection of a change in profile to provide an output for interrupting the feeding of said strand material.

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