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(54) **ON-PALLET DUAL-BELT MECHANISM DRIVEN BY OFF-PALLET MOTOR FOR CABLE HANDLING AT PROCESSING MODULE**

(57) A system for processing a cable end (10a) of a cable (10). The system includes: a pallet delivery system (60); a cable processing module (30); a pallet (64) supported by the pallet delivery system; an on-pallet dual-belt cable feed mechanism (140) configured for linear feeding of the cable end into the cable processing module; and an off-pallet electric motor (102) operatively coupled for driving circulation of a pair of belts (86a, 86b) of the dual-belt cable feed mechanism. The cable processing module includes cable processing equipment (24)

configured to perform an operation on the cable end and a computer (162b). The computer is configured to: (a) cause the dual belts to circulate in respective cable pushing directions to cause a specified length of cable to be inserted into the cable processing equipment; (b) activate the cable processing equipment to perform an operation on the inserted end of the cable; and (c) cause the dual belts to circulate in respective cable pulling directions to cause the specified length of cable to be withdrawn from the cable processing equipment.

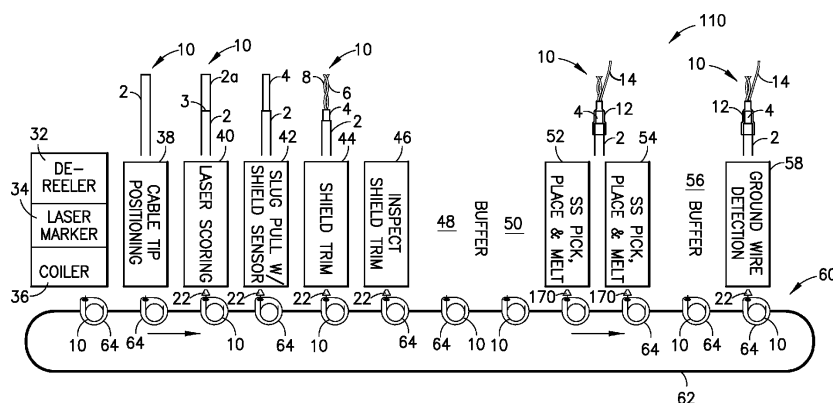


FIG. 1

Description

BACKGROUND

[0001] This disclosure generally relates to systems, methods, and apparatus for processing cable. In particular, this disclosure relates to systems, methods, and apparatus for automatically handling a cable at a cable processing module located along an automated production line. As used herein, the verb "to handle" means "to act on or perform a required function with regard to" and is not limited to managing manually (i.e., by hand), but rather may also be managed by machine.

[0002] Operators that manually feed cables into benchtop equipment for processing risk misalignment of the cable upon insertion, which can result in quality issues. Manual feeding into benchtop equipment requires operator skill to maintain alignment of the cable and to feed a correct length of cable into the equipment and also increases cycle time.

[0003] The risks posed by manual handling of cables during cable processing may be ameliorated by adopting an automated solution. One known automated solution uses a drive wheel mechanism mounted to a cable-carrying pallet which enables reliable feeding of common wire types, but does not accurately feed edge case cables with much larger or smaller diameters.

SUMMARY

[0004] The subject matter disclosed in some detail below is directed to technology to automate at least some, if not all of the processing of cables. The overall system is in the form of a production line. In accordance with a fully automated solution, the production line includes a pallet delivery system and a multiplicity of workstations accessible to the pallet delivery system. Each workstation is equipped with a respective cable processing module (including hardware and software) that performs a respective specific operation in a sequence of operations designed to produce a finished cable. Each cable to be processed is carried on a respective pallet that is conveyed along a conveyor track in the form of a belt or a chain. Cables pulse down the conveyor track and are inserted into a series of cable processing modules in sequence, each cable processing module including cable processing equipment for performing successive operations. By utilizing automation, the cycle time to produce cables is reduced, labor costs are decreased, and repeatable quality is ensured.

[0005] In particular, the subject matter disclosed in some detail below is directed to apparatus for automatically feeding the end of a cable into cable processing equipment at respective workstations. That cable processing equipment may be one of a multiplicity of modules at separate workstations in a fully automated production line or may be benchtop cable processing equipment (e.g., equipment mounted on a workbench

and accessible to a human operator).

[0006] The apparatus disclosed herein implements an integrated pallet and belt concept for feeding an end of a cable into cable processing equipment. (As used herein, the term "belt" means an endless belt.) In accordance with some examples, the apparatus includes a pallet for carrying a length of wound cable, an on-pallet dual-belt cable feed mechanism configured for feeding a cable end into and then withdrawing the cable end from a cable processing module, and an off-pallet motor operatively coupled for driving circulation of the belts to enable cable insertion/withdrawal. A respective off-pallet motor is situated at each processing station.

[0007] The apparatus disclosed herein enables paced cable processing automation. The pallet is preferably sized to accommodate a typical coiled length of cable. An operator loads the pallet with a length of wound cable and then places the cable end between the opposing belts of the dual-belt cable feed mechanism. The loaded pallet is then transported to a workstation that is equipped with an off-pallet nut driver apparatus comprising a motor-driven drive shaft having a socket attached at one end. Upon arrival of the pallet at an expected position adjacent to the workstation, the drive shaft is lowered so that the socket engages the head of an input (driven) shaft of the on-pallet dual-belt cable feed mechanism. Then the off-pallet electric motor is activated to drive rotation of the drive shaft, which in turn causes the cable-feeding belts to circulate concurrently in opposite directions. More specifically, mutually confronting portions of the belts which contact the cable push more cable through the dual-belt cable feed mechanism to insert the cable end into the cable processing module (for example, into a funnel which centers the cable end for insertion into the cable processing equipment).

[0008] In accordance with some examples, the pair of belts each have outer peripheral contact surfaces made of compliant material. The belt surfaces are separated by a distance which is a function of the diameter of the cable being fed. The presence of compliant material on both sides of the cable enables wires or cables of varying diameters and cross-sectional profiles to be handled. This apparatus is intended to be universal, that is, useable on any equipment (including benchtop equipment) that processes wires and/or cables.

[0009] Additionally, the system is able to define the amount (length) of cable that is fed into the cable processing equipment via a control system, depending on the particular type of cable to be processed and its related requirements. The motor residing off of the pallet enables the pallet to be lightweight, less expensive, and less complex than a motorized pallet. By increasing the contact surface area between the cable and the belts (as compared to the contact surface area of rollers), slippage is reduced and the desired level of precision is achievable.

[0010] As used herein, the term "tip of a cable" means a portion of a cable exposed by cutting the cable in a cross-sectional plane. As used herein, the term "end of

a cable" means a section of cable having a tip and a length of cable extending from the tip. For example, removal of a length of the jacket of a cable that extends to the cable tip creates an end of the cable in which the shielding is exposed. As used herein, the term "wound cable" means that a portion of a cable is arranged in a series of loops. For example, the loops of a wound cable may be corralled by an arc-shaped wall that subtends a central angle of 270° or more.

[0011] Although various examples of systems, methods and apparatus for feeding cable into cable processing equipment will be described in some detail below, one or more of those examples may be characterized by one or more of the following examples.

[0012] One example of the subject matter disclosed in detail below is an apparatus for feeding a cable into cable processing equipment, the apparatus comprising a pallet configured to carry the cable and a dual-belt cable feed mechanism mounted to the pallet. The dual-belt cable feed mechanism comprises: first through fourth pulleys which are rotatable relative to the pallet; a drive gear which is rotatable in tandem with the first pulley along a first common axis of rotation, wherein the drive gear comprises a multiplicity of teeth; an idler gear which is rotatable in tandem with the third pulley along a second common axis of rotation, wherein the idler gear comprises a multiplicity of teeth and some of the teeth of the idler gear are meshed with some of the teeth of the drive gear; a first belt that passes around the first and second pulleys; and a second belt that passes around the third and fourth pulleys. The first and second belts are arranged to contact opposing sides of a portion of the cable disposed therebetween. The first and second belts circulate concurrently and in opposite directions during rotation of the drive gear.

[0013] Another example of the subject matter disclosed in detail below is a system comprising a nut driver apparatus installed at a workstation and a cable feeding apparatus positioned adjacent to the workstation. The nut driver apparatus comprises: a bearing assembly comprising a guide which is oriented vertically and a carriage which is translatable coupled to the guide; a linear actuator comprising an elongated machine element fixedly coupled to the carriage; an arm having one end affixed to the carriage; an electric motor mounted to the arm and comprising a motor output shaft; a drive shaft fixedly coupled to the motor output shaft; and a socket fixedly coupled to an end of the drive shaft. The cable feeding apparatus comprises: a pallet configured to carry a length of wound cable; and a dual-belt cable feed mechanism carried by the pallet. The dual-belt cable feed mechanism comprises: an input shaft which is rotatable relative to the pallet about an axis of rotation and comprises a head which is configured to interlock with the socket when the drive shaft is aligned with and in contact with the input shaft; and first and second belts which circulate concurrently in opposite directions when the input shaft is rotated.

[0014] A further example of the subject matter disclosed in detail below is a method for processing an end of a cable, the method comprising: (a) placing a coil of cable on a pallet that supports a dual-belt cable feed mechanism comprising an input shaft which is rotatable relative to the pallet and first and second belts which circulate concurrently in opposite directions when the input shaft is rotated, wherein the input shaft comprises a head which is configured to interlock with a socket which is fixedly coupled to an end of a drive shaft; (b) placing the end of the cable between the first and second belts; (c) moving the pallet to a cable feed position whereat the input shaft is aligned with the socket; (d) activating a linear actuator to displace the drive shaft downward until the socket engages the head of the input shaft; (e) activating an electric motor to drive rotation of the drive shaft in a first direction while the socket is engaged with the head, thereby causing the belts to push the cable forward into cable processing equipment; (f) activating the cable processing equipment to perform the cable processing operation on the end of the cable; and (g) activating the electric motor to drive rotation of the drive shaft in a second direction opposite to the first direction while the socket is engaged with the head, thereby causing the belts to pull the cable out of the cable processing equipment. Steps (d) through (g) are performed under control by a computer.

[0015] Further examples are set out in the clauses below.

[0016] Clause 1. An apparatus for feeding a cable into cable processing equipment, the apparatus comprising a pallet configured to carry the cable and a dual-belt cable feed mechanism mounted to the pallet, wherein the dual-belt cable feed mechanism comprises: first through fourth pulleys which are rotatable relative to the pallet; a drive gear which is rotatable in tandem with the first pulley along a first common axis of rotation, wherein the drive gear comprises a multiplicity of teeth; an idler gear which is rotatable in tandem with the third pulley along a second common axis of rotation, wherein the idler gear comprises a multiplicity of teeth and some of the teeth of the idler gear are meshed with some of the teeth of the drive gear; a first belt that passes around the first and second pulleys; and a second belt that passes around the third and fourth pulleys, wherein the first and second belts are arranged to contact opposing sides of a portion of the cable disposed therebetween; and wherein the first and second belts circulate concurrently and in opposite directions during rotation of the drive gear; or an apparatus for feeding a cable into cable processing equipment, the apparatus comprising a cable, a pallet configured to carry the cable, the apparatus further comprising a dual-belt cable feed mechanism mounted to the pallet, wherein the dual-belt cable feed mechanism comprises: first through fourth pulleys which are rotatable relative to the pallet; a drive gear which is rotatable in tandem with the first pulley along a first common axis of rotation, wherein the drive gear comprises a multiplicity of teeth; an idler gear which

is rotatable in tandem with the third pulley along a second common axis of rotation, wherein the idler gear comprises a multiplicity of teeth and some of the teeth of the idler gear are meshed with some of the teeth of the drive gear; a first belt that passes around the first and second pulleys; and a second belt that passes around the third and fourth pulleys, wherein the first and second belts are arranged to contact opposing sides of a portion of the cable disposed therebetween; and wherein the first and second belts circulate concurrently and in opposite directions during rotation of the drive gear.

[0017] Clause 2. The apparatus as recited in Clause 1, further comprising a first shaft assembly that is rotatably coupled to the pallet and comprises a head, wherein the drive gear and the first pulley are fixedly mounted to the first shaft assembly.

[0018] Clause 3. The apparatus as recited in Clause 2, further comprising a second shaft assembly that is rotatably coupled to the pallet, wherein the idler gear and the third pulley are fixedly mounted to the second shaft assembly.

[0019] Clause 4. The apparatus as recited in Clause 3, wherein the first shaft assembly further comprises an input shaft, a first gear shaft, and a first pulley shaft fixedly coupled in series, the apparatus further comprising a second pulley shaft, wherein: the head projects from an end of the first shaft; the drive gear is fixedly mounted to the first gear shaft; the first pulley is fixedly mounted to the first pulley shaft; and the second pulley is fixedly mounted to the second pulley shaft.

[0020] Clause 5. The apparatus as recited in Clause 4, wherein the second shaft assembly comprises a second gear shaft and a third pulley shaft fixedly coupled to the second gear shaft, the apparatus further comprising a fourth pulley shaft, wherein: the idler gear is fixedly mounted to the second gear shaft; the third pulley is fixedly mounted to the third pulley shaft; and the fourth pulley is fixedly mounted to the fourth pulley shaft.

[0021] Clause 6. The apparatus as recited in any of Clauses 2 to 5, wherein the head comprises a solid body having at least one rectangular planar side surface.

[0022] Clause 7. The apparatus as recited in any of Clauses 2 to 6, wherein the head comprises a solid body having at least one trapezoidal planar side surface.

[0023] Clause 8. The apparatus as recited in any of Clauses 2 to 7, wherein the head comprises a solid body having splines.

[0024] Clause 9. The apparatus as recited in any of Clauses 1 to 8, wherein: each of the first through fourth pulleys has a respective multiplicity of teeth along a respective outer periphery thereof; each of the first and second belts has a respective multiplicity of teeth molded on an inner surface thereof; some of the teeth of the first belt are meshed with some of the teeth of the first pulley, while other teeth of the first belt are meshed with some of the teeth of the second pulley; and some of the teeth of the second belt are meshed with some of the teeth of the third pulley, while other teeth of the second belt are

meshed with some of the teeth of the fourth pulley.

[0025] Clause 10. The apparatus as recited in any of Clauses 1 to 9, wherein the first and second belts are made of compliant material.

[0026] Clause 11. The apparatus as recited in any of Clauses 1 to 10, wherein: the pallet comprises a corral (66) that defines a recess; the corral comprises a circular wall having a discontinuity and first and second planar walls extending from the discontinuity; and the first and second belts are disposed side-by-side in a portion of the recess between the first and second planar walls.

[0027] Clause 12. A system comprising a nut driver apparatus installed at a workstation and a cable feeding apparatus positioned adjacent to the workstation, wherein the nut driver apparatus comprises: a bearing assembly comprising a guide which is oriented vertically and a carriage which is translatably coupled to the guide; a linear actuator comprising an elongated machine element coupled to the carriage; an arm having one end affixed to the carriage; an electric motor mounted to the arm and comprising a motor output shaft; a drive shaft fixedly coupled to the motor output shaft; and a socket fixedly coupled to an end of the drive shaft, and wherein the cable feeding apparatus comprises: a pallet configured to carry wound cable (and, optionally, the wound cable); and a dual-belt cable feed mechanism mounted to the pallet, wherein the dual-belt cable feed mechanism comprises: an input shaft which is rotatable relative to the pallet about a first axis of rotation and comprises a head which is configured to interlock with the socket when the drive shaft is aligned with and in contact with the input shaft; and first and second belts which circulate concurrently in opposite directions when the input shaft is rotated.

[0028] Clause 13. The system as recited in Clause 12, wherein the socket is not interlocked with the head when the carriage is at a first elevation and is interlocked with the head when the carriage is at a second elevation below the first elevation.

[0029] Clause 14. The system as recited in Clause 12 or 13, wherein the elongated machine element comprises a lead screw, the linear actuator further comprising a nut that is attached to the carriage and threadably coupled to the lead screw.

[0030] Clause 15. The system as recited in any of Clauses 12 to 14, wherein the elongated machine element comprises a rack, the linear actuator further comprising a pinion gear which is rotatable relative to the guide.

[0031] Clause 16. The system as recited in any of Clauses 12 to 15, wherein the linear actuator is a pneumatic actuator and the elongated machine element comprises a piston rod which is linearly displaceable and has an end fixedly coupled to the carriage.

[0032] Clause 17. The system as recited in any of Clauses 12 to 16, further comprising: a motor controller which is configured to control operation of the electric motor in response to commands; and a computer which is configured to output commands to the motor controller

to control operation of the electric motor.

[0033] Clause 18. The system as recited in Clause 17, wherein the computer is further configured to activate the linear actuator to lower the drive shaft by a distance sufficient to interlock the head with the socket and then issue commands to the motor controller that controls the electric motor to drive rotation of the drive shaft while the socket is interlocked with the head, thereby causing the input shaft to rotate and the first and second belts to circulate.

[0034] Clause 19. The system as recited in Clause 18, wherein the computer is further configured to issue commands to the motor controller that control the electric motor to drive rotation of the drive shaft by a number of degrees calculated to cause the first and second belts to feed a predetermined length of cable disposed between and contacted by the first and second belts.

[0035] Clause 20. The system as recited in any of Clauses 12 to 19, wherein the dual-belt cable feed mechanism further comprises: first through fourth pulleys which are rotatable relative to the pallet; a drive gear which is rotatable in tandem with the first pulley about the first axis of rotation, wherein the drive gear comprises a multiplicity of teeth; an idler gear which is rotatable in tandem with the third pulley about a second axis of rotation, wherein the idler gear comprises a multiplicity of teeth and some of the teeth of the idler gear are meshed with some of the teeth of the drive gear; a first belt that passes around the first and second pulleys; and a second belt that passes around the third and fourth pulleys.

[0036] Clause 21. A system comprising a nut driver apparatus installed at a workstation and an apparatus according to any of Clauses 1 to 11 positioned adjacent to the workstation, wherein the nut driver apparatus comprises: a bearing assembly comprising a guide which is oriented vertically and a carriage which is translatable coupled to the guide; a linear actuator comprising an elongated machine element coupled to the carriage; an arm having one end affixed to the carriage; an electric motor mounted to the arm and comprising a motor output shaft; a drive shaft fixedly coupled to the motor output shaft; and a socket fixedly coupled to an end of the drive shaft, and wherein the dual-belt cable feed mechanism of the apparatus comprises: an input shaft which is rotatable relative to the pallet about an axis of rotation and comprises a head which is configured to interlock with the socket when the drive shaft is aligned with and in contact with the input shaft.

[0037] Clause 22. The system as recited in Clause 21, wherein the socket is not interlocked with the head when the carriage is at a first elevation and is interlocked with the head when the carriage is at a second elevation below the first elevation.

[0038] Clause 23. The system as recited in Clause 21 or 22, wherein the elongated machine element comprises a lead screw, the linear actuator further comprising a nut that is attached to the carriage and threadably coupled to the lead screw.

[0039] Clause 24. The system as recited in any of Clauses 21 to 23, wherein the elongated machine element comprises a rack, the linear actuator further comprising a pinion gear which is rotatable relative to the guide.

[0040] Clause 25. The system as recited in any of Clauses 12 to 24, wherein the linear actuator is a pneumatic actuator and the elongated machine element comprises a piston rod which is linearly displaceable and has an end fixedly coupled to the carriage.

[0041] Clause 26. The system as recited in any of Clauses 21 to 25, further comprising: a motor controller (164b) which is configured to control operation of the electric motor in response to commands; and a computer (162b) which is configured to output commands to the motor controller to control operation of the electric motor.

[0042] Clause 27. The system as recited in Clause 26, wherein the computer is further configured to activate the linear actuator to lower the drive shaft by a distance sufficient to interlock the head with the socket and then issue commands to the motor controller that controls the electric motor to drive rotation of the drive shaft while the socket is interlocked with the head, thereby causing the input shaft to rotate and the first and second belts to circulate.

[0043] Clause 28. The system as recited in Clause 27, wherein the computer is further configured to issue commands to the motor controller that control the electric motor to drive rotation of the drive shaft by a number of degrees calculated to cause the first and second belts to feed a predetermined length of cable disposed between and contacted by the first and second belts.

[0044] Clause 29. A method for processing a cable end of a cable using the system of any of Clauses 12 to 28, the method comprising: (a) placing a coil of cable on the pallet; (b) placing the end of the cable between the first and second belts; (c) moving the pallet to a cable feed position whereat the input shaft is aligned with the socket; (d) activating a linear actuator to displace the drive shaft downward until the socket engages the head of the input shaft; and (e) activating an electric motor to drive rotation of the drive shaft in a first direction while the socket is engaged with the head, thereby causing the first and second belts to push the cable forward into cable processing equipment, wherein steps (d) and (e) are performed under control by a computer.

[0045] Clause 30. The method of Clause 29, further comprising: (f) activating the cable processing equipment to perform a cable processing operation on the end of the cable; and (g) activating the electric motor to drive rotation of the drive shaft in a second direction opposite to the first direction while the socket is engaged with the head, thereby causing the belts to pull the cable out of the cable processing equipment, wherein steps (f) and (g) are performed under control by the computer.

[0046] Other examples of systems, methods and apparatus for feeding shielded cable into cable processing equipment are disclosed below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0047] The features, functions, and advantages discussed in the preceding section may be achieved independently in various examples or may be combined in yet other examples. Various examples will be hereinafter described with reference to drawings for the purpose of illustrating the above-described and other examples. None of the diagrams briefly described in this section are drawn to scale.

FIG. 1 is a diagram representing and identifying components of an automated system for performing respective operations on an end of a cable at a plurality of cable processing modules.

FIG. 2 is a diagram representing a top view of a pallet in a position adjacent a cable processing module where a tip of the cable is positioned in front of a funnel.

FIG. 3A is a diagram representing a side view of a pallet in a position adjacent a cable processing module, which pallet is equipped with a reelette for holding a coil of cable and a drive wheel for feeding an end of the cable into cable processing equipment.

FIG. 3B is a diagram representing a top view of the apparatus depicted in FIG. 3A.

FIG. 4 is a block diagram identifying some components of the cable processing module identified in FIGS. 3A and 3B.

FIG. 5 is a diagram representing a top view of an end of a cable being pushed forward by a pair of belts circulating around respective pairs of pulleys of a dual-belt cable feed mechanism.

FIG. 5A is a diagram representing a top view of a portion of a toothed belt wrapped around a portion of a toothed pulley.

FIG. 6 is a diagram representing a three-dimensional view of an apparatus comprising a pallet configured for holding a wound portion of a cable and an on-pallet dual-belt cable feed mechanism that receives the end of the cable.

FIG. 7A is a diagram depicting an automated system comprising a nut driver apparatus installed at a workstation and a cable feeding apparatus which has arrived at a position adjacent to the workstation in a state wherein the nut driver apparatus is disengaged from the cable feeding apparatus.

FIG. 7B is a diagram depicting an automated system comprising a nut driver apparatus installed at a workstation and a cable feeding apparatus which has arrived at a position adjacent to the workstation in a state wherein the nut driver apparatus is engaged with the cable feeding apparatus.

FIG. 8 is a block diagram identifying some components of a cable feeding system in accordance with the example depicted in FIG. 7A.

FIG. 9 is a block diagram identifying some components of a cable feeding system that uses a pneu-

matic actuator to displace the carriage depicted in FIG. 7A such that an off-pallet motor-driven socket engages the head of an input shaft of an on-pallet dual-belt cable feed mechanism.

FIG. 10 is a block diagram identifying some components of a cable feeding system that uses an electric linear actuator to displace the carriage depicted in FIG. 7A such that an off-pallet motor-driven socket engages the head of an input shaft of an on-pallet dual-belt cable feed mechanism.

FIG. 11 is a flowchart representing steps of a partly automated method for processing the ends of cables using the automated system depicted in FIGS. 1, 6, and 7A.

[0048] Reference will hereinafter be made to the drawings in which similar elements in different drawings bear the same reference numerals.

DETAILED DESCRIPTION

[0049] Illustrative examples of systems, methods, and apparatus for feeding shielded cable into cable processing equipment are described in some detail below. However, not all features of an actual example are described in this specification. A person skilled in the art will appreciate that in the development of any such actual example, numerous example-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one example to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

[0050] For the purpose of illustration, various examples of an apparatus for automatically feeding the end of a cable into cable processing equipment at a workstation will now be described. That cable processing equipment may be one of a multiplicity of modules at separate workstations in a fully automated production line or may be benchtop cable processing equipment (e.g., equipment mounted on a workbench and accessible to a human operator).

[0051] FIG. 1 is a diagram representing and identifying components of a system 110 for performing respective operations on an end of a cable 10. The system 110 includes a cable delivery system 60. For example, the cable delivery system 60 may take the form of a conveyor system with locating modules (not shown in FIG. 1). Locating modules are components for positioning pallets in preparation for performance of an automated operation. In accordance with the example depicted in FIG. 1, the cable delivery system 60 includes a conveyor track 62 in the form of an endless belt or chain. The entire conveyor track 62 is continuously moving. In alternative examples, the cable delivery system 60 is not endless, in which case pallets 64 arriving at the end of a linear conveyor track

may be transported to the starting point by other means. In accordance with alternative examples, the cable delivery system 60 may be a gantry robot or a robotic arm.

[0052] As seen in FIG. 1, the cable delivery system 60 includes multiple pallets 64 that travel on the conveyor track 62, each pallet 64 carrying a respective coil of cable 10. The system 110 depicted in FIG. 1 further includes a multiplicity of automated workstations situated adjacent to and spaced at intervals along the conveyor track 62. Each workstation is equipped with hardware that performs a respective specific operation in a sequence of operations designed to produce a shielded cable 10 having a solder sleeve 12 installed on one end of the cable 10. The locating modules (not shown in FIG. 1) of the system 110 are used to lift each pallet 64 off of the conveyor track 62 when an operation has to be performed at a workstation on the coil carried by that pallet 64 and later place the pallet 64 back on the conveyor track 62 after the operation has been completed so that the pallet 64 can move onto the next workstation.

[0053] Each pallet 64 carries a respective coil of cable 10. Pallets 64 move intermittently along the conveyor track 62 in the forward direction indicated by the arrows in FIG. 1, advancing from one automated workstation to the next and then stopping. (This example of the cable delivery system 60 will be referred to hereinafter as "pulsing".) A respective bar code reader (not shown in the drawings) is mounted on the side of the conveyor track 62 opposite to each workstation. Each pallet 64 has a bar code printed on a forward side portion thereof. When the bar code reader detects the arrival of a pallet 64, each workstation has a respective controller (e.g., a computer programmed to execute computer numeric control (CNC) commands) that activates the cable processing module of that workstation to begin an automated cable processing operation.

[0054] Each shielded cable 10 to be processed is carried on a respective pallet 64 that is conveyed along the conveyor track 62. The pallets 64 pulse down the conveyor track 62 and the end of each shielded cable is inserted into a series of cable processing modules in sequence, each cable processing module including cable processing equipment for performing successive operations of a solder sleeve installation process. In accordance with the example depicted in FIG. 1, the cable processing modules include the following: a de-reeler module 32, a laser marker 34, a coiler module 36, a cable tip positioning module 38, a laser scoring module 40, a jacket slug pulling module 42, a shield trimming module 44, a shield trim inspection module 46, two solder sleeve installation modules 52 and 54 (which perform automated solder sleeve pick, place, and melt functions), and a ground wire detection module 58. In accordance with the proposed example depicted in FIG. 1, there are three open positions where cable processing does not occur. These open positions are referred to herein as buffers 48, 50, and 56. The purpose of these buffers will be explained later.

[0055] As indicated in FIG. 1 by triangle symbols, some of the workstations include funnels 22 which center the inserted end of the cable 10 in the cable processing equipment at the respective workstation. Other workstations, such as the workstation where the cable tip positioning module 38 is located, do not have a funnel. The workstations where the two solder sleeve installation modules 52 and 54 are located have open-top or split funnels 170, which also guide the end of the cable 10, but differ in structure from the funnels 22 in that the cable may be lifted vertically out of the open or split funnel 170 upon completion of the solder sleeve melting operation.

[0056] The respective cable processing modules identified in FIG. 1 will be described briefly in the order in which the respective cable processing operations are performed on one cable. The starting material is a continuous length of multi-conductor shielded cable of a particular type wound on a reel. The de-reeler module 32 de-reels the continuous length of cable and then cuts the cable to a specified length, which length of cable will be referred to hereinafter as "cable 10". For each length of cable 10, the laser marker 34 laser marks the jacket 2 of the cable 10 with pertinent information (bundle number, wire number, gauge). The coiler module 36 then coils the cable 10. The coil of cable 10 is then taken off of the coiler and placed on a pallet 64. The pallet 64 is then transferred from the coiler module 36 to the cable tip positioning module 38.

[0057] The cable tip positioning module 38 serves to initially position the tip of the cable 10 at a preset cable tip position prior to the cable 10 continuing through the system 110. The preset cable tip position is selected to prevent the cable end from being too long as it travels along the conveyor track (hitting other objects within the system, being crushed or otherwise damaged, etc.). The pallet 64 then moves to the laser scoring module 40. The laser scoring module 40 lightly scores the jacket 2 of the cable 10 along a score line 3 which extends circumferentially in a plane that intersects an annular region of the jacket 2. The presence of the score line 3 prepares the applicable segment of jacket 2 (hereinafter "the jacket slug 2a") to be removed by the jacket slug pulling module 42. The jacket slug pulling module 42 removes the jacket slug 2a to reveal the shield 4 in theunjacketed portion of the cable 10. Next, the pallet 64 moves to the shield trimming module 44, which trims off a portion of the exposed portion of the shield 4 to reveal respective portions of the wires 6 and 8 of the cable 10. Then the shield trim inspection module 46 performs a quality check of the trimmed shield using a vision inspection system. The pallet 64 then moves to one of two solder sleeve installation modules 52 and 54, which are configured to install a solder sleeve 12 with a ground wire 14 onto the cable 10 using automated picking, placing, and melting operations. Two cables 10 may have solder sleeves installed concurrently using the two solder sleeve installation modules 52 and 54. Next, the pallet 64 moves to ground wire detection module 58, which detects the ground wire 14

of the solder sleeve 12.

[0058] As seen in FIG. 1, the cable delivery system 60 includes multiple pallets 64 that travel on the conveyor track 62, each pallet 64 carrying a respective coil of cable 10. In accordance with some examples, the apparatus on the pallet 64 included a pair of cable-displacing wheels designed to push and pull cables through a cable-guiding funnel which centers the cable for insertion into the cable processing equipment. One or both of the pairs of wheels may be moved closer or farther apart to enable wires or cables of varying diameters and cross-sectional profiles to be placed between the belts. This apparatus is intended to be universal, i.e., to be able to be used on any equipment (including benchtop equipment) that processes wires and/or cables. Additionally, the system is able to define the amount (length) of cable that is fed into the equipment, depending on the cable that is to be processed and its related requirements.

[0059] In the proposed example shown in FIG. 2, each pallet 64 has a drive wheel 16 and an idler wheel 18 which are rotatably coupled to the pallet 64. The drive wheel 16 and idler wheel 18 are preferably padded with a compliant material capable of conforming to different cross-sectional profiles (e.g., a single conductor cable versus a twisted-pair cable). The pallet 64 also includes a corral 66 in the form of a curved wall that is contoured to guide the cable end 10a toward the drive wheel 16 and idler wheel 18. The drive wheel 16 and idler wheel 18 cooperate to move the cable end 10a into and out of an adjacent cable processing module 30. The apparatus includes a drive wheel 16 and an idler wheel 18 configured to drive the cable 10 forwards or backwards between the wheels and a funnel 22 capable of capturing the cable end 10a. While the wheels control the motion of the cable 10, the funnel 22 serves to center the cable 10 for insertion into the cable processing equipment 24. This function will be used to insert and position the cable 10 into different modules for processing as the cable 10 is transported through the system.

[0060] The starting position of the cable tip 10b may be either beyond or short of a scanning plane 11 (indicated by a dashed line in FIG. 2) located at a known position. This known position is a known distance from a preset cable tip position. The drive wheel 16 and idler wheel 18 are then rotated to move the cable tip 10b closer to the scanning plane 11. The movement of the cable tip 10b is monitored by a photoelectric sensor (not shown in FIG. 2, but see photoelectric sensor 28 in FIGS. 3A and 3B) mounted to a fixed portion of the system and configured to function as a light gate. FIG. 2 shows the state wherein the cable tip 10b is aligned with the scanning plane 11 following movement of the cable end 10a from the starting position. In response to the photoelectric sensor 28 detecting a transition between a state of light being interrupted (e.g., blocked) in the scanning plane 11 and a state of light not being interrupted, the photoelectric sensor 28 issues a cable tip position signal indicating the transition between interruption and no inter-

ruption of transmitted light at the scanning plane. In response to issuance of the cable tip position signal, the computer of the cable positioning module activates a motor (not shown in FIG. 2, but see motor 72 in FIGS. 3A and 3B) to rotate the drive wheel 16 by an amount and in a direction such that at the end of the rotation, the cable 10 does not extend beyond a preset cable tip position. This preset cable tip position is a known distance from the scanning plane 11. The preset cable tip position may be selected to ensure that the cable tip 10b may travel along the conveyor track 62 with sufficient clearance to avoid damage from stationary objects. At this juncture, the conveyor track 62 pulses forward, causing the pallet to move to the next workstation.

[0061] FIG. 3A is a diagram representing a side view of a pallet 64 in a position adjacent a cable processing module 30, which pallet 64 is equipped with a reelette 26 for holding a coil of cable 10 and a drive wheel 16 (not visible in FIG. 3A) for feeding an end of the cable 10 into the cable processing module 30. FIG. 3B shows a top view of the pallet 64 in a position adjacent the cable processing module 30.

[0062] As seen in FIG. 3A, the cable processing module 30 is mounted on a stationary plate 68. A stanchion 70 is affixed to the stationary plate 68 in a position in front of the cable processing module 30. Each workstation depicted in FIG. 1 includes a motor 72 (e.g., an electric stepper motor). The motor 72 is configured to rotate either clockwise or counterclockwise. The motor 72 is mounted to a base 70a of the stanchion 70. The motor 72 has an output shaft 74 which drives rotation of the drive wheel 16 (not visible behind the idler wheel 18 in FIG. 3A). In addition, the photoelectric sensor 28 is mounted to an upright portion 70b of the stanchion 70.

[0063] In accordance with the proposed example depicted in FIG. 3A, each coil of cable 10 is individually wound onto its own reelette 26, which reelette 26 is supported by and rotatably coupled to the pallet 64. The corral 66 (see FIG. 2) is not shown in FIG. 3A so that the reelette 26 is visible. The reelette 26 has an opening (not shown in FIG. 3A) on its outer periphery through which a portion of the cable 10 (including cable end 10a) passes. FIG. 3A shows a state in which the cable end 10a is disposed between rotating drive wheel 16 and idler wheel 18 (drive wheel 16 is located directly behind the idler wheel 18 and not visible in FIG. 3A), while the cable tip 10b is moving in a direction (indicated by an arrow in FIG. 3A) toward the cable processing module 30.

[0064] In response to detection of the arrival of the pallet 64 at the cable processing module 30 by a pallet detector (not shown in FIGS. 3A and 3B, but see pallet detector 160 in FIG. 4), the motor 72 is operatively coupled to the drive wheel 16. Subsequently the motor 72 is activated to drive the drive wheel 16 to rotate in the cable pushing direction. The shaft of the motor 72 is optionally equipped with a rotation encoder 73 (see FIG. 4) for determining the angular rotation of the drive wheel 16. During rotation of the drive wheel 16 in the cable pushing

direction, the rotation encoder 73 tracks the rotation of the motor shaft to generate digital position information representing the length of cable 10 which has been fed past the scanning plane 11.

[0065] When a pallet 64 stops at the cable processing module 30, the drive wheel 16 and idler wheel 18 are driven to rotate in a cable pushing direction to cause the cable tip 10b to pass the photoelectric sensor 28, through the funnel 22, and into the cable processing equipment 24. Once the photoelectric sensor 28 is triggered, the rotation encoder 73 will begin to output pulses indicating increments of rotation by the motor shaft. This provides a way to track the inserted length of the cable 10 in real time, and subsequently cause the motor 72 to stop once the correct length of cable 10 has been fed into the cable processing equipment 24. The drive wheel 16 and idler wheel 18 continue to rotate in the cable pushing direction until a specified length of cable 10 has been inserted into the cable processing equipment 24 via the funnel 22.

[0066] FIG. 3B shows a top view of the pallet 64 when the cable tip 10b is positioned at a scanning plane 11 of the photoelectric sensor 28. In accordance with some examples, the photoelectric sensor 28 is a laser sensor of the "position recognition" type. In a laser scanner of this type, a scanning laser beam is emitted from a scanning light beam transmitter 28a, which scanning light beam scans in the scanning plane 11 and is then received by the light-detecting sensor 28b (e.g., a column of pixels in a charge coupled device).

[0067] The double-headed straight arrow superimposed on the idler wheel 18 in FIG. 3B indicates that the idler wheel 18 is laterally movable away from and toward the drive wheel 16. Meanwhile the curved arrows superimposed on the drive wheel 16 and idler wheel 18 are intended to indicate that the drive wheel 16 and idler wheel 18 are rotating in a cable pushing direction. At the instant of time depicted in FIG. 3B, the cable tip 10b is positioned at the scanning plane 11 and is moving toward the cable processing module 30.

[0068] FIG. 4 is a block diagram identifying some components of the cable processing module identified in FIGS. 3A and 3B. The cable processing module 30 includes a computer 162a which is configured to perform the following operations: activate the motor 72 to drive rotation of the drive wheel 16 in a cable pushing direction to cause a specified length of cable 10 to be inserted into the cable processing equipment 24; activate the cable processing equipment 24 to perform an operation on the inserted cable end 10a; and activate the motor 72 to drive rotation of the drive wheel 16 in a cable pulling direction to cause the specified length of cable 10 to be removed from the cable processing equipment 24.

[0069] Still referring to FIG. 4, the rotation encoder 73 is configured to output pulses representing the incremental angular rotations of an output shaft of the motor 72. The photoelectric sensor 28 is positioned and configured to issue a cable tip position signal indicating that interruption of transmitted light in the scanning plane 11 has

started. In other words, the cable tip position signal is issued in response to the photoelectric sensor 28 detecting that a state of light not being blocked in the scanning plane 11 has transitioned to a state of light being blocked.

The computer 162a is configured to start a count of pulses output by the rotation encoder 73 in response to the cable tip position signal and then de-activate the motor 72 in response to the count reaching a specified value corresponding to a specific target length of cable 10 having been inserted in the cable processing equipment 24. The computer 162a also receives sensor feedback from a pallet detector 160 used to detect a pallet position. The computer 162b is configured to send commands to a motor controller 164a for controlling the motor 72 in accordance with feedback from photoelectric sensor 28, rotation encoder 73, and pallet detector 160.

[0070] The dual-wheel cable feeding mechanism depicted in FIG. 2 may not provide required drive distance precision for certain cable types. One improvement proposed herein entails the use of a dual-belt cable feeding mechanism instead of the dual-wheel cable feeding mechanism. A pair of pulley-mounted belts are arranged on the pallet with a gap therebetween. The length of the section of cable in contact with the mutually confronting belt surfaces is equal or approximately equal to the distance between centers of the two pulley shafts associated with one belt. In contrast, the length of the section of cable in contact with the mutually confronting wheel surfaces is less than the diameter of one wheel. Accordingly, the cable contact surface area may be increased using belts as opposed to using wheels. By increasing the contact surface area between the cable and the contact surfaces of the cable feed mechanism, slippage is reduced and a desired level of precision is achievable.

[0071] The apparatus disclosed hereinafter implements an integrated pallet and belt concept for enabling transport and pushing of cables for insertion into cable processing equipment. In accordance with some examples, the apparatus includes a pallet for carrying a length of wound cable, an on-pallet dual-belt cable feed mechanism configured for linear feeding of a cable end into a cable processing module, and an off-pallet motor operatively coupled for driving circulation of the belts to enable cable insertion/withdrawal. A respective off-pallet motor is situated at each processing station.

[0072] In accordance with some examples, the apparatus on the pallet 64 includes a pair of cable-displacing belts designed to push or pull a cable end through a cable-guiding funnel. The funnel is designed to center the cable end for insertion into the cable processing equipment. Each belt circulates around a respective pair of belt pulleys. Means may be provided for adjusting the separation distance of the mutually confronting portions of the circulating belts to enable wires or cables of varying diameters and cross-sectional profiles to be inserted automatically. This apparatus is intended to be universal, i.e., able to be used on any equipment (including benchtop equipment) that processes wires and/or cables. Addition-

ally, the system is able to define the amount (length) of cable that is fed into the equipment, depending on the cable that is to be processed and its related requirements

[0073] FIG. 5 is a diagram representing a top view of a cable end 10a of a cable 10 being pushed forward by a pair of belts 86a/86b (hereinafter "first belt 86a" and "second belt 86b") of a dual-belt cable feed mechanism 140. The first belt 86a passes around a first pulley 84a and a second pulley 84b; the second belt 86b passes around a third pulley 84c and a fourth pulley 84d. The first through fourth pulleys 84a-84d are fixedly mounted on respective pulley shafts 78a-78d. The pulley shafts 78a-78d are journaled within respective blocks by bearing assemblies (not shown in FIG. 5) in a well-known manner. Those blocks in turn are incorporated in a pallet (not shown in FIG. 5). The first and second belts are arranged to contact opposing sides of a portion of the cable 10 disposed therebetween.

[0074] The cable end 10a of cable 10 is shown in FIG. 5 being pushed in the direction of arrow A as the first belt 86a circulates in the direction indicated by arrows B and the second belt 86b circulates in the direction indicated by arrows C. The first belt 86a circulates in response to rotation of a drive gear (not shown in FIG. 5) which is mounted to a first gear shaft 79a. The drive gear comprises a multiplicity of teeth. The first gear shaft 79a is coaxial with and connected to the first pulley shaft 78a. The drive gear is driven to rotate by an input shaft (not shown in FIG. 5) which is coaxial with and connected to the first gear shaft 79a. Thus, the first gear shaft 79a and the first pulley shaft 78a are rotatable in tandem relative to the pallet when the input shaft is rotated. Circulation of the first belt 86a causes the second pulley shaft 78b to rotate.

[0075] Similarly, the second belt 86b circulates in response to rotation of an idler gear (not shown in FIG. 5) which is mounted to a second gear shaft 79b. The idler gear comprises a multiplicity of teeth. Some of the teeth of the idler gear are meshed with some of the teeth of the drive gear, so that the idler gear will be driven to rotate by a rotating drive gear. The second gear shaft 79b is coaxial with and connected to the third pulley shaft 78c, so that the second gear shaft 79b and the third pulley shaft 78c rotate in tandem relative to the pallet when the idler gear is driven to rotate. Circulation of the second belt 86b causes the fourth pulley shaft 78d to rotate.

[0076] In summary, the first and second belts 86a/86b circulate concurrently and in opposite directions during rotation of an input shaft not shown in FIG. 5. When a cable end 10a is disposed between first and second belts 86a/86b which are arranged to exert sufficient frictional force to move the cable 10, the circulating belts are able to push or pull the cable end 10a toward or away from a funnel 22 disposed in front of the cable processing equipment 24 identified in FIG. 2. Optionally, sufficient frictional force may be assured by including one or more pairs of pressure or contact rollers arranged to press the mutually confronting portions of the belts against the intervening

cable. The pressure or contact rollers may be fixedly mounted on laterally movable shafts which are journaled in spring-loaded blocks.

[0077] In accordance with some examples, the first through fourth pulleys 84a-84d are toothed pulleys and the first and second belts 86a/86b are toothed belts. FIG. 5A is a diagram representing a top view of a portion of a toothed belt 86 passed (wrapped) around a portion of a toothed pulley 84. The toothed pulley 84 has a multiplicity of teeth 85 projecting outward from an outer periphery thereof. The toothed belt 86 has a multiplicity of teeth 87 which engage the teeth 85 of the toothed pulley 84. As a result, toothed belt 86 circulates (indicated by the straight arrows in FIG. 5A) in conjunction with rotation (indicated by the curved arrow in FIG. 5A) of toothed pulley 84.

[0078] For example, each of the first and second belts 86a/86b seen in FIG. 5 may be provided with a respective multiplicity of teeth 87 molded on an inner surface of the belt and each of the first through fourth pulleys 84a-84d may be provided with a respective multiplicity of teeth 85 projecting outward from an outer periphery thereof. Some of the teeth of the first belt 86a are meshed with some of the teeth of the first pulley 84a, while other teeth of the first belt 86a are meshed with some of the teeth of the second pulley 84b. Accordingly, rotation of the first pulley 84a causes the first belt 86a to circulate, which in turn causes the second pulley 84b to rotate. Likewise some of the teeth of the second belt 86b are meshed with some of the teeth of the third pulley 84c, while other teeth of the second belt 86b are meshed with some of the teeth of the fourth pulley 84d. Accordingly, rotation of the third pulley 84c causes the second belt 86b to circulate, which in turn causes the fourth pulley 84d to rotate.

[0079] FIG. 6 is a diagram representing a three-dimensional view of a cable-feeding apparatus 130 that includes a pallet 64 configured to carry a length of wound cable (not shown in FIG. 6) and a dual-belt cable feed mechanism 140 carried by the pallet 64. The pallet 64 comprises a corral 66 that defines a recess 98 configured to support and contain the length of wound cable. To facilitate manipulation of the pallet 64 by a human operator, a pair of handles 65a/65b are attached to the pallet 64 outside and on opposite sides of the recess 98. The corral 66 comprises a circular wall 96c having a discontinuity and first and second planar walls 96a/96b which extend from the discontinuity. The first and second belts 86a/86b are disposed side-by-side in a portion of the recess 98 which is partly bounded by first and second planar walls 96a and 96b of corral 66.

[0080] As seen in FIG. 6, the dual-belt cable feed mechanism 140 includes first through fourth pulley shafts 78a-78d which are rotatably coupled to the pallet 64. The axes of rotation of first through fourth pulley shafts 78a-78d are parallel to each and perpendicular to the plane of the pallet surface on which the wound cable is placed. The first through fourth pulleys 84a-84d are respectively fixedly mounted to the first through fourth pulley shafts

78a-78d.

[0081] The dual-belt cable feed mechanism 140 depicted in FIG. 6 further includes a first gear shaft 79a and an input shaft 77. The input shaft 77, first gear shaft 79a, and first pulley shaft 78a are fixedly coupled in series (with the first gear shaft 79a connecting first pulley shaft 78a to input shaft 77) to form a first shaft assembly that rotates around a first common axis of rotation. A drive gear 80 is fixedly mounted to first gear shaft 79a. The first gear shaft 79a, drive gear 80, first pulley shaft 78a, and first pulley 84a all rotate in unison when the input shaft 77 is rotated. Rotation of first pulley 84a in turn causes the first belt 86a to circulate, which in turn causes the second pulley 84b and the second pulley shaft 78b to rotate concurrently.

[0082] The dual-belt cable feed mechanism 140 further includes a second gear shaft 79b which is fixedly coupled to the third pulley shaft 78c to form a second shaft assembly that rotates around a second common axis of rotation (parallel to the first common axis of rotation). An idler gear 82 is fixedly mounted to the second gear shaft 79a. Some teeth of idler gear 82 are meshed with some teeth of drive gear 80. Thus, the second gear shaft 79b, idler gear 82, third pulley shaft 78c, and third pulley 84c all rotate in unison when the drive gear 80 is rotated. Rotation of third pulley 84c in turn causes the second belt 86b to circulate, which in turn causes the fourth pulley 84d and the fourth pulley shaft 78d to rotate concurrently.

[0083] The input shaft 77 is configured with a head 88 designed to engage a socket of a nut driver (not shown in FIG. 6). The head 88 projects from an upper end face of the input shaft 77. The socket and head 88 are configured to have interlocking shapes that ensure rotation of the head 88 when the socket is rotated. In some example configurations, the head 88 comprises a solid body having at least one rectangular planar side surface. For example, a hexagonal nut or bolt head has six rectangular planar side surfaces. In other example configurations, the head 88 comprises a solid body having at least one trapezoidal planar side surface, such as a pyramidal body having four trapezoidal planar side surfaces and a square top surface. In further example configurations, the head 88 comprises a solid body having a multiplicity of splines (e.g., grooves having arc-shaped or V-shaped cross-sectional profiles).

[0084] As will be described below with reference to FIGS. 7A and 7B, the nut driver is able to drive rotation of the input shaft 77 when the socket 108 is interlocked with the head 88, thereby causing the input shaft 77 to rotate. The first and second belts 86a/86b circulate concurrently in opposite directions when input shaft 77 is driven to rotate. The first belt 86a circulates around and contacts the first and second pulleys 84a/84b. The second belt 86b circulates around and contacts the third and fourth pulleys 84c/84d. The first and second belts 86a/86b are made of compliant material. The first and second belts 86a/86b are arranged to contact opposing sides of a portion of the cable disposed therebetween

with sufficient friction to linearly feed or withdraw the cable as the belts circulate. For example, the end of a cable to be processed may be pushed into a funnel 22 in front of the cable processing equipment 24 identified in FIG. 2 in response to the issuance of an insert cable end command from a control computer (not shown in FIG. 6).

[0085] FIG. 7A is a diagram depicting an automated system comprising a nut driver apparatus 100 installed at a workstation and a cable-feeding apparatus 130 which has arrived at a position adjacent to the workstation. The nut driver apparatus 100 includes a motor-driven drive shaft 106 that is vertically displaceable relative to a stanchion 118 installed at the workstation. A socket 108 is fixedly coupled to a lower end of the drive shaft 106. In the scenario depicted in FIG. 7A, the motor-driven drive shaft 106 is disposed at an upper vertical position at a first elevation such that socket 108 is separated (disengaged) from a head 88 which is fixedly coupled to or integrally formed with the input shaft 77 of the cable-feeding apparatus 130.

[0086] In accordance with the example depicted in FIG. 7A, the nut driver apparatus 100 further includes a bearing assembly 120 comprising a guide 116 which is oriented vertically and a carriage 114 which is translatable coupled to the guide 116 for vertical displacement. The lower end of guide 116 is attached to the upper end of stanchion 118. The nut driver apparatus 100 further includes a linear actuator 122 comprising an elongated machine element 128 which is mechanically coupled to drive vertical displacement of carriage 114. The vertically displaceable platform of nut driver apparatus 100 further includes an arm 112 having one (proximal) end affixed to the carriage 114. An electric motor 102 is mounted to the other (distal) end of arm 112. The electric motor 102 comprises a motor output shaft 74. The drive shaft 106 is mechanically coupled to the motor output shaft 74 by means of a shaft coupler 104.

[0087] Still referring to FIG. 7A, the cable-feeding apparatus 130 comprises a pallet 64 and a dual-belt cable feed mechanism 140 mounted to pallet 64. The dual-belt cable feed mechanism 140 includes all of the components previously described with reference to FIG. 6, including dual belts 86a and 86b, pulleys 84a-84d, and gears 80 and 82.

[0088] As previously disclosed, input shaft 77, gear shaft 79a, and first pulley shaft 78a are connected in series to form a first shaft assembly. In some alternative examples, drive gear 80 and first pulley 84a (not visible in FIG. 7A, but see FIG. 6) may be mounted to a monolithic shaft. The head 88 may be either attached to or integrally formed with the upper end of input shaft 77. The head 88 is a solid body having a geometric shape configured to engage and interlock with socket 108 of the nut driver apparatus 100. For example, head 88 may comprise a solid body having multiple rectangular planar side surfaces (e.g., a hexagonal head) or multiple trapezoidal planar side surfaces (e.g., a truncated pyramidal head). FIG. 6 shows a head 88 having four trapezoidal

planar side surfaces, only one of which is visible. In the alternative, the head 88 may have a splined surface with splines that match projections inside a cavity of the socket 108. In general, the geometric shape of head 88 should match the geometric shape of the cavity of socket 108 to enable the socket 108 to turn the head 88 about the axis of rotation of input shaft 77.

[0089] FIG. 7B depicts the automated system in a state wherein the socket 108 of nut driver apparatus 100 is engaged with the head 88 of cable-feeding apparatus 130. In the scenario depicted in FIG. 7B, the head 88 is interlocked with the socket 108 following a downward vertical displacement of carriage 114 by a predetermined distance. More specifically, the arm 112 has been lowered until the socket 108 engages the head 88 of input shaft 77. While the socket 108 is engaged with head 88, the electric motor 102 is activated to drive rotation of socket 108. The drive gear 80, idler gear 82, first pulley 84a, and third pulley 84c convert rotation of the input shaft 77 into concurrent circulation of the first and second belts 86a/86b in opposite directions.

[0090] FIG. 8 is a block diagram identifying additional components of the cable feeding system proposed herein. The state of the linear actuator 122 is controlled by a computer 162b that is programmed to coordinate operations at the workstation, including the operations performed by the cable processing equipment (not identified in FIG. 8). In particular, a predetermined linear displacement of carriage 114 and arm 112 is produced by activation of the linear actuator 122 in response to a first command from computer 162b. The electric motor 102 operates under the control of a motor controller 164b. The motor controller 164b activates electric motor 102 in response to issuance of a second command (subsequent in time to issuance of the first command) by the computer 162b. The electric motor 102 then drives rotation of the drive shaft 106 and the socket 108 until computer 162b issues a third command which causes the motor controller 164b to de-activate electric motor 102, thereby terminating the automated cable insertion or withdrawal operation.

[0091] Various types of linear actuators may be employed. FIG. 9 is a block diagram identifying some components of a cable feeding system that uses a pneumatic actuator 150 to vertically displace a carriage 114 downward or upward. The cable feeding system further comprises a control valve 148 (e.g., a solenoid valve) that is configured to control the flow of compressed air from a compressed air supply 146 to the pneumatic actuator 150 in response to a command received from computer 162b. The pneumatic actuator 150 comprises a cylinder, a piston inside the cylinder, and a piston rod 152 (connected to the piston) which projects forward and out of the cylinder. The piston rod 152 is linearly displaceable from a retracted position to an extended position in response to the supply of compressed air to the cylinder, which compressed air drives the piston and piston rod forward. The pneumatic actuator 150 may be arranged

such that extension (or, in the alternative, retraction) of the piston rod 152 causes the carriage 114 to displace vertically until the socket 108 on drive shaft 106 engages the head 88 on input shaft 77 as seen in FIG. 7B.

[0092] FIG. 10 is a block diagram identifying some components of a cable feeding system that uses an electric linear actuator 122 to vertically displace the carriage 114. In accordance with some examples, the electric linear actuator 122 comprises a rotary-to-linear motion conversion mechanism 126 (e.g., a rack and pinion mechanism or a lead screw and nut mechanism) that converts rotary motion of an electric motor 124 into linear displacement of carriage 114. The electric motor 124 is controlled by a motor controller 164b, which in turn receives commands from the computer 162b. In the case of a rack and pinion mechanism, the pinion gear is coupled to the output shaft of electric motor 124, while the rack is attached to the carriage 114. In the case of a lead screw and nut mechanism, the lead screw is coupled to the output shaft of electric motor 124, while the nut is attached to the carriage 114.

[0093] FIG. 11 is a flowchart representing steps of a partly automated method 200 for processing the ends of cables at a cable processing module using the automated system depicted in FIGS. 1, 6, and 7A. First, a coil of cable 10 is manually placed on a pallet 64 by a technician (step 202). Then the technician manually places the cable end 10a of the cable 10 between the first and second belts 86a and 86b (step 204). After the pallet 64 has been loaded, the pallet 64 is moved to a cable feed position whereat the input shaft 77 is aligned with the socket 108 at the workstation (step 206). Next, the linear actuator 102 is activated to displace the arm 112 downward until the socket 108 engages the head 88 while the pallet 64 remains at the cable feed position (step 208). Following engagement of the socket 108 with the head 88 of the input shaft 77, the electric motor 102 is activated to drive rotation of socket 108 in a cable pushing direction (step 210). As a result of this action, the first and second belts 86a and 86b push the cable 10 forward into the cable processing equipment 24. Next, the cable processing equipment 24 is activated to perform a cable processing operation on the cable end 10a of cable 10 (step 212). After the cable processing operation has been completed, the electric motor 102 is activated to drive rotation of socket 108 in a cable pulling direction while the socket 108 is still engaged with the head 88 (step 214). As a result of this action, the first and second belts 86a and 86b pull the cable 10 out of the cable processing equipment 24. The pallet 64 is then moved to a cable feed position adjacent the next workstation (step 216). At least steps 208, 210, 212, and 214 are performed under the control of the computer 162b seen in FIG. 8.

[0094] While systems, methods and apparatus for feeding shielded cable into cable processing equipment have been described with reference to various examples, it will be understood by those skilled in the art that various changes may be made and equivalents may be substi-

tuted for elements thereof without departing from the scope of the claims. Therefore it is intended that the claims not be limited to the particular examples disclosed herein.

[0095] The examples disclosed above use one or more computer systems. As used in the claims, the term "computer system" comprises a single processing or computing device or multiple processing or computing devices that communicate via wireline or wireless connections. Such processing or computing devices typically include one or more of the following: a processor, a controller, a central processing unit, a microcontroller, a reduced instruction set computer processor, an application-specific integrated circuit, a programmable logic circuit, a field-programmable gated array, a digital signal processor, and/or any other circuit or processing device capable of executing the functions described herein. The above examples are not intended to limit in any way the definition and/or meaning of the term "computer system".

[0096] The methods described herein may be encoded as executable instructions embodied in a non-transitory tangible computer-readable storage medium, including, without limitation, a storage device and/or a memory device. Such instructions, when executed by a processing or computing system, cause the system device to perform at least a portion of the methods described herein.

[0097] In the method claims appended hereto, alphabetic ordering of steps is for the sole purpose of enabling subsequent short-hand references to antecedent steps and not for the purpose of limiting the scope of the claim to require that the method steps be performed in alphabetic order. In other words, the method claims recite steps of claimed methods but do not require that all of the steps occur in the order recited or listed in the claims.

Claims

1. An apparatus (130) for feeding a cable (10) into cable processing equipment (24), the apparatus comprising a pallet (64), configured to carry the cable, and a dual-belt cable feed mechanism (140) mounted to the pallet, wherein the dual-belt cable feed mechanism comprises:

first through fourth pulleys (84a-84d) which are rotatable relative to the pallet;
a drive gear (80) which is rotatable in tandem with the first pulley along a first common axis of rotation, wherein the drive gear comprises a multiplicity of teeth;
an idler gear (82) which is rotatable in tandem with the third pulley along a second common axis of rotation, wherein the idler gear comprises a multiplicity of teeth and some of the teeth of the idler gear are meshed with some of the teeth of the drive gear;
a first belt (86a) that passes around the first and

second pulleys (84a, 84b); and
a second belt (86b) that passes around the third and fourth pulleys (84c, 84d),
wherein the first and second belts are arranged to contact opposing sides of a portion of the cable disposed therebetween; and
wherein the first and second belts circulate concurrently and in opposite directions during rotation of the drive gear.

2. The apparatus as recited in claim 1, further comprising:

a first shaft assembly that is rotatably coupled to the pallet and comprises a head, wherein the drive gear and the first pulley are fixedly mounted to the first shaft assembly; and
a second shaft assembly that is rotatably coupled to the pallet, wherein the idler gear and the third pulley are fixedly mounted to the second shaft assembly.

3. The apparatus as recited in claim 2, wherein the first shaft assembly further comprises an input shaft, a first gear shaft, and a first pulley shaft fixedly coupled in series, the apparatus further comprising a second pulley shaft, wherein:

the head projects from an end of the input shaft;
the drive gear is fixedly mounted to the first gear shaft;
the first pulley is fixedly mounted to the first pulley shaft; and
the second pulley is fixedly mounted to the second pulley shaft.

4. The apparatus as recited in claim 3, wherein the second shaft assembly comprises a second gear shaft and a third pulley shaft fixedly coupled to the second gear shaft, the apparatus further comprising a fourth pulley shaft, wherein:

the idler gear is fixedly mounted to the second gear shaft;
the third pulley is fixedly mounted to the third pulley shaft; and
the fourth pulley is fixedly mounted to the fourth pulley shaft.

5. The apparatus as recited in any of claims 2 to 4, wherein the head comprises:

a solid body having at least one rectangular planar side surface and/or at least one trapezoidal planar side surface; and/or
a solid body having splines.

6. The apparatus as recited in any preceding claim,

wherein:

each of the first through fourth pulleys has a respective multiplicity of teeth (85) along a respective outer periphery thereof; 5
each of the first and second belts has a respective multiplicity of teeth (87) molded on an inner surface thereof;
some of the teeth of the first belt are meshed with some of the teeth of the first pulley, while other teeth of the first belt are meshed with some of the teeth of the second pulley; and 10
some of the teeth of the second belt are meshed with some of the teeth of the third pulley, while other teeth of the second belt are meshed with some of the teeth of the fourth pulley. 15

7. The apparatus as recited in any preceding claim, wherein:

the pallet comprises a corral (66) that defines a recess (98);
the corral comprises a circular wall (96c) having a discontinuity and first and second planar walls (96a, 96b) extending from the discontinuity; and 20
the first and second belts are disposed side-by-side in a portion of the recess between the first and second planar walls. 25

8. A system comprising a nut driver apparatus (100) installed at a workstation and a cable feeding apparatus (130) positioned adjacent to the workstation, 30

wherein the nut driver apparatus comprises:

a bearing assembly (120) comprising a guide (116) which is oriented vertically and a carriage (114) which is translatable coupled to the guide;
a linear actuator (122) comprising an elongated machine element (128) coupled to the carriage;
an arm (112) having one end affixed to the carriage;
an electric motor (102) mounted to the arm and comprising a motor output shaft (74);
a drive shaft (106) fixedly coupled to the motor output shaft; and
a socket (108) fixedly coupled to an end of the drive shaft, and 40
50

wherein the cable feeding apparatus comprises:

a pallet (64) configured to carry wound cable; and
a dual-belt cable feed mechanism (140) mounted to the pallet, wherein the dual-belt cable feed mechanism comprises: 55

an input shaft (77) which is rotatable relative to the pallet about a first axis of rotation and comprises a head (88) which is configured to interlock with the socket when the drive shaft is aligned with and in contact with the input shaft; and
first and second belts (86a, 86b) which circulate concurrently in opposite directions when the input shaft is rotated.

9. The system as recited in claim 8, wherein the socket is not interlocked with the head when the carriage is at a first elevation and is interlocked with the head when the carriage is at a second elevation below the first elevation.

10. The system as recited in claim 8 or 9, wherein the elongated machine element comprises:

a lead screw, the linear actuator further comprising a nut that is attached to the carriage and threadably coupled to the lead screw; and/or
a rack, the linear actuator further comprising a pinion gear which is rotatable relative to the guide.

11. The system as recited in any of claims 8 to 10, wherein the linear actuator is a pneumatic actuator and the elongated machine element comprises a piston rod which is linearly displaceable and has an end fixedly coupled to the carriage.

12. The system as recited in any of claims 8 to 11, further comprising:

a motor controller (164b) which is configured to control operation of the electric motor in response to commands; and
a computer (162b) which is configured:

to output commands to the motor controller to control operation of the electric motor; and
to activate the linear actuator to lower the drive shaft by a distance sufficient to interlock the head with the socket and then issue commands to the motor controller that controls the electric motor to drive rotation of the drive shaft while the socket is interlocked with the head, thereby causing the input shaft to rotate and the first and second belts to circulate.

13. The system as recited in claim 12, wherein the computer is further configured to issue commands to the motor controller that control the electric motor to drive rotation of the drive shaft by a number of de-

grees calculated to cause the first and second belts to feed a predetermined length of cable disposed between and contacted by the first and second belts.

14. The system as recited in any of claims 8 to 13, wherein the dual-belt cable feed mechanism further comprises:

first through fourth pulleys (84a-84d) which are rotatable relative to the pallet; 10
a drive gear (80) which is rotatable in tandem with the first pulley about the first axis of rotation, wherein the drive gear comprises a multiplicity of teeth;
an idler gear (82) which is rotatable in tandem with the third pulley about a second axis of rotation, wherein the idler gear comprises a multiplicity of teeth and some of the teeth of the idler gear are meshed with some of the teeth of the drive gear; 20
a first belt (86a) that passes around the first and second pulleys (84a, 84b); and
a second belt (86b) that passes around the third and fourth pulleys (84c, 84d). 25

15. A method for processing a cable end (10a) of a cable (10), the method comprising:

(a) placing a coil of cable on a pallet (64) that supports a dual-belt cable feed mechanism (140) comprising an input shaft (77) which is rotatable relative to the pallet and first and second belts (86a, 86b) which circulate concurrently in opposite directions when the input shaft is rotated, wherein the input shaft comprises a head (88) which is configured to interlock with a socket (108) which is fixedly coupled to an end of a drive shaft (106); 30
(b) placing the end of the cable between the first and second belts; 40
(c) moving the pallet to a cable feed position whereat the input shaft is aligned with the socket;
(d) activating a linear actuator (102) to displace the drive shaft downward until the socket engages the head of the input shaft; and 45
(e) activating an electric motor to drive rotation of the drive shaft in a first direction while the socket is engaged with the head, thereby causing the first and second belts to push the cable forward into cable processing equipment (24), wherein steps (d) and (e) are performed under control by a computer (162b); and, optionally, the method further comprises: 50

(f) activating the cable processing equipment to perform a cable processing operation on the end of the cable; and 55

(g) activating the electric motor to drive rotation of the drive shaft in a second direction opposite to the first direction while the socket is engaged with the head, thereby causing the belts to pull the cable out of the cable processing equipment, wherein steps (f) and (g) are performed under control by the computer.

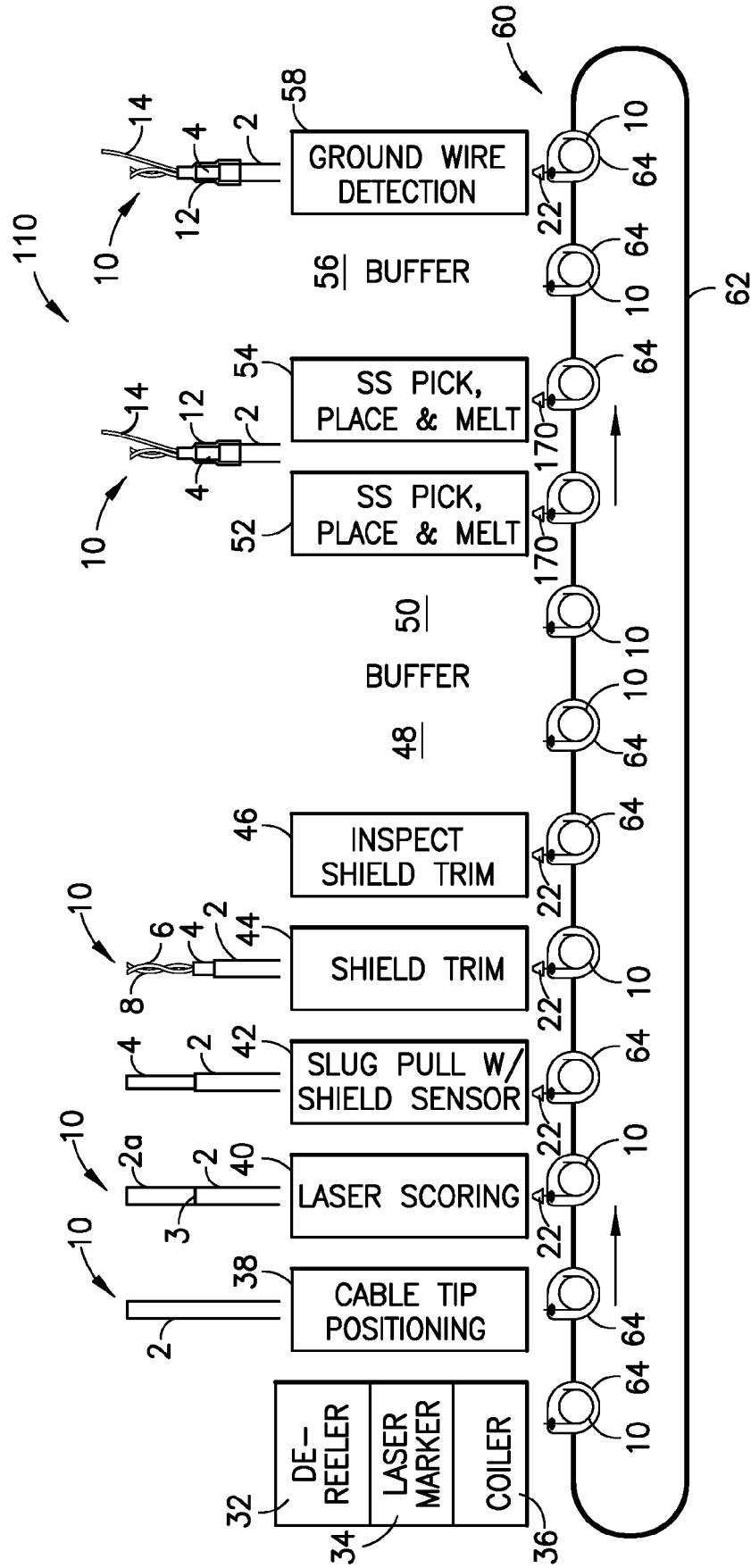


FIG. 1

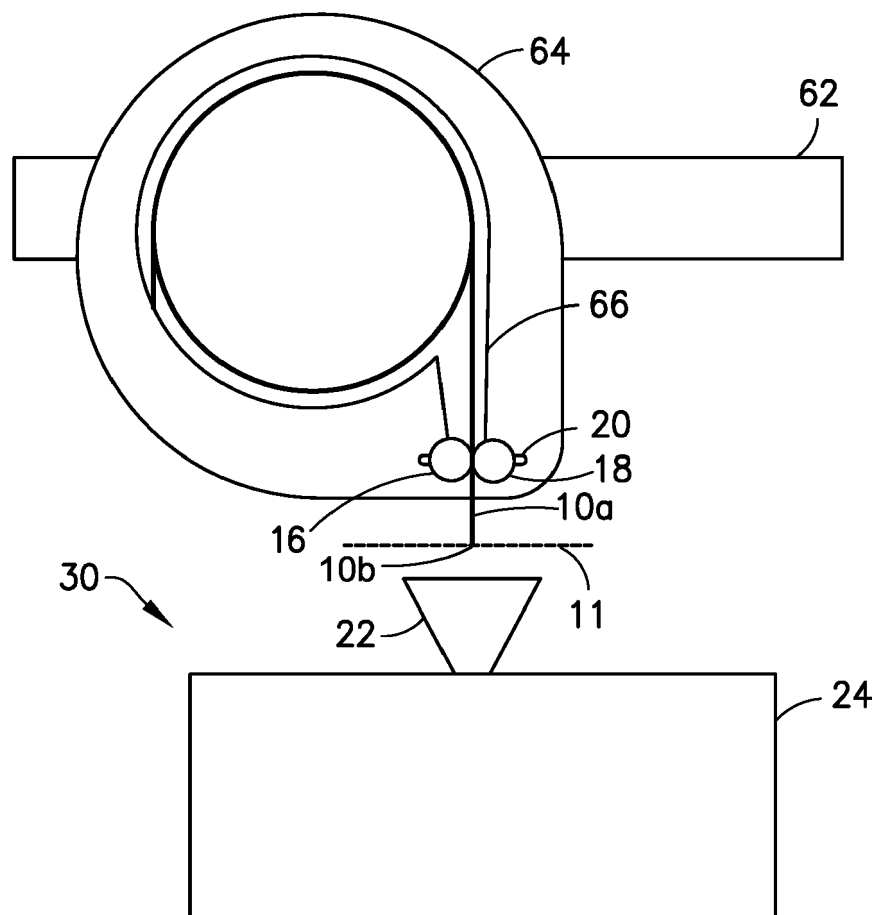
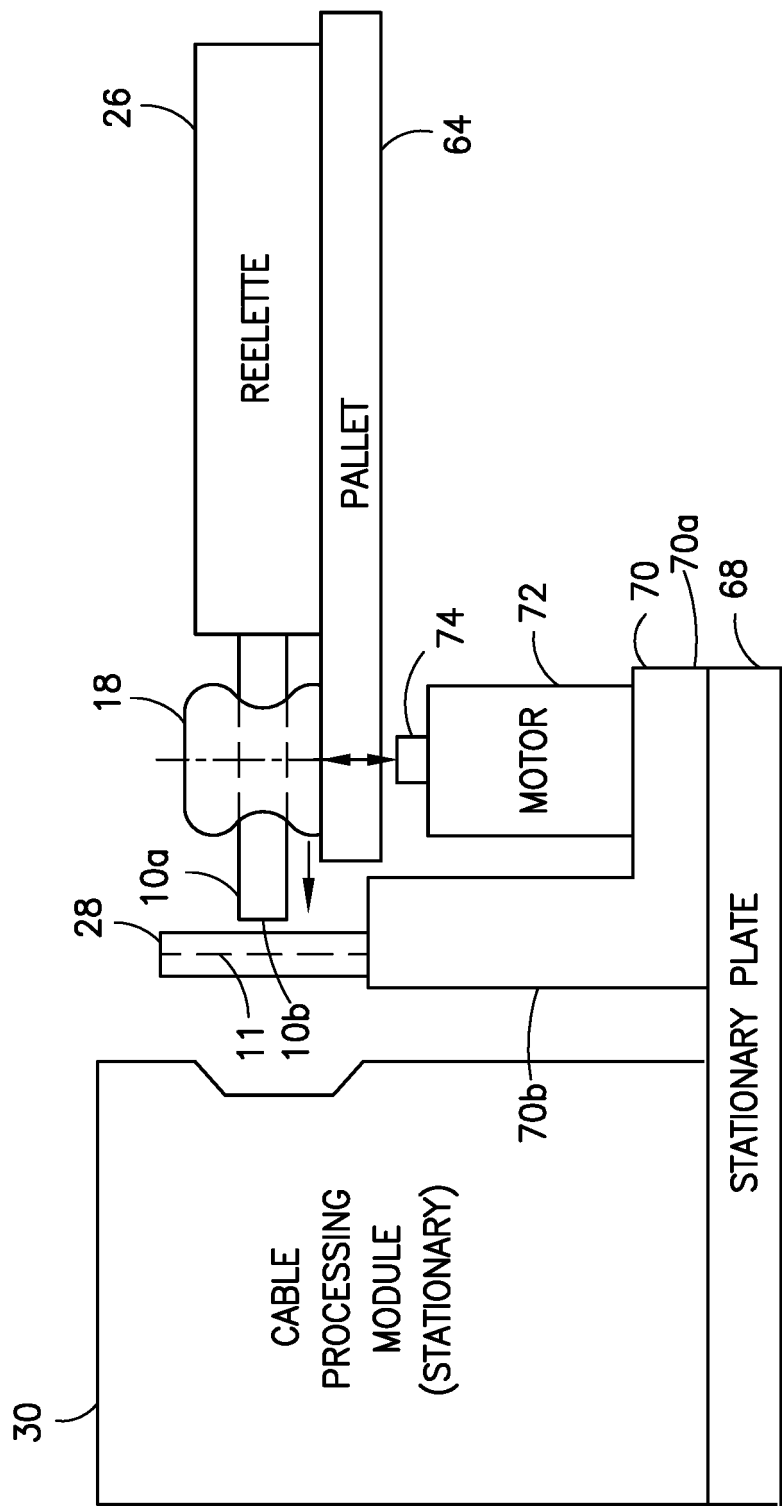


FIG. 2
PRIOR ART



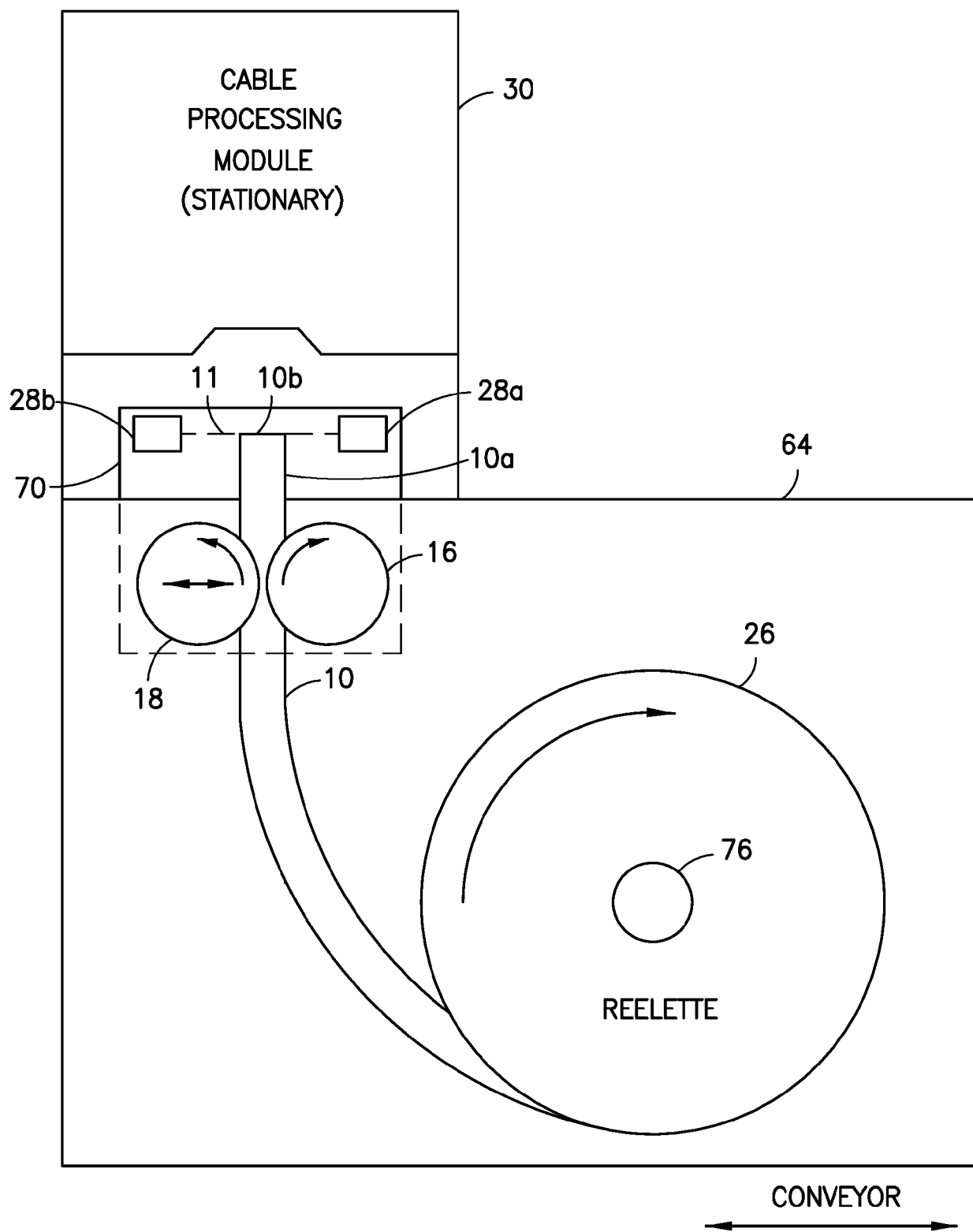


FIG. 3B
PRIOR ART

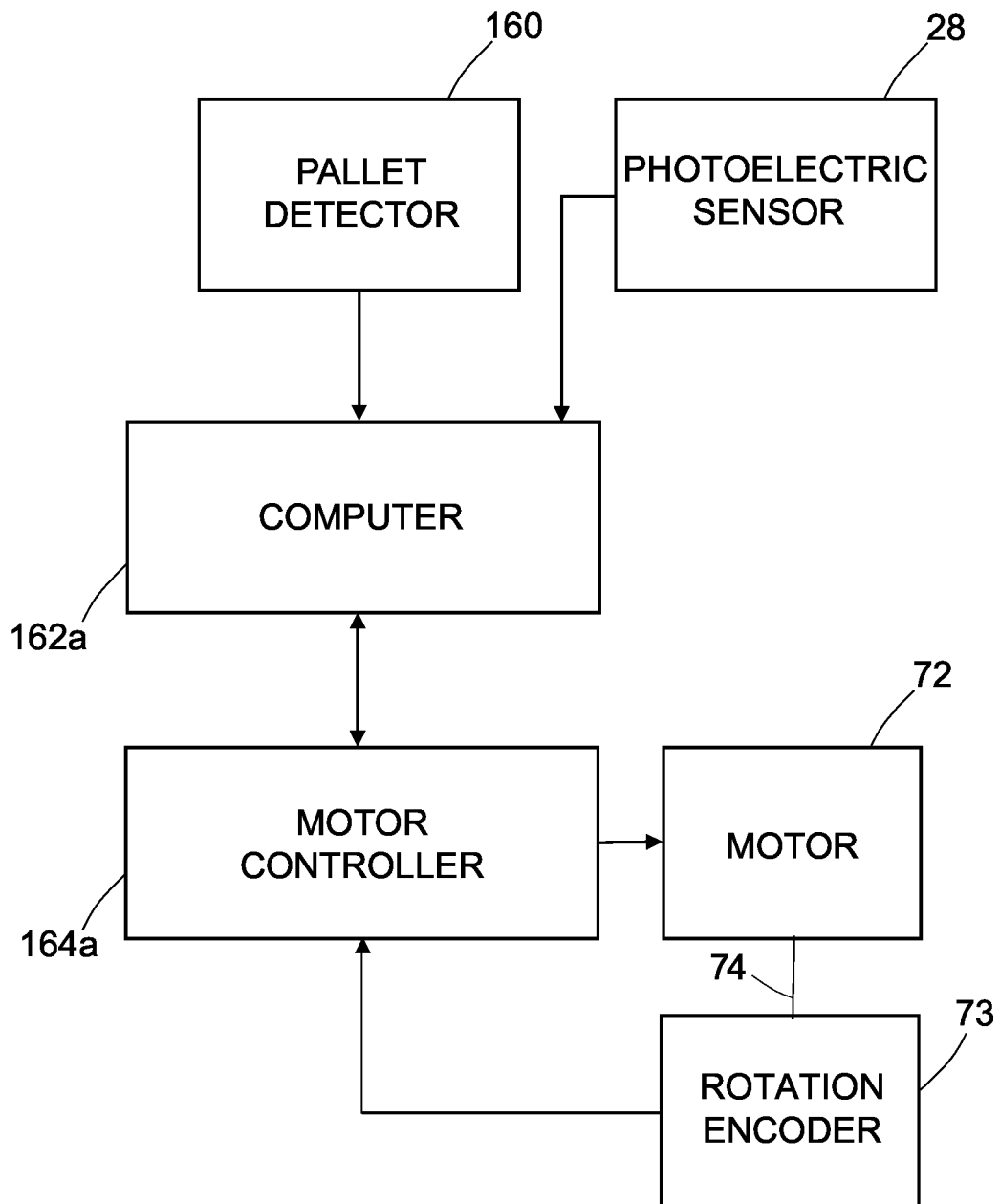
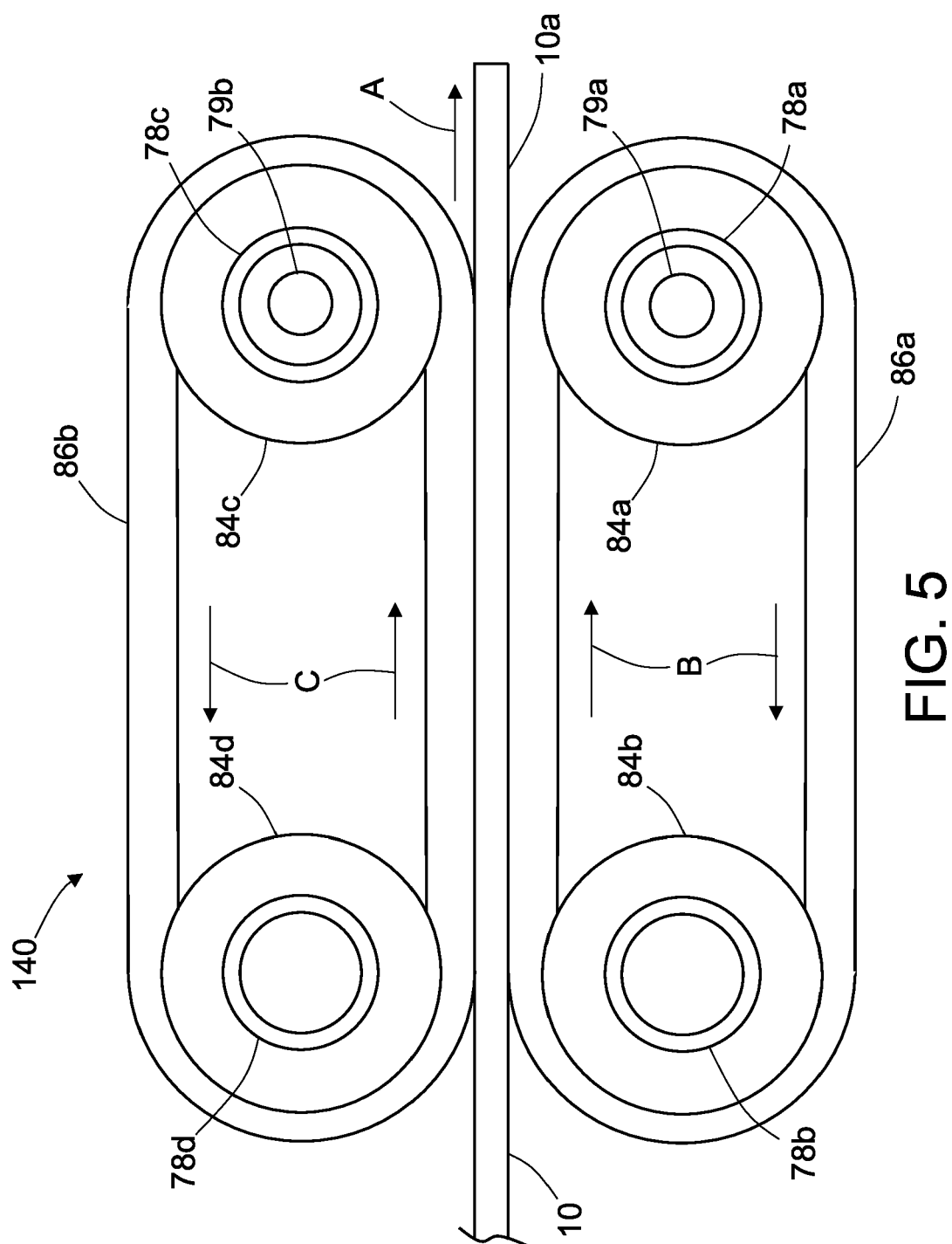


FIG. 4
PRIOR ART



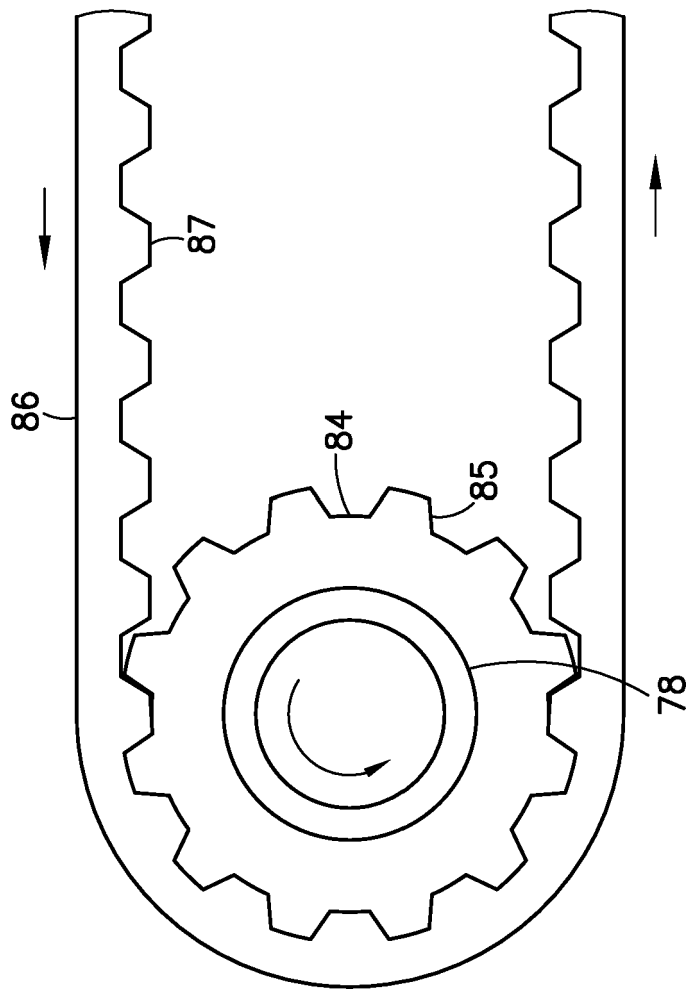


FIG. 5A

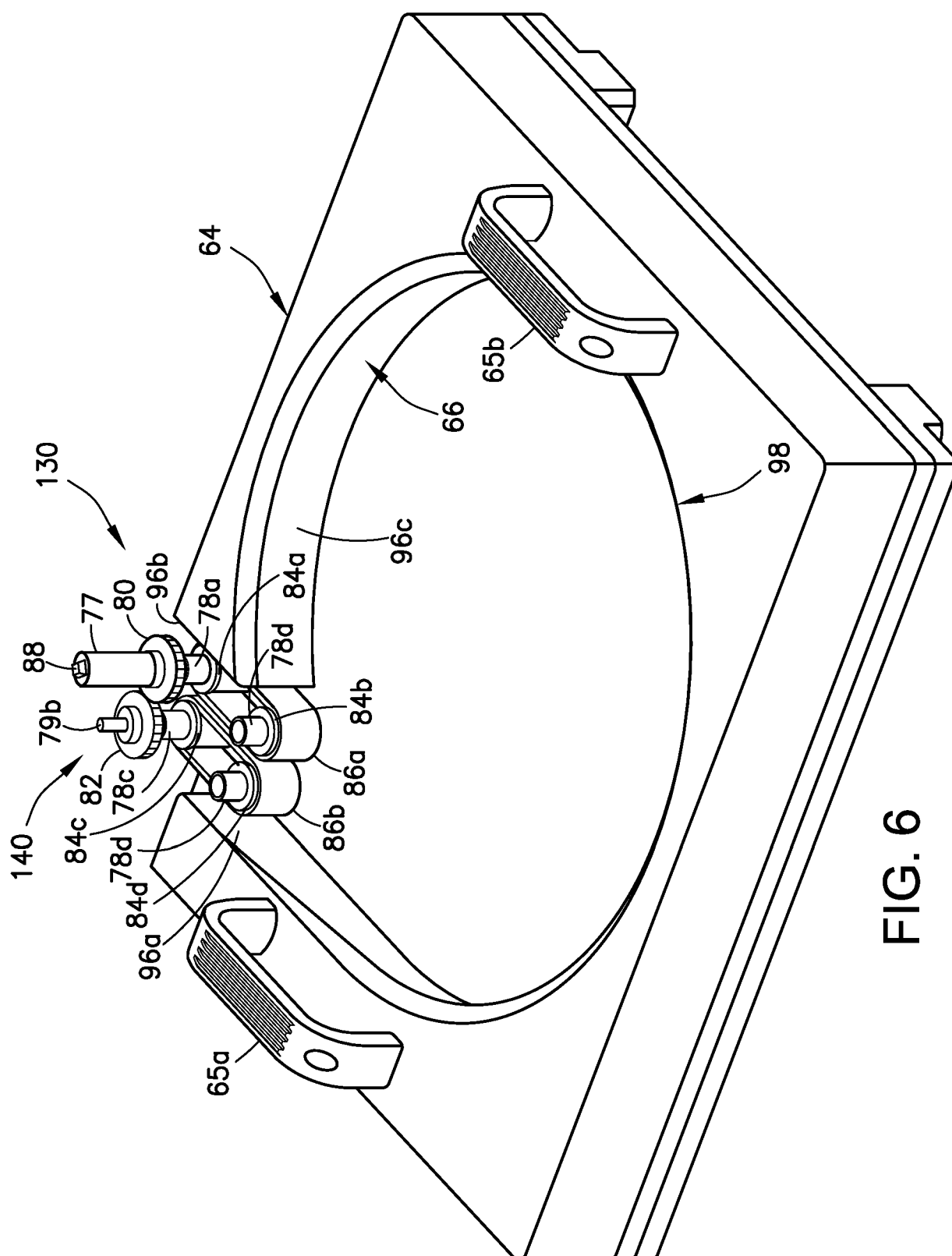


FIG. 6

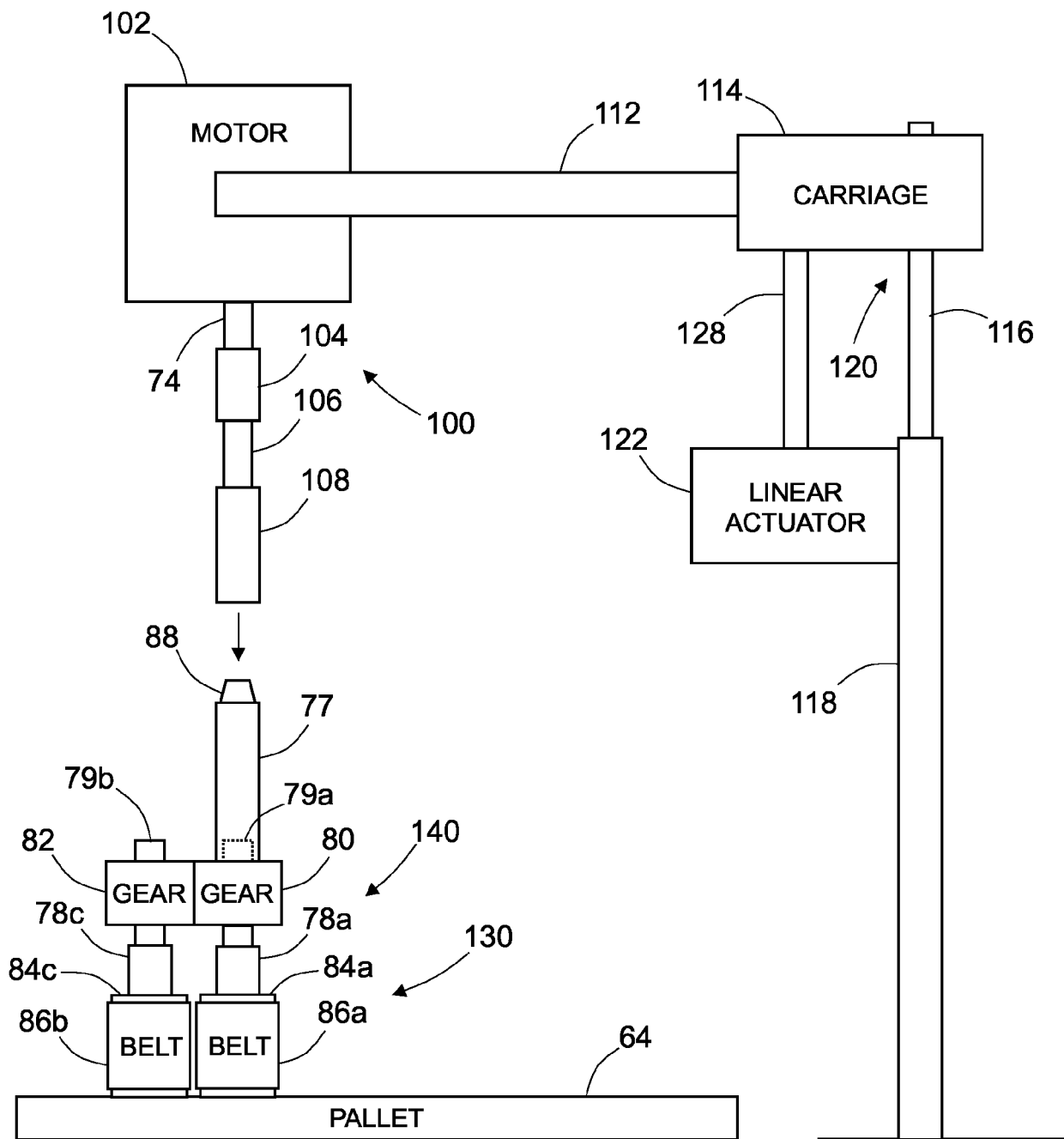


FIG. 7A

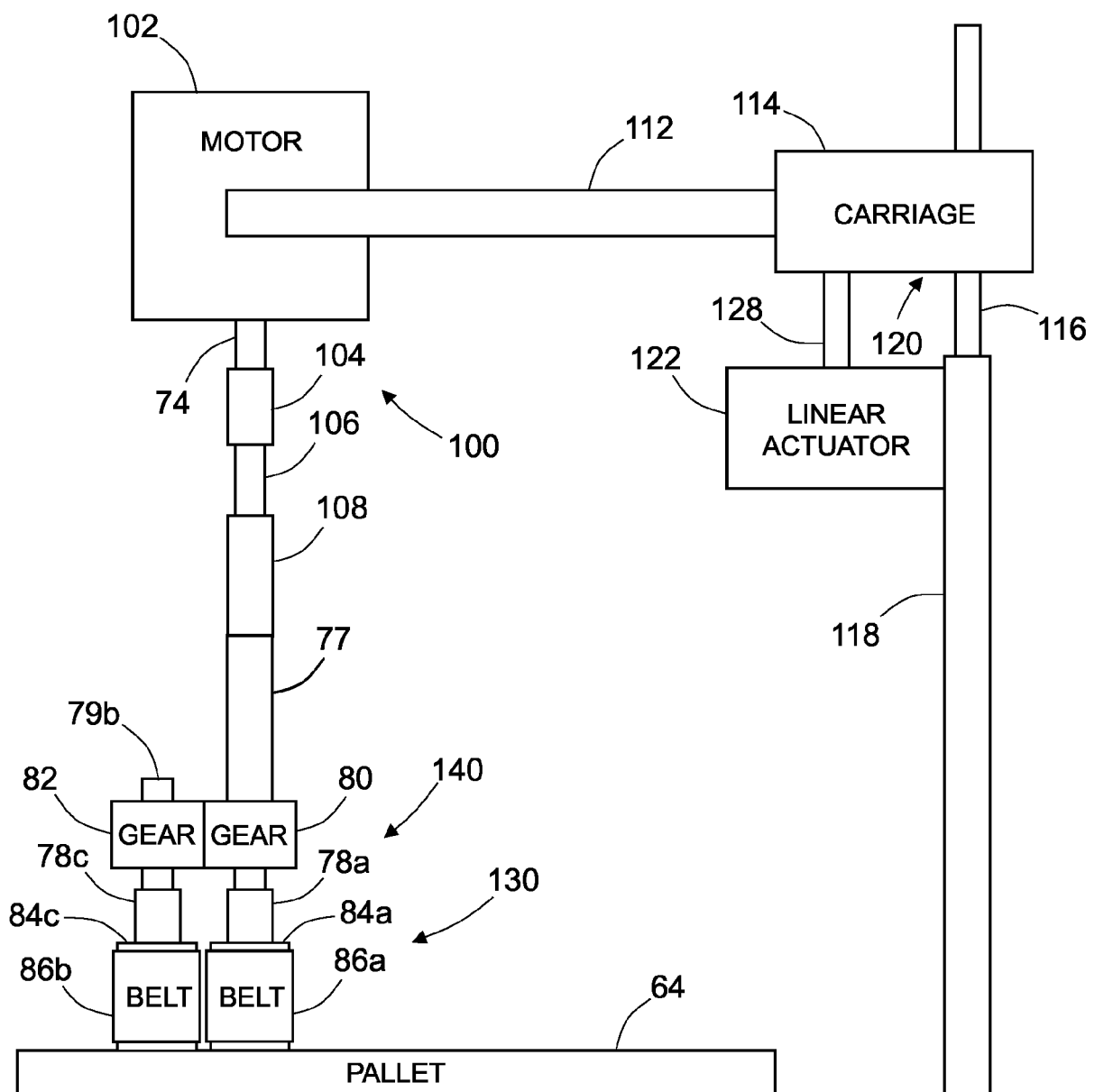


FIG. 7B

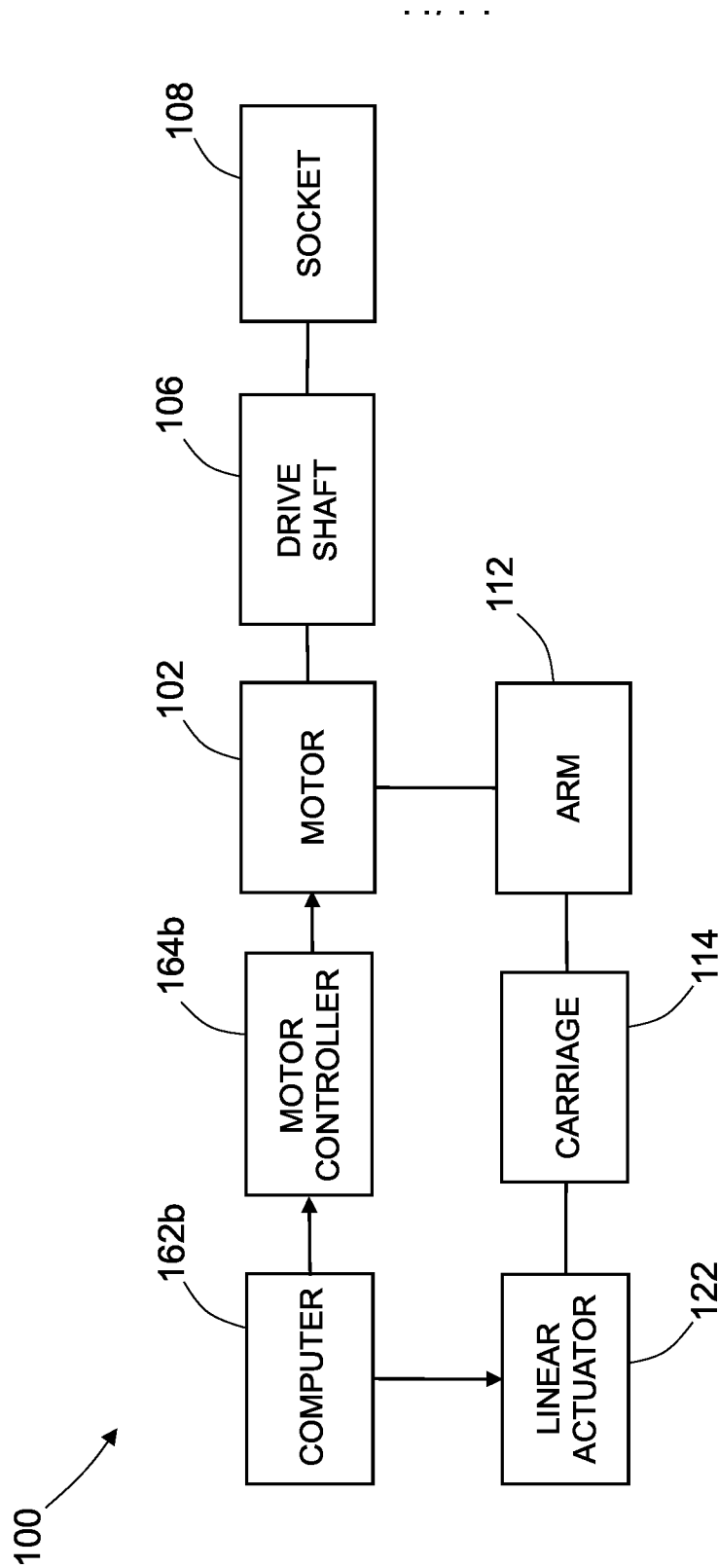


FIG. 8

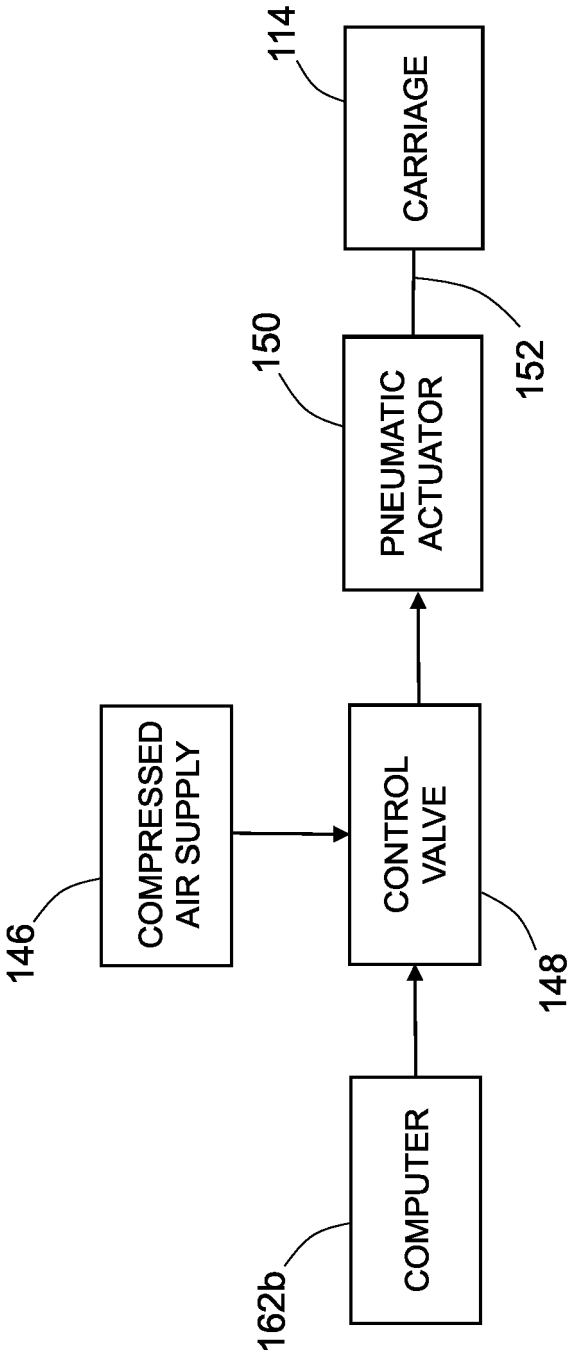


FIG. 9

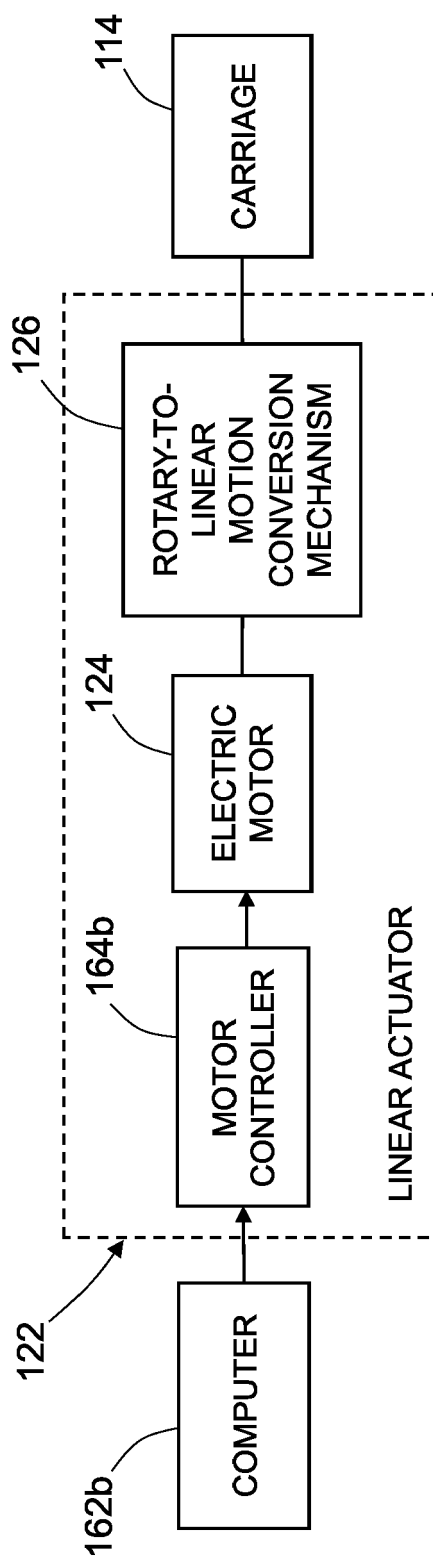


FIG. 10

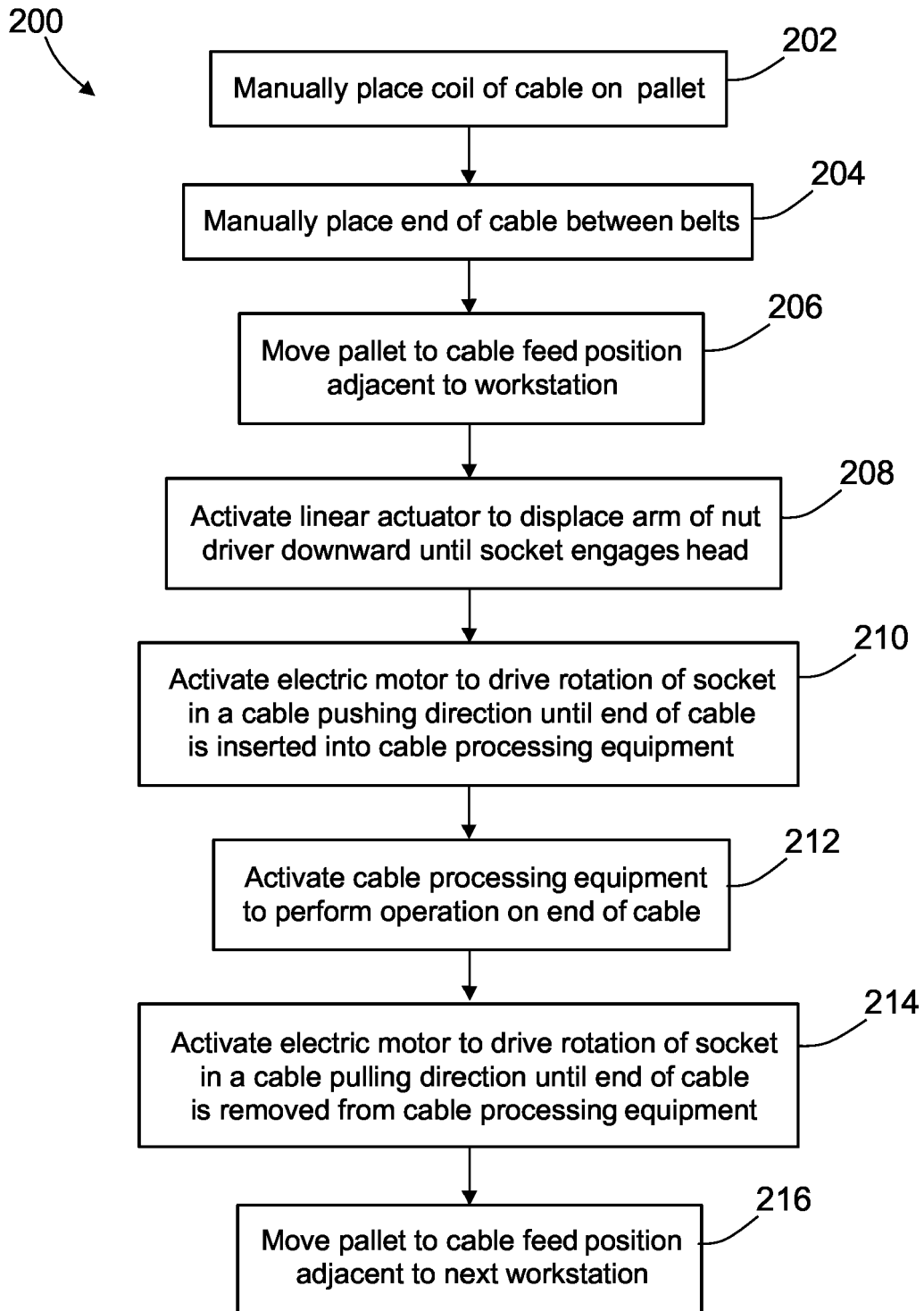


FIG. 11



EUROPEAN SEARCH REPORT

Application Number

EP 24 15 1289

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EPO FORM 1503 03.82 (P04C01)

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CN 206 735 490 U (SUZHOU PAUL MACHINERY ENG CO LTD) 12 December 2017 (2017-12-12)	1 - 6	INV. B65H51/14
A	* paragraph [0009] * * paragraph [0019] * * paragraph [0034] * * figures 1,2 * -----	7 - 15	
A	EP 3 674 237 A1 (BOEING CO [US]) 1 July 2020 (2020-07-01) * the whole document * -----	1 - 15	
A	CN 102 195 226 B (KOMAX HOLDING AG) 3 September 2014 (2014-09-03) * paragraph [0002] * * paragraph [0065] - paragraph [0077] * * figure 1 * -----	1 - 15	
			TECHNICAL FIELDS SEARCHED (IPC)
			B65H H01R H02G
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		5 June 2024	Guisan, Thierry
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T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EP 24 15 1289

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05-06-2024

10	Patent document cited in search report	Publication date	Patent family member(s)	Publication date
	CN 206735490 U	12-12-2017	NONE	

15	EP 3674237 A1	01-07-2020	BR 102019024238 A2	02-06-2020
			CN 111199815 A	26-05-2020
			EP 3674237 A1	01-07-2020
			JP 2020113533 A	27-07-2020
			KR 20200059171 A	28-05-2020
20			RU 2019136792 A	17-05-2021
			US 2020161810 A1	21-05-2020

	CN 102195226 B	03-09-2014	NONE	

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