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Mercer

[11] **3,842,496**

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[54] **METHOD AND APPARATUS FOR SEMIAUTOMATICALLY MANUFACTURING ELECTRICAL WIRE HARNESS**

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[52] **U.S. Cl.** ..... **29/624,** 29/203 B, 29/203 P, 140/71 R, 174/72 A, 317/122

[51] **Int. Cl.** **H01b 13/00**

[58] **Field of Search** ..... 317/99, 122; 174/72 R, 174/72 A, 72 TR, 112, 117, 146; 29/624, 203 MW, 203 B, 203 P, 407; 140/92.1, 140, 112, 71 R

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[57] **ABSTRACT**

A method for assembling electrical wire harnesses of the type used to interconnect electrical components on aircraft is initiated by applying identifying indicia to several portions of a continuous wire and marking the termination point of each of the wire portions in a predetermined sequence along the continuous wire. The continuous strand is then respooled and placed on a numerically controlled wire laydown machine. The machine lays down the individual wire portions in a predetermined sequence along a predetermined path on a formboard prepared for that purpose. The machine also severs the continuous wire to produce individual wires as they are being laid on the formboards. Means are provided on the formboard for holding individual wire ends at a predetermined location on the formboard near the termination point for the predetermined wire paths. Certain of the individual wire ends are retained on the formboard in several groupings each of which is in an ordered array. The several groups of wires are then tied together a spaced distance from the ends of the groups, forming a harness skeleton. Wire order retention devices are then applied to the individual wires in a grouping to retain the ordered array of the segment end when the harness skeleton is removed from the formboard. Thereafter the individual wires are removed from the formboard and identifying indicia applied to each of the groupings. Thereafter, the harness skeleton is taken to another processing zone in which electrical insulation is stripped from the ends of the individual wires and pin-type connector contacts are applied or fastened to the wire ends. The pin-type contacts are inserted into preselected sockets in a multi-plug type connector by selecting an individual wire from a particular wire order retention device and inserting it into the appropriate socket. Thereafter subsequent wires are removed from the wire order retention device in the predetermined order and inserted into preselected sockets in the connector. The harness and an appropriate subassembly, if any, are then placed on a test apparatus to determine quality, continuity and correctness of assembly of the wire harness. Thereafter the wire harness and subassembly if any can be installed on an aircraft.

25 Claims, 7 Drawing Figures

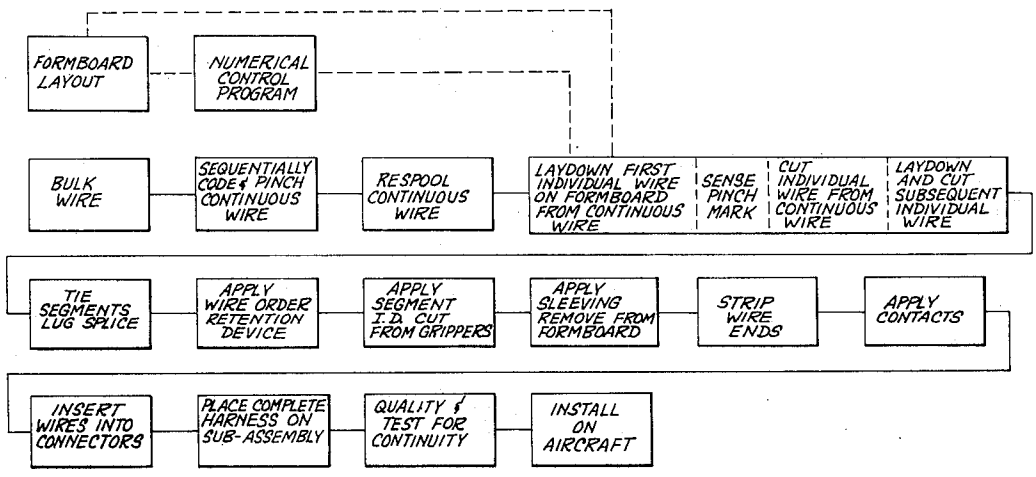
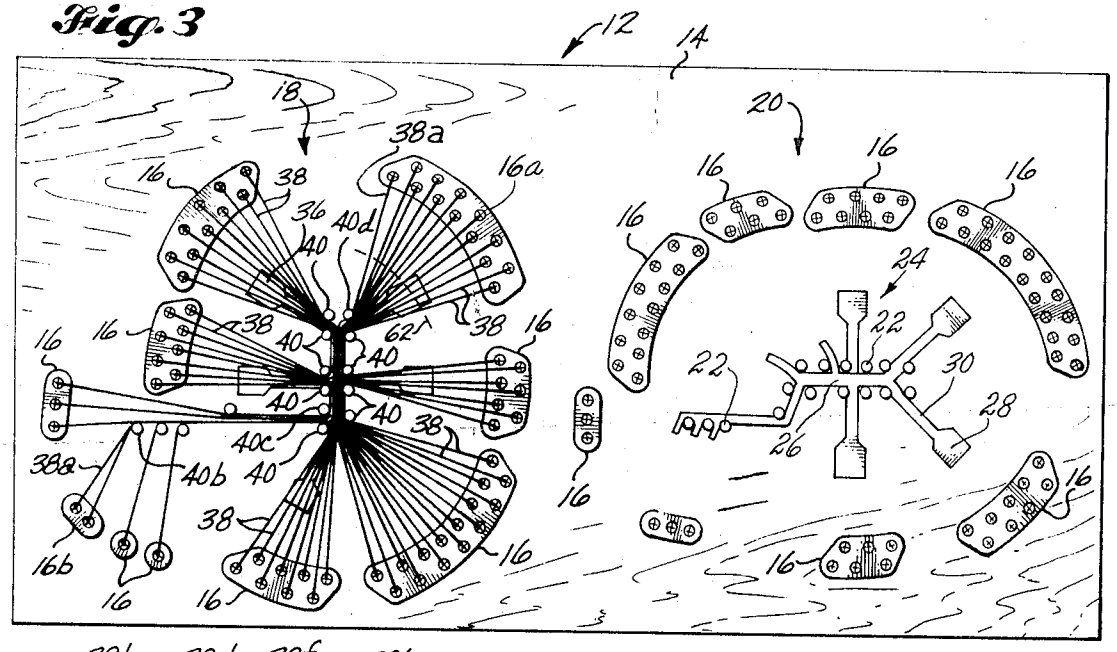


Fig. 1

Fig. 4

Fig. 5

Fig. 3



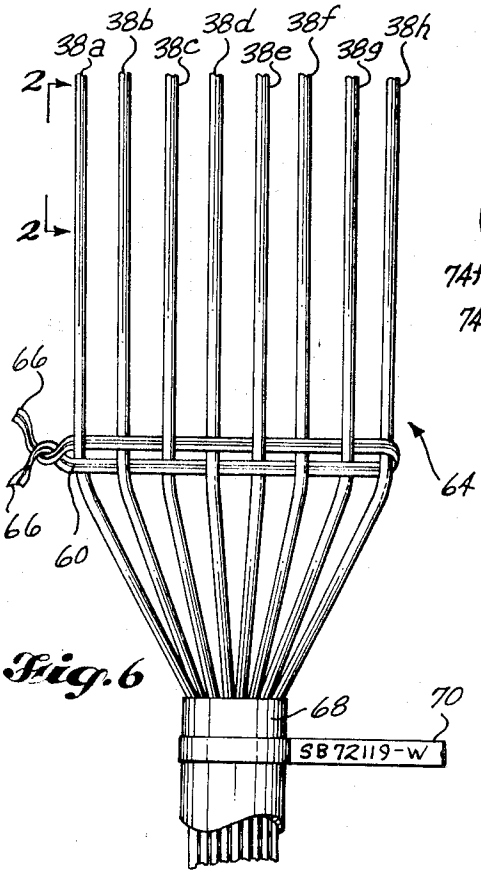


Fig. 6

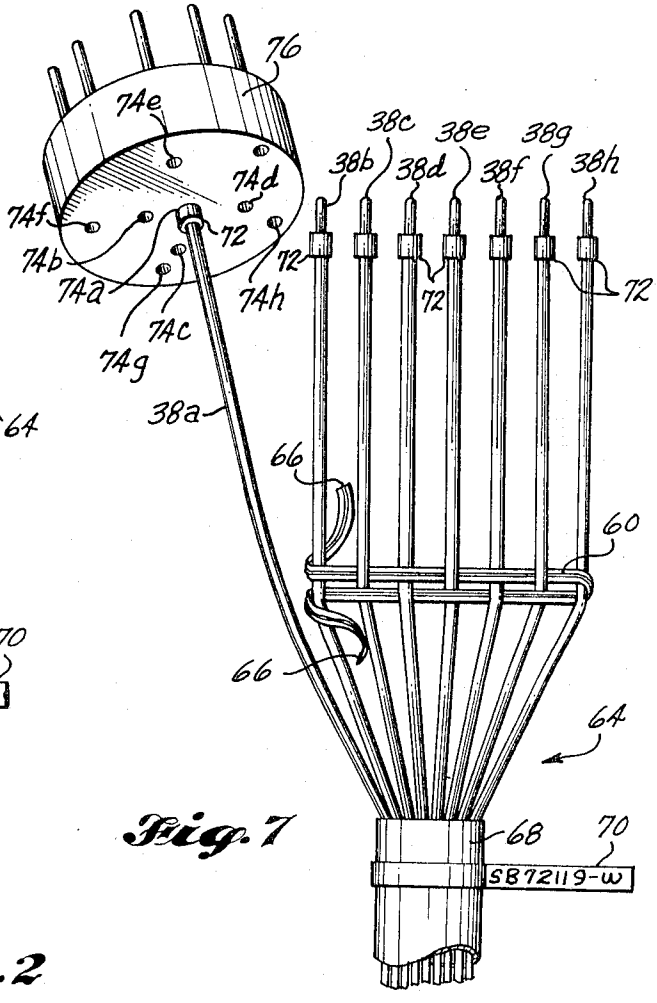


Fig. 7

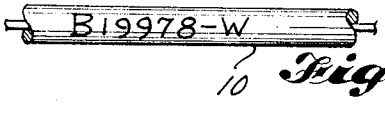


Fig. 2

METHOD AND APPARATUS FOR SEMIAUTOMATICALLY MANUFACTURING ELECTRICAL WIRE HARNESS

BACKGROUND OF THE INVENTION

The present invention relates to a method for assembling electrical wire harnesses, to a formboard for use with the method, and to a wire order retention device.

An electrical wire harness, as the term is used herein, is typically a bundle of wires of varying gauges and wire types arranged in a particular order. Ends of individual wires in the wire harness are grouped into segments and can be connected to multiple-plug type connectors. If desired, certain groups of wires can be spliced together or lug-type contacts applied to the wire ends. Wire harnesses are typically bound together as by tying to facilitate installation and replacement of wire harnesses. Such harnesses are utilized to interconnect the various electrical components and subassemblies in commercial and military aircraft and the like. Wire harnesses of this nature are also utilized to interconnect electrical systems in automobiles and trucks, to interconnect computer components, and in other relatively complex electrical devices requiring a large number of external leads. A typical wire harness utilized in aircraft manufacture has an average of eight connectors per harness and at least one segment end containing wires to which electrical splices have been made or to which lug-type contacts have been applied. Typically, an average of five different wires types and gauges are used in a harness. An average of 100 wires per harness and 28 wires per segment end are encountered. In addition, the harness can contain twisted pairs of wires and sometimes very large gauge wire greater than the typical diameters ranging from 0.047 inch to 0.084 inch.

Most users of wire harnesses of the type outlined above form the wire harnesses in a generally conventional sequence and manner. Typically, the large percentage of the work necessary to manufacture such wire harnesses is tedious, time-consuming labor, requiring continuous attention and perserverance.

In conventional fabrication bulk wire is removed from large spools and routed through a semiautomated coding machine. The coding machine applies alphanumeric indicia by printing on the insulation of the wire at spaced intervals along the wire. Individual wires of a predetermined length are then cut from the continuous bulk wire after it has been coded. Coding machines of this type are generally operated by numerical control from punched cards or tape. The machine is programmed to produce all of the individual wires needed for a wire harness of a particular gauge or type. Such machines can handle wires of different gauges and types.

After all of the individual wires of varying gauge and type have been coded, they are placed in a tote box in no particular order and transferred to the next processing station. At the next station an individual visually searches through the large number of wires and groups them according to segments which will form a part of a final harness.

After the wires are grouped by segments, they are forwarded to the next station at which the individual wires on one end of a segment are stripped, i.e., the electrical insulation is removed from the end of the individual wires. Pin-type contacts are then applied to the stripped ends of the wires and the segments are again transferred to the next station. Connectors of the multiple contact type are fitted to the pins on one end of the segment. Here again, the worker must visually search through the wires to identify by the coding indicia each individual wire since each individual wire must be placed in the proper socket in the connector. Here again the searching for and sorting of individual wires is time-consuming and is susceptible to introduction of an error factor.

After the plugs have been applied to one end of the segment, all segments which will form a single wire harness are routed to the next fabricating station where they manually are laid down on formboards. Generally, formboards are prepared by outlining a particular wire harness on a large sheet of, for example, plywood. Forming pegs are then inserted into holes drilled in the formboard at appropriate locations to facilitate the routing of wires of any individual segment. To route wires on a formboard the connector from a first segment is placed at the appropriate location on the formboard. At this point in the conventional fabrication the worker must again sort through the individual wires of a segment, identify each by its codified indicia, and route it through the routing pegs to the appropriate segment terminus for that individual wire. This process is repeated for each of the segments which will make up the harness. Since the typical segment contains many wires and the typical harness contains about eight connectors or segment ends, error can be introduced at this point in the conventional fabrication not only by incorrectly identifying an individual wire but also by incorrectly routing the wire on the formboard. In addition, this fabrication stage is tedious and time-consuming.

After all the connected segment ends have been placed on the formboard and the individual wires of each of the segments routed to their appropriate termini on the formboard the harness is bound together in a conventional manner by wrapping cordage or other tying material around the central portion of the harness and tying it. The ends of the segments are cut to length and bound together a spaced distance from the end of the unconnected segments. Lug-type terminals and splices in the harness are then applied by again searching for the appropriate individual wires to be spliced together or to which lug-type connectors are to be applied. Identification tags are then applied to each one of the segments and to the harness as a whole. Sleeving is then applied to the formed harness after which the harness is removed from the formboard and transferred to the next fabrication station.

At this fabrication station the individual wires of the unconnected segments are stripped and pin-type contacts are applied. Thereafter the pin-type contacts in each segment must again be inserted into appropriate sockets in a multiple plug-type connector. To accomplish this the worker must again sort through each individual wire in a segment end, identify it by the codified indicia on the wire, refer to a specific chart for a given connector and insert each one of the pin-type contacts on the individual wire into an appropriate socket in the connector. Here again the need for search and identification of each individual wire is a tedious, time-consuming job which provides for additional op-

portunity to introduce error into the harness forming process.

The harness is thereafter installed on a subassembly and placed on a testing machine where the correctness of formation as well as quality, continuity and other electrical tests will be made. According to present technology this testing is performed in a semiautomated manner according to a preprogrammed numerically controlled operation. If the harness passes all the requisite tests it is then ready for installation on the equipment with which it will be used.

Both numerical and digital computer control have contributed toward automation in electronic manufacturing. Automated wire harness manufacture has, however, been difficult to effectuate. A number of reasons exist for this difficulty, among which are the following. Wire harnesses are often fabricated according to a customized requirement for an individual user. Frequently the configuration of wire harnesses are changed to accommodate new electronic features in the equipment with which it will be used. As outlined above, each harness contains a multiple of wire types and gauges as well as a variety of wire lengths. For many applications coding of each individual wire is required regardless of its use. Electrical wire is a difficult medium to manipulate other than by hand. Due to the foregoing factors, the lead time and captial expenditure necessary to completely automate wire harness fabrication is in most cases economically unjustifiable. In addition, there has been a reluctance throughout the industry to change present manufacturing methods in reliance upon unproven automated procedures.

It is an object of this invention, therefore, to provide a method of fabricating electrical wire harness which will provide the feasibility and economic justification to at least partially automate such fabrication.

It is another object of the invention to eliminate most of the tedious and time consuming searching, sorting, and handling procedures for individual wires in the harness. It is a further object of the invention to reduce the amount of time necessary to route the individual wires on a formboard. It is a further object of the present invention to substantially reduce the amount of time necessary to insert the connectors on individual wire ends into multiple plug-type connectors. An additional object of the invention is to reduce the overall process flow time needed to produce an individual wire harness, thus cutting the lead time and creating the ability to incorporate last minute changes into a particular harness. An additional object of the invention is to reduce the in-process inventory thus reducing capital investment in the wire harness fabrication portion of a production operation.

It is a still further object of the present invention to improve the reliability, quality and finish of wire harnesses. A related object of the invention is to eliminate much of the possibility of error introduced by manual manipulation in the fabrication process. Another related object of the present invention is to reduce manpower requirements for the production of individual wires.

SUMMARY OF THE INVENTION

The present invention therefore provides a method for assembling electrical wire harnesses comprising: marking an elongate wire at predetermined points along its length to indicate severing locations for individual wires, laying a first individual wire from an end of the elongate wire along a predetermined path on a formboard, severing the elongate wire at a first of the predetermined points before laying the next subsequent individual wire from the elongate wire, repetitively laying subsequent individual wires each along a predetermined path and severing the elongate wire at a subsequent of the predetermined points before laying a next subsequent individual wire, retaining the ends of an individual wire on the formboard near the termination of the predetermined path, selecting ends of certain ones of individual wires to form a harness segment end, attaching the individual wires on a harness segment end to a connector.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the present invention can be derived by reading the ensuing specification in conjunction with the accompanying drawings wherein:

FIG. 1 is a flow diagram of the steps of a preferred method of the present invention for assembling electrical wire harnesses,

FIG. 2 is a portion of an individual wire showing the codifying indicia applied thereto;

FIG. 3 is a plan view of a formboard prepared for the production of two individual wire harnesses showing a wire harness skeleton at one location on the formboard;

FIG. 4 is an enlarged detailed plan view of a wire end hold-down device incorporated into the formboard of FIG. 3;

FIG. 5 is a cross-sectional view of FIG. 4 along section 5—5;

FIG. 6 is a pictorial view of a harness segment end containing individual wires in an ordered array to which a wire order retention device has been applied; and

FIG. 7 is a view of a harness segment end containing individual wires to which pin-type contacts have been applied and showing the use of the wire order retention device in inserting the contacts into the appropriate sockets in a multiple-plug connector.

DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 is a flow diagram of a preferred method of wire harness fabrication in accord with the present invention. Referring to the flow diagram, bulk wire of a first gauge and type is unwound from a spool and fed to a numerically controlled coding and marking machine. The coding machine prints identifying indicia at spaced intervals on the insulation of a continuous length of the electrical wire fed to it. Usually the indicia are applied by a printer using an indelible ink which will permanently imprint the indicia on the synthetic polymeric insulation normally used for electrical wiring. An example of the type of indicia used is shown in FIG. 2 as the letters "B19978–W." Typically this coded identification will identify an individual wire within a harness and will additionally relate the particular wire to an individual plug or connector.

The continuous length of wire of a first gauge and type is divided by marking individual portions of predetermined length, each of which will become an individual wire in the harness and each of which contains the identifying indicia peculiar to that particular individual wire. In accord with the preferred embodiment of the invention, the individual wire portions are divided by

applying a pinch mark, that is, physically deforming the wire insulation at the end of each of the individual portions. As will be understood more fully below, the dividing mark is capable of either being visually or preferably machine-sensed at a later step in the harness fabrication process. The individual wire portions are coded and marked in a predetermined sequence according to a master plan or program fed to the numerically controlled machine. After the continuous strand of wire of first gauge and type has been sequentially coded and the individual portions thereof marked, the continuous strand is cut at its end and is respooled on a small holding spool. Typically, all wire portions of the first gauge and type necessary for a single harness are coded and marked in a single run. It is, of course, to be understood that individual wire portions for a plurality of like harnesses or for a plurality of different harnesses can be coded and marked on a single continuous strand.

Thereafter, a continuous strand of wire of a second gauge and type is fed to the coding machine for coding and marking of individual portions necessary for the production of one or more harnesses. The sequence of marking and coding of the second strand is also dependent upon the predetermined master plan and program. After all the wire portions of the continuous strand of second gauge and type have been coded and marked, the strand is rewound onto a holding spool. Since a typical wire harness contains about five different types and gauges of electrical wire, all of the single strand wires necessary for fabrication of a particular harness are thus coded, marked and rewound on a holding spool. In the preferred embodiment only wires of small gauge (for example, 0.047 inch to 0.084 inch) are coded and marked on the coding machine. Large gauge wire and twisted pairs are separately prepared. This limitation is due primarily to the mechanical limitations of present coding machines. It is to be understood however that any large gauge or necessary twisted pairs or the like necessary for the fabrication of a particular harness could be processed in a manner similar to the continuous strands above.

The individual holding spools containing the continuous strands of premarked and coded wire are then placed on a numerically controlled wire routing machine. This machine pays out wire from a first of the holding spools and lays it down on a formboard. The individual portions of the continuous strand of the wire are laid down or routed along a predetermined path on the formboard. This path is dependent, in part, upon the final configuration of the wire harness being assembled. The machine senses the marks along the continuous strand which divide the strand into individual portions. It then automatically severs the individual portions from the continuous wire strand forming individual wires. All of the individual wires are sequentially laid down and cut from the first continuous strand of wire. Thereafter, this procedure is repeated by withdrawing a continuous strand of wire of different gauge and type from a second holding spool. The individual portions are then laid down and severed from the continuous strand in the predetermined sequence. This procedure is repeated until all the wires of varying gauges and types are routed on the formboard. If there are any large gauge wires or any twisted pairs, they can now be manually laid on the formboard along the path predetermined for them.

In the preferred embodiment the numerically controlled wire routing machine operates from a predetermined program introduced by punched cards or tape into the machine with proper input circuitry and mechanism. The input program, of course, is properly implemented by suitable known mechanism including feedback circuitry to locate and sever the ends of individual wire portions on the continuous strand.

The actual sequence in which the continuous wire strands are coded and marked, and consequently, the sequence in which the individual wires are laid down, is determined in large part by the initial design and layout of the formboard utilized with the present method. The ultimate design of the formboard is dependent upon the particular wire harness being fabricated. Among the factors which are considered when designing the formboard, and thus the predetermined plan or program to be utilized to numerically control the coding and routing machines, are the final wire harness configuration, space requirements of the formboard, limitations in the routing mechanism of the routing machine, proper placement and separation of the groupings of individual wire ends which will form segment ends, and allowances for sufficient wire lengths required for handling in downstream operations.

Referring to FIG. **3** a preferred formboard for use with the present invention is illustrated and generally designated by the numeral **12.** Formboard **12** is made from a sheet **14** of plywood or other suitable relatively rigid material. In the preferred embodiment the formboard is of rectangular configuration having a width of three feet and a length of six feet. The formboard **12** includes wire end hold-down devices **16** for two different harness assemblies. One harness assembly **18** is shown. The location for laying down a second harness assembly is generally designated **20.** It is to be understood that for larger harnesses an individual formboard will be prepared for a single harness assembly. With reference to the harness assembly location **20,** the formboard **12** further includes a plurality of routing pegs **22** at predetermined locations across the surface of the formboard **12.** The routing pegs normally extend about three inches above the formboard surface. A photo-silhouette **24** or other suitable facsimile of a completed wire harness is also printed upon or otherwise applied to the surface of the formboard. As is apparent the photo-silhouette shows the trunk **26** as well as an outline of connectors **28** on the ends of the various segments **30.** Other of the segment ends **30** are not shown with connectors since the wires forming these segments will either be spliced or will be attached to lug-type connectors.

As shown with reference to harness assembly **18,** the photo-silhouette **36** corresponds in location to the plurality of wire end hold-down devices **16.** Each one of the segment ends illustrated in conjunction with the silhouette **36** represents the plurality of wires **38** which combine to form the segment end. A plurality of individual wires **38** are shown lying on the formboard **12** in connection with harness assembly **18.** It will be noted that the wires **38** generally follow the outline of the silhouette **36.** Individual wires **38** which make up a particular segment end are laterally confined between two routing pegs **40** and are spread in an array toward a corresponding hold-down device **16.** Wires **38** forming a particular segment end are in a stacked and a side-by-side relationship as they pass through the routing pegs

40. However, in the preferred form of the invention, as they approach the hold-down devices **16** they are spread into a spaced substantially planar array.

A preferred wire end hold-down device **16**a is shown in FIGS. **4** and **5** in plan and in cross-sectional views, respectively. The hold-down device **16**a is positioned on the surface of the base sheet **14** above a plurality of apertures **42** thereon. A first layer **44** of a resilient material such as a natural or synthetic elastomer is positioned on the base sheet **14.** Crossed cuts or slits **46** are then made in the elastomeric material **44** which are aligned with the apertures **42** in sheet **12.** A metallic cover plate **48** is positioned on top of the elastomeric layer **44** and is fastened to sheet **14** by means of screws **50.** As illustrated, a plurality of wires **38** extend from the routing pegs **40** (FIG. **3**) out to the hold-down device **16***a*. The ends **54** of the wires are passed through the slits **46** down into the aperture **42.** Since layer **44** is an elastomer and has a high coefficient of friction, the wire ends **54** are held in place by frictional forces. Wire ends **54** can be inserted through slits **46** either manually, or as in the preferred mode by a numerically controlled routing machine.

Referring back to wire harness assembly **18** in FIG. **3,** an individual wire **38***a* can be routed from hold-down device **16***b* around routing pegs **40***b*, **40***c*, **40***d* to the second hold-down device **16***a*. The path prescribed for wire **38***a* between hold-down device **16***b* and hold-down device **16***a* is predetermined dependent upon the particular needs of the wire harness being fabricated. The length of the wire **38***a* also of course is predetermined dependent upon the length of the route or path which it must follow on the formboard **12** to reach the respective slits **46** in each of the hold-down devices **16***a* and **16***b* and be retained therein. The order in which the remainder of the plurality of wires **38** are laid down is dependent upon the predetermined path of each of the wires **38** in the harness assembly **18.** The factors which aid in determination of the particular path in the preferred mode of operation include optimization of the total path which the payout apparatus for the continuous wire in the numerically controlled routing machine must follow, as well as which particular gauge and type of wire the machine is laying at a particular time. In the preferred mode of operation, all of the individual wires of the first gauge and type are laid in a predetermined sequence dependent on the above factors, followed by laying wires of a second type and gauge, and so on. Although, changing gauge and type at any time is possible. It will now become apparent that the sequence in which the continuous wire of the first gauge and type was marked and coded is dependent upon the sequence in which the individual wires are laid. Thus the sequence of laying down and the path which the programmed routing machine must operate and the sequence of coding and marking of the continuous wire are interdependent. It will furthermore be apparent that the initial step which precedes the programming of the coding, marking and routing operations is the design and layout of the formboard itself.

The generation of a numerical control program for this portion of the wire harness assembly begins with the documentation which describes a selected harness. This data would include the different wire gauges, types, part numbers, wire lengths and routing information as well as particular connector specifications. From these specifications a programmed punched card deck or the like can be prepared indicating the necessary wire specifications for each of the individual wires. From an initially preassembled mockup of a wire harness a photo-silhouette is generated. The configuration of the photo-silhouette is specifically determined for optimum utilization of machine lay-down on a formboard. Typical examples of the photo-silhouettes are shown in FIG. **3** as silhouettes **24** and **36** belonging to harness assembly location **20** and harness assembly **18,** respectively. From the foregoing a numerical control program can be developed for routing of the wire and for locating the routing pegs and hold-down devices. The numerically controlled lay-down machine can include an attachment which will automatically drill the apertures (such as **42** in FIG. **5**) in the formboard **12** to provide necessary clearance for the wire end below hold-down devices **16.** A program for drilling can also be generated from the foregoing information.

When a particular harness is to be fabricated, the formboard thus produced is aligned on the numerically controlled routing machine. The precoded and premarked wires of various gauges and types which have been stored on the holding spools are then selected in proper sequence and loaded on the numerically controlled routing machine. The individual wires, such as **38** in FIG. **3,** are routed from a first hold-down device to a second hold-down device. Likewise all remaining wires of a particular gauge and type are laid down. Thereafter a wire of second gauge and type is selected and the lay-down machine automatically routes the individual wires formed from the continuous wire of second type and gauge. This procedure is repeated until all the precoded and premarked wires necessary to fabricate a particular harness are laid down. Thereafter, if desired or if necessary, specialty wires such as twisted pairs or very large gauge wires can be laid down or inserted on the board by hand.

At this point a harness skeleton including all the electrical wires which will make up the particular harness have been laid down on a formboard. All of the ends of the wires are retained on the formboard in the wire hold-down devices a spaced distance from each other. Each one of the segment ends included in the harness have been identified and segregated from the other. As can be seen by viewing the harness skeleton of assembly **18,** FIG. **3,** the individual wires **38** extend a distance beyond the end of the photo-silhouette of the harness. This extra wire length provides working handling room for future operations.

After the foregoing operations are complete, the formboard is removed from the numerically controlled routing machine and transferred to another processing station. At this station an operator will tie the particular wires of each segment end of the main body of the skeleton together in a bundle to prevent them from separating. Tying in this manner will form the final wire bundle for at least the central portions of the harness. At this station the operator will also strip the ends of preselected wires and apply lug-type connectors to preselected wires while the harness skeleton remains on the board. In addition, clamp-type splices can be applied to connect certain of the wires together to create an electrical contact between a plurality of individual wire ends in the harness. The individual wires are selected by an operator from a chart prepared from the original harness design information supplied to lay out the formboard. In this operation some visual and manual

searching and sorting is required. However, this is the only such searching and sorting required in the entire process as presently envisioned.

Referring briefly to FIGS. **4** and **5**, it will be noted that the individual apertures **52** of each of the hold-down devices **16** are spaced at a sufficient distance from each other to allow each of the individual wires **38** to be spaced from each other. For example, the lateral spacing of each wire can be on the order of from one-fourth inch to one-half inch at a position near the wire hold-down devices. A particular sequence of wires from left to right is manifested on the board from the original programmed routing information. This sequence is important to the next stage of assembly. The ordered sequence of wires **38***a* through **38***f* can be visualized by numbering each of the apertures **52** in sequence, **52***a*, **52***b*, **52***c*, **52***d*, **52***e* and **52***f*, respectively. An individually coded, identifiable wire **38***a* has been inserted in the particular aperture **52***a*. Likewise another individually coded wire **38***b* has been inserted and retained in aperture **52***b*, and so on down the line under an ordered sequence **38***a*, **38***b*, **38***c* . . . has been formed for each of the segments of a particular harness **18.**

Referring to the next operation a wire order retention device is applied to all wires in each of the particular segments prior to removing the harness skeleton from the board. In FIG. **6** the wire order retention device or strap **60** is applied to the individual wires **38** in a segment end **64.** In a preferred embodiment of the invention the wire order retention device **60** is composed of a plastically deformable material. For example, the wire order retention device **60** can be a strap composed of two strips of paper laminated on each other with a small steel wire running between the laminations. Such a device is commonly used for twist-tying bread wrappers and the like. The two ends **66** of the retention strap **60** are woven alternately and oppositely through the wires **38** of segment **64,** beginning with the first wire **38***a* in the array. After one end of the retention strap **60** has been woven through all of the wires **38***a* through **38***h*, the other end of the strap **60** is wrapped around wire **38***h* and rewoven through wires **38***h* through **38***a*. Then the ends **66** of the strap **60** are twisted together. Thus as shown in FIG. **6** all of the wires **38** are retained in an ordered array predetermined by the order of the apertures **52***a* . . . in the hold-down device (FIG. **4**). By convention the twisted ends **66** are always on the left looking toward the plug or connector, thus indicating the first wire **38**a to be removed. At this point the individual wires **38** of the segment **64** can be separated from the formboard as by pulling them from the hold-down device, or more preferably, by cutting the wires to their finished length at a predetermined cut mark **62** (FIG. **3**) located on the formboard **12.** Thus even though the ends of the wires **38** are now free, the order of the wires will be retained for future use by retention device **60.** After wire order retention devices have been applied to all of the wires in the several segments constituting the harness and the individual wires cut from the board, the harness skeleton can be removed from the formboard and the formboard returned to storage to await fabrication of other harnesses.

At this point protective sleeving **68** for segment **64** can be applied over the ends of the individual wires **38** and over the wire retention device **60.** In addition, identification tags **70** containing indicia identifying each particular segment can be applied to the sleeving **68.** Thereafter the partially completed wire harness is transferred to a subsequent processing station where the insulation from the ends of the wires comprising the individual segments is stripped. Pin-type contacts **72,** such as those shown in FIG. **7,** are then clamped on to the exposed electrical wiring.

Referring now specifically to FIG. **7** it will be seen that pin-type connectors **72** have been applied to all of the ends of wires **38***a* through **38***h*, in preparation for their insertion into predetermined sockets **74***a* through **74***h* in a multiple-plug type connector **76.** Here again the use of the wire order retention device **60** plays an important role. Prior to the present invention, each of the individual wires **38** had to be sorted according to their identifying indicia (FIG. **2**). Reference had to be made to a plug-chart indicating by indicia which wire went into which particular socket in the connector. The particular socket had to be located from the chart information. Thereafter, insertion of the particular wire into the appropriate socket was made.

By using the wire order retention device **60** each of the particular sockets **74** in the connector **76** can be identified by a simple numeral as **1, 2, 3,** . . . or by a letter, as *a*, *b*, *c*, . . . corresponding to the order from left to right in which the wires will be separated from the wire order retention device **60.** Thus an operator can separate the first wire **38**a by unwrapping the ends **66** of the wire order retention device **60** and retain the remaining wires by wrapping the ends **66** in the opposite direction around the second wire **38***b*. Thus, the remaining wire **38***b* through **38***h* are retained in the original predetermined order. Wire **38***a* is now free for insertion into the appropriate socket **74***a* in the connector **76.** The appropriate socket **74** can be selected by reference to a greatly simplified connector chart or by previously applying the simplified indicia to the back of the connector itself. The appropriate sockets of course are chosen from the original harness data and coordinated with the simplified indicia and the preselected wire order on the formboard.

In the preferred embodiment, the wire order in segment end **64** is chosen such that the first wire **38***a* is appropriately inserted in the center socket **74***a*. Thereafter the next wire **38***b* can be inserted into the next adjacent socket **74***b* in connector **76.** Likewise subsequent wires can be inserted in their respective sockets spiraling outwardly in order. This particular method of inserting the individual wires into the appropriate sockets in plug **76** can save as much as **50%** of the time originally necessary to insert wires when a search, sort and insertion technique was utilized.

Likewise all of the other segment ends which are to be interconnected with a multiple plug-type connector such as **76** are assembled. The assembly of the last wire onto a plug-type connector signifies the formation of a completed wire harness. For many applications such as in the aircraft industry a wire harness is then installed upon the particular subassembly with which it is to be used. Typically, all of the lug-type contacts are connected to the subassembly and, where appropriate, the plug-type connectors are inserted into the subassembly. The wire harness and its subassembly are then transferred to a testing station where a series of tests, including continuity, correct assembly, defective individual

wires, insulation breakdown and the like, are conducted.

When the harness and its subassembly have been tested and found satisfactory the harness and subassembly are transferred to inventory to await installation in or on an airframe.

The programming of the numerically operated coding and pinching machine and of the numerically controlled lay-down machine is accomplished by conventional techniques. The choice of coding is dependent, of course, upon the particular automated mechanism, but is also dependent upon the application by the ultimate consumer or user of the wire harness. A typical coding machine is available from the Conrac Corporation, Westminster, Calif., and can be identified by the name Wire Coding Machine, Conrac identification WMM–103–20. The numerically controlled wire router for use in the present process was produced specifically to be incorporated in the present process. The specification and design of the particular machine are available through the Hughes Aircraft Company, Industrial Products Division, Oceanside, Calif. and can be identified by name as a Harness Center, code number HC–2.

Many significant beneficial results are obtained by using the method of assembly of the present invention. Savings in tangible labor costs such as in searching, handling, routing on and off the formboard are very significant factors. A great reduction in the time required to build a harness, that is in the flow time in process, significantly decreases the lead time necessary to build a wire harness. Thus, engineering design changes can be made at the last possible moment while yet incorporating these changes into a harness. Similarly, in-process inventory can be reduced as a direct result of the rapid in-process flow time. The reliability of assembly is enhanced by virtue of elimination of the searching and sorting of the coded wires which are inserted into the connectors. Also significantly reduced is the actual individual wire routing time which previously had to be accomplished by a search and sort method. It can now be accomplished by a numerically controlled machine or can be quickly and efficiently done manually on a wire-by-wire basis utilizing the methodology and formboard of the present invention.

What is claimed is:

1. A method for assembling electrical wire harnesses comprising:

withdrawing an elongate wire from a storage zone and laying a first portion thereof onto a formboard along a predetermined path,

severing the elongate wire at a first predetermined severing location to produce a first individual wire,

retaining the ends of the first individual wire on the formboard at predetermined locations,

laying subsequent portions of the elongate wire along individually predetermined paths and severing the elongate wire in a predetermined sequence to produce subsequent individual wires,

retaining the ends of the subsequent individual wires on the formboard at predetermined locations, the predetermined locations including at least one grouping of certain ones of the wire ends adjacently retained in an ordered array to form a harness segment end,

interconnecting the individual wires of the segment end retaining the ordered array,

removing the segment end from the board,

sequentially selecting an individual wire from the array and mating each of the ends of the individual wires with a preselected socket in a connector.

2. The method of claim **1** further comprising:

marking an elongate electrical wire at predetermined spaced points along the length thereof to divide the wire into portions in said predetermined sequence to indicate severing locations for producing said individual wires and placing said elongate wire in a storage zone.

3. The method of claim **2** wherein the marking further comprises:

applying identifying indicia to each of the wire portions between the spaced points.

4. The method of claim **1** wherein a plurality of harness segment ends are formed, the method further comprising:

splicing preselected individual wire ends.

5. The method of claim **1** wherein a plurality of segment ends are formed further comprising:

applying connector contacts to the wire ends in a preselected segment prior to mating the ends thereof into preselected sockets in a connector.

6. The method of claim **5** wherein the electrical wire is insulated further comprising:

prior to applying the connector contacts, stripping insulation from a finite portion of the end of the individual wires and applying the contacts to the stripped portion of the wire.

7. The method of claim **1** further comprising:

prior to removing the segment end from the board, tying the individual wires in the segment together.

8. The method of claim **7** further comprising:

prior to removing the segment end from the board, applying indicia to identify the segment.

9. The method of claim **1** wherein

the individual wires of a segment are connected by weaving the two ends of an elongate retention member alternately and oppositely through the ordered array of individual wires and connecting the ends of the retention member extending beyond the last of the individual wires, and wherein

the individual wires are sequentially selected for mating with the sockets by unweaving the retention member from a last wire in the array, inserting the last wire into a preselected socket,

thereafter sequentially and individually unweaving subsequent wires from the array and individually inserting the subsequent wires into preselected sockets.

10. The method of claim **9** wherein the strap comprises:

a nonelastically deformable material.

11. A method for assembling electrical wire harnesses comprising:

laying a first individual wire from an end of an elongate wire along a predetermined path on a formboard,

severing the elongate wire at a first predetermined severing location before laying the next subsequent individual wire from the elongate wire,

repetitively laying subsequent individual wires each along a predetermined path and severing the elon-

gate wire at subsequent predetermined severing locations before laying a next subsequent individual wire,

retaining the ends of an individual wire on the formboard near the termination of the predetermined paths,

selecting ends of certain ones of the individual wires to form a harness segment end,

attaching the harness segment end to a connector.

12. The method of claim **11** further comprising:

prior to laying said individual wires, marking said elongate wire at predetermined points along its length to indicate a plurality of severing locations for individual wires.

13. The method of claim **12** further comprising:

placing the elongate wire on a container after marking,

withdrawing wire from the container as required for laying on the formboard.

14. The method of claim **13** further comprising:

applying indicia to the elongate wire between each of the predetermined points to distinguish one individual wire from another.

15. The method of claim **12** wherein the marking comprises:

forming an indicator at the predetermined points capable of being machine sensed,

when laying down the first individual wire, sensing the presence of the first indicator on the elongate wire,

severing the elongate wire in response to the presence of the indicator for a first individual wire,

when laying down subsequent individual wires, severing them from the elongate wire in response to the presence of subsequent indicators.

16. The method of claim **12** further comprising:

locating the predetermined path such that the ends of preselected individual wires are grouped to form a plurality of harness segment ends.

17. The method of claim **16** further comprising:

splicing preselected ones of the individual wire ends in a segment end.

18. The method of claim **17** further comprising:

applying contacts to individual wire ends in a preselected segment end,

inserting the contacts into preselected mating contacts in a connector.

19. A method for assembling electrical wire harnesses comprising:

marking an elongate electrical wire at variably spaced points in predetermined sequential spacing along its length to indicate severing locations for individual wires,

storing the elongate wire in a holding location,

retrieving an end of the elongate wire from the holding location,

laying the individual wires from the elongate wire in predetermined sequence on a formboard, each of the individual wires being laid in a predetermined path, the terminus of the predetermined path of certain ones of the individual wires being grouped in a sequential array to form a segment end,

severing the elongate wire in predetermined sequence at the severing locations to form an individual wire before laying a subsequent individual wire,

retaining the ends of the individual wires on the formboard near the terminus of the predetermined path,

temporarily interconnecting the individual wires of the segment end in the order of the sequential array,

removing the segment end from the formboard and inserting the ends of the individual wires in the segment end into a connector by sequentially selecting an individual wire from the sequential array and electrically connecting each of the ends of the individual wires with a preselected receptacle on the connector.

20. The method of claim **19** wherein

the individual wires are temporarily interconnected in sequential array by weaving the two ends of an elongate retention member alternately and oppositely through the sequential array of individual wires and connecting the ends of the retention member extending beyond the last of the individual wires, and wherein

the individual wires are selected for mating with the sockets by unweaving the retention member from the last wire in the array, inserting the last wire into a preselected socket, thereafter sequentially and individually unweaving the subsequent wires and individually inserting the subsequent wires into preselected sockets.

21. The method of claim **20** wherein the retention member comprises:

a nonelastically deformable material.

22. The method of claim **19** wherein the storing and retrieving of the individual wire comprises:

winding the marked elongate wire onto a storage spool,

withdrawing the wire from the spool and to lay the wire onto the formboard.

23. The method of claim **19** further comprising tying together the individual wires of a segment at a spaced distance from the segment end.

24. A method for coding and assembling electrical wire harnesses comprising:

applying identifying indicia to serial portions of an elongate wire, said identifying indicia being different for each of said serial portions and being applied to said serial portions in a predetermined sequence, each of said serial portions having a predetermined length and having a first end and a second end;

retaining the first end of a first serial portion of said elongate wire at a predetermined location on a formboard;

laying said first serial portion along a predetermined path on said formboard;

retaining the second end of said first serial portion on the formboard at a predetermined location on the formboard near the termination of said predetermined path;

laying subsequent serial portions of said elongate wire each along individually predetermined paths and retaining the first and second ends of the subsequent serial portions at predetermined locations on said formboard;

severing said serial portions of said elongate wire from each other to produce individual wire portions;

selecting certain ends of certain ones of the individual wire portions to form a harness segment end; and,

attaching the harness segment end to a connector.

25. The method of claim **24** further comprising:

marking said elongate wire at predetermined spaced points along the length thereof to indicate predetermined severing locations between said serial portions, said elongate wire being severed at a predetermined severing location before a next subsequent serial portion of said elongate wire is laid along a next subsequent predetermined path.

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